Bureau of Mines
Special Publication

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LIST OF BUREAU OF MINES PUBLICATIONS AND ARTICLES

January 1, 1965, to December 31, 1969

With Subject and Author Index

UNITED STATES DEPARTMENT OF THE INTERIOR

1970

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Special Publication

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Compiled by Rita D. Sylvester

UNITED STATES DEPARTMENT OF THE INTERIOR
Walter J. Hickel, Secretary

BUREAU OF MINES
Elburt F. Osborn, Director

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Introduction

The Bureau of Mines was established in the public interest to conduct inquiries and scientific and technologic investigations concerning mining and the preparation, treatment, and utilization of mineral substances; to promote health and safety in the mineral industries; to conserve material resources and prevent their waste; to further economic development; to increase efficiency in the mining, metallurgical, quarrying, and other mineral industries; and to inquire into the economic conditions affecting these industries. The organic act of the Bureau, as amended by Congress and approved February 25, 1913, made it the province and duty of the Bureau to "disseminate information concerning these subjects in such manner as will best carry out the purposes of this Act."

In accordance with this directive, the Bureau reports the findings of its research and investigations in its own series of publications and also in articles that appear in scientific, technical, and trade journals; in proceedings of conventions and seminars; in reference books; and in other non-Bureau publications. The number of these reports, the wide range of subjects they cover, and the variety of mediums in which they appear make the kind of list and index presented in this special publication both necessary and valuable. This issue describes reports and articles published during the period January 1, 1965, to December 31, 1969. **It supplements the 50-year list of Bureau publications issued from July 1, 1910, to January 1, 1960;[2] the 50-year list of articles by Bureau authors published outside the Bureau from July 1, 1910, to January 1, 1960;[3] the 5-year list of Bureau publications and articles from January 1, 1960, to December 31, 1964.[4] It includes all the material in the four annual lists of Bureau publications and articles from January 1, 1965, to December 31, 1968, as well as the Bureau publications and articles for 1969.**

[1] Editor, Division of Technical Reports, Bureau of Mines, Washington, D.C.

[2] Obtainable from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. (Price, $4.25.)

[3] See footnote 2. (Price, $1.75.)

[4] See footnote 2. (Price, $1.75.)

BUREAU PUBLICATIONS

Some Bureau publications including Bulletins and the Minerals Yearbook, are sales publications; other series contain both free and sales publications. Because the cost of sales publications varies, the price is indicated in the individual listing of any publication for which a charge is made.

Sales publications of the Bureau of Mines must be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, to whom orders should be sent directly. Remittances for such publications may be made by money order or check or by coupons, sold in sets of 20 for $1 and good until used. Do not send postage stamps. Remittances from foreign countries should be made by international money order or a draft on an American bank payable to the Superintendent of Documents.

Free publications of the Bureau of Mines may be obtained from the Publications Distribution Branch, Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pa. 15213. (Because of the limited editions, only one copy of any free publication can be sent to the person applying and only a few different publications to any one applicant.) The following series or types of publications are listed in this directory:

Bulletins describe major Bureau investigations or studies that are considered to have permanent value. Usually a Bulletin describes research that has been completed, but sometimes one is issued upon completion of a significant part of the research. Bulletins are sales publications and prices are given under the individual listing.

Minerals Yearbook—annual statistical publication of the Bureau—reviews the mineral industry in the United States and foreign countries; contains official Government statistics on metals, minerals, and mineral products; and includes factual accounts of economic and technologic developments and trends. In 1968 the Minerals Yearbook was published in three volumes: Volume I–II, Metals, Minerals, and Fuels; Volume III, Area Reports; Domestic; and Volume IV, Area Reports: International. Individual chapters are preprinted separately. Any volume of the Minerals Yearbook or any preprinted chapter is available from the Superintendent of Documents at the price quoted.

Reports of Investigations describe the principal features and results of minor investigations or phases of major investigations, thus keeping the mineral industries and the public informed on the progress of original research.

Information Circulars are easily understood digests designed primarily for compilations, reviews, abstracts, and discussion of virtually all activities and developments in the mineral industries. One of their important uses is to provide concise information for replies to inquires received by the Bureau.

Technical Progress Reports, a new Bureau of Mines series initiated in 1968, make known new or improved systems and techniques in mining and metallurgy developed by the Bureau.

Mineral Industry Surveys cover a wide variety of timely statistical and economic reports designed to keep the public, particularly the business community, and Government agencies regularly informed of trends in the production, distribution, stocks, and consumption of approximately 100 different mineral commodities, including the several mineral fuels. These surveys, prepared by various commodity specialists, are issued weekly, monthly, quarterly, or at other regular intervals, depending on the need for current data. Summary statistics for man-hours worked and fatal and non-fatal injuries in the mineral industries are also reported in this series. The material contained in Mineral Industry Surveys is later published in permanent form in the Minerals Yearbook.

Foreign Mineral Reports are issued to keep the domestic producers and consumers abreast of developments in the mineral industries and markets abroad and to provide a summary or brief inventory of significant information from U.S. Foreign Service offices and other sources, which may not otherwise be available to the general public.

Special Publications include comprehensive lists of Bureau publications and articles by Bureau authors and any publication of the Bureau of Mines that is not included in its regular series.

Schedules describe the procedures and methods followed by the Bureau in testing materials and equipment to determine their permissibility for use by the mineral industries.

Handbooks are special manuals issued as guides to practices recommended by the Bureau in promoting safety and efficiency in the mineral industries and in the use of mineral products. Handbooks may also give details or explanations of mine safety laws.

Miscellaneous Publications include any Bureau of Mines publication that is not part of a Bureau series. Such publications may consist of short descriptions of Bureau research, special aspects of such research, or general information about the Bureau.

ASSOCIATED DOCUMENTS

Although the material in the categories that follow is not published by the Bureau of Mines, it is listed and indexed in this publication as a service to those who may be interested:

Cooperative Publications describe research conducted cooperatively with other Government agencies, State departments of geology or mines, universities or colleges, or other recognized organizations and are issued by the cooperating agency.

Open-File Reports are unpublished reports that are available for reference at certain Bureau offices and libraries. See the list of open-file reports for information as to where they are available.

Outside Publications (OP's) are articles by Bureau authors that have been published in the technical press, in proceedings of meetings, and in books. It is recommended that information on the availability of copies be obtained from the publishing organization. If copies are not available, many libraries can supply photocopies of such articles at a nominal price.

Patents issued to Bureau personnel from January 1, 1965 to December 31, 1969, are listed with instructions on how to apply for permission to use such patents.

Reprints of selected Bureau of Mines publications that have been made available by the Clearinghouse for Federal Scientific and Technical Information, U.S. Department of Commerce, are listed in the section "Reports Available From the Clearinghouse."

LIBRARIES

Under the provisions of the law, certain libraries are designated by Congress as depositories for printed publications issued by the Government agencies. Through these libraries, various documents printed by the Government Printing Office are made available to residents of every State. Distribution of these printed publications is made by the Superintendent of Documents.

Many of these depository libraries also receive multilithed publications of the Bureau of Mines, particularly the Reports of Investigations and the Information Circulars, which are distributed mainly by the Bureau. Libraries maintaining a file of Bureau of Mines publications are the best sources for reports published by the Bureau when the publications are out of print or copies no longer are available from the Superintendent of Documents or the Bureau.

In the United States some libraries maintain complete files of Bureau reports; others carry only selected series. The following list contains the names and locations of depository libraries receiving various series of reports and documents issued by the Bureau of Mines. The figures in parentheses, following the names of the libraries, indicate the type of Bureau publications generally received on a regular basis by each library.

(1) Reports of Investigations and Information Circulars.

(2) Bulletins.

(3) Minerals Yearbooks.

State	City	Library and Type of Publication Received
Alabama	Alexander City	Alexander City State Junior College (2, 3).
	Auburn	Auburn University, Ralph Brown Draughon Library (1, 2, 3).
	Birmingham	Birmingham Public (1, 2, 3).
		Birmingham Southern University, M. Paul Phillips Library (1, 3).
	Enterprise	Enterprise State Junior College (3).
	Florence	Florence State College, Collier Library (3).
	Gadsden	Gadsden Public (2, 3).
	Huntsville	University of Alabama (1, 2, 3).
	Jacksonville	Jacksonville State University, Ramona Wood Library (3).
	Mobile	Mobile Public (1, 2, 3).
		Spring Hill College (3).
	Normal	Alabama Agricultural and Mechanical College, Carnegie Library (3).
	St. Bernard	St. Bernard College (3).
	Troy	Troy State College (3).
	Tuskegee Institute	Tuskegee Institute, Hollis Burke Frissell Library (2, 3).
	University	University of Alabama (3).
Alaska	Anchorage	Alaska Methodist University (3).
		Anchorage Community College (1, 2, 3).
	College	University of Alaska (1, 2, 3).
Arizona	Flagstaff	Northern Arizona University (1, 2, 3).
	Phoenix	Department of Library and Archives (1, 2, 3).
		Phoenix Public (1, 2, 3).
	Tempe	Arizona State University (1, 2, 3).
	Tucson	University of Arizona (1, 2, 3).
	Yuma	Yuma City-County (1, 2, 3).
Arkansas	Arkadelphia	Ouachita Baptist University, Riley Library (3).
	College Heights	Arkansas A&M College (3).
	Conway	Hendrix College, O. C. Bailey Library (3).
	Fayetteville	University of Arkansas (1, 2, 3).
	Little Rock	Little Rock Public (1, 3).
	Magnolia	Southern State College, J. M. Peace Library (2, 3).
	Russellville	Arkansas Polytechnic College (3).
	Searcy	Harding College, Harding Memorial Library (3).
	State College	Arkansas State University, Dean B. Ellis Library (1, 2, 3).
	Walnut Ridge	Southern Baptist College, Felix Goodson Library (3).

State	City	Library and Type of Publication Received
California	Anaheim	Anaheim Public (3).
	Arcata	Humboldt State College (1, 2, 3).
	Bakersfield	Kern County Free (1, 2, 3).
	Berkeley	University of California (1, 2, 3).
	Chico	Chico State College (3).
	Claremont	Pomona College, Honnold Library (1, 2, 3).
	Culver City	Culver City (3).
	Davis	University of California (1, 2, 3).
	Downey	Downey City (3).
	Fresno	Fresno County Free (2, 3). Fresno State College (1, 2, 3).
	Fullerton	California State College (2, 3).
	Gardena	Gardena Public (3).
	Hayward	California State College (2, 3).
	Inglewood	Inglewood Public (3).
	Irvine	University of California (1, 2, 3).
	La Jolla	University of California (1, 2, 3).
	Lancaster	Lancaster Regional (3).
	Long Beach	California State College (1, 2, 3). Long Beach Public (1, 2, 3).
	Los Angeles	California State College, John F. Kennedy Memorial Library (1, 2, 3). Los Angeles Public (1, 2, 3). Loyola University of Los Angeles (3). Occidental College, Mary Norton Clapp Library (3). University of California (1, 2, 3). University of Southern California (1, 2, 3).
	Lynwood	Lynwood (3).
	Marysville	Yuba College (3).
	Montebello	Montebello (3).
	Monterey Park	Bruggemeyer Memorial (3).
	Newhall	Newhall (3).
	Northridge	San Fernando Valley State College (2, 3).
	Oakland	Oakland Public (1, 2, 3).
	Orange	Orange County Free (3).
	Pasadena	California Institute of Technology (1, 2, 3). Pasadena Public (1, 2, 3).
	Pleasant Hill	Contra Costa County (3).
	Redding	Shasta County (2, 3). University of Redlands (2, 3).
	Redwood City	Redwood City Public (3).
	Reseda	West Valley Regional Branch (3).
	Richmond	Richmond Public (3).
	Riverside	Riverside Public (1, 2, 3). University of California (1, 2, 3).
	Sacramento	California State (1, 2, 3). Sacramento City (2, 3). Sacramento State College (2, 3).
	San Bernadino	San Bernadino County Free (2, 3).
	San Diego	San Diego County (3). San Diego Public (1, 2, 3). San Diego State College (1, 2, 3).
	San Francisco	Mechanics' Institute (2, 3). San Francisco Public (1, 2, 3). San Francisco State College (1, 2, 3). University of San Francisco, Gleeson Library (2, 3).
	San Jose	San Jose State College (1, 2, 3).
	San Leandro	San Leandro Community (3).
	Santa Ana	Santa Ana Public (3).
	Santa Barbara	University of California (1, 2, 3).
	Santa Clara	University of Santa Clara, Michel Orradre Library (3).
	Santa Cruz	University of California (1, 2, 3).
	Santa Rosa	Santa Rosa-Sonoma County Public (3).
	Stanford	Stanford University (1, 2, 3).
	Stockton	Stockton Public (2, 3).
	Thousand Oaks	California Lutheran College (2, 3).
	Turlock	Stanislaus State College (3).
	Walnut	Mount San Antonio College (3).
	West Covina	West Covina (3).

State	City	Library and Type of Publication Received
Colorado	Alamosa	Adams State College (1, 2, 3).
	Boulder	University of Colorado (1, 2, 3).
	Colorado Springs	Colorado College, Charles Leaming Tutt Library (1, 2, 3).
	Denver	Bureau of Mines, U.S. Department of the Interior (1, 2, 3).*
		Colorado State (1, 2, 3).
		Denver Pub ic (1, 2, 3).
		Regis College (2, 3).
		University of Denver, Mary Reed Library (1, 2, 3).
	Fort Collins	Colorado State University (1, 2, 3).
	Golden	Colorado School of Mines, Arthur Lakes Library (1, 2, 3).
	Greeley	Colorado State College (3).
	Gunnison	Western State College, Leslie J. Savage Library (3).
	La Junta	Otero Junior College (3).
	Pueblo	McClelland Public (2, 3).
		Southern Colorado State College (1, 2, 3).
Connecticut	Bridgeport	Bridgeport Public (1, 2, 3).
	Hartford	Connecticut State (1, 2, 3).
		Hartford Public (1, 2, 3).
		Trinity College (2, 3).
	Middletown	Wesleyan University, Olin Library (1, 2, 3).
	New Haven	Yale University (2, 3).
	New London	Connecticut College, Palmer Library (3).
	Storrs	University of Connecticut, Wilbur Cross Library (1, 2, 3).
	Waterbury	Silas Bronson (3).
Delaware	Dover	Delaware State College, William C. Jason Library (3).
	Newark	University of Delaware, Morris Library (1, 2, 3).
	Wilmington	Wilmington Institute Free (1, 2, 3).
District of Columbia	Washington	U.S. Department of the Interior (1, 2, 3).
Florida	Boca Raton	Florida Atlantic University (1, 2, 3).
	Coral Gables	University of Miami (1, 2, 3).
	Fort Lauderdale	Nova University Library (3).
	Gainesville	University of Florida (1, 2, 3).
	Leesburg	Lake Sumter Junior College (3).
	Miami	Miami-Dade Junior College (3).
		Miami Public (1, 2, 3).
	Orlando	Florida Technological University (2, 3).
	Palatka	St. Johns River Junior College (2, 3).
	Pennsacola	University of West Florida (3).
	St. Petersburg	St. Petersburg Public (3).
	Tallahassee	Florida State (3).
		Florida A&M University (1, 2, 3).
		Florida State University, R. M. Strozier Library (3).
	Tampa	Tampa Public (2, 3).
		University of South Florida (1, 2, 3).
		University of Tampa (3).
	Winter Park	Rollins College, Mills Memorial Library (3).
Georgia	Albany	Albany Public (2, 3).
	Americus	Georgia Southwestern College, Wade Lott Memorial Library (2, 3).
	Athens	University of Georgia (1, 2, 3).
	Atlanta	Atlanta Public (1, 2, 3).
		Atlanta University, Trevor Arnett Library (3).
		Emory University, Asa Griggs Candler Library (2, 3).
		Georgia Institute of Technology, Price Gilbert Memorial Library (1, 2, 3).
		Georgia State (3).
	Augusta	Augusta College (1, 2, 3).
	Carrollton	Sanford (2, 3).
	Dahlonega	North Georgia College (3).
	Savannah	Savannah Public and Chatham-Effingham Liberty Regional (3).
	Statesboro	Georgia Southern College, Rosenwald Library (3).
	Valdosta	Valdosta State College, Richard Holmes Powell Library (3).
Hawaii	Hilo	University of Hawaii (2, 3).
	Honolulu	Chaminade College (2, 3).
		Hawaii State (3).
		University of Hawaii (1, 2, 3).
Idaho	Boise	Boise College (3).
		Boise Public (1, 2, 3).
	Caldwell	College of Idaho, Terteling Library (2, 3).
	Moscow	University of Idaho (1, 2, 3).
	Pocatello	Idaho State University (1, 2, 3).
	Rexburg	Ricks College, David O. McKay Library (1, 2, 3).

*Not a depository library.

State	City	Library and Type of Publication Received
Illinois	Carlinville	Blackburn (3).
	Carbondale	Southern Illinois University (1, 2, 3).
	Charleston	Eastern Illinois University, Booth Library (3).
	Chicago	Chicago Public (1, 2, 3).
		Chicago State College (3).
		Field Museum of Natural History (1, 2, 3).
		John Crerar (1, 2, 3).
		Loyola University, E. M. Cudahy Memorial Library (2, 3).
		Northeastern Illinois State College (3).
		University of Chicago (1, 2, 3).
		University of Illinois (1, 2, 3).
	Decatur	Decatur Public (3).
	De Kalb	Northern Illinois University, Swen Franklin Parson Library (1, 2, 3).
	Edwardsville	Southern Illinois University, Lovejoy Memorial Library (1, 2, 3).
	Evanston	Northwestern University (1, 2, 3).
	Freeport	Freeport Public (3).
	Galesburg	Galesburg Public (3).
	Lisle	St. Procopius College (3).
	Monmouth	Monmouth College (2, 3).
	Normal	Illinois State University, Milner Library (1, 2, 3).
	Peoria	Bradley University (3).
		Peoria Public (1, 2, 3).
	River Forest	Rosary College (3).
	Rock Island	Rock Island Public (2, 3).
	Rockford	Rockford Public (3).
	Springfield	Illinois State (1, 2, 3).
	Urbana	University of Illinois (1, 2, 3).
	Wheaton	Wheaton College (3).
Indiana	Anderson	Anderson College, Charles E. Wilson Library (3).
	Bloomington	Indiana University (1, 2, 3).
	Crawfordsville	Wabash College, Lilly Library (3).
	Elsah	Principia College, Marshall Brooks Library (3).
	Evansville	Evansville and Vanderburgh County Public (1, 2, 3).
	Fort Wayne	Fort Wayne and Allen County Public (1, 2, 3).
		Indiana-Purdue Universities, Regional Campus Library (3).
	Gary	Gary Public (2, 3).
		Indiana University (2, 3).
	Greencastle	De Pauw University, Roy O. West Library (2, 3).
	Hammond	Hammond Public (2, 3).
	Hanover	Hanover College (3).
	Huntington	Huntington College (3).
	Indianapolis	Butler University, Irwin Library (2, 3).
		Indiana State (1, 2, 3).
		Indianapolis Public (1, 3).
	Lafayette	Purdue University (1, 2, 3).
	Macomb	Western Illinois University (3).
	Muncie	Ball State University (1, 2, 3).
		Muncie Public (3).
	Notre Dame	University of Notre Dame, Memorial Library (1, 2, 3).
	Rensselaer	St. Joseph's College (1, 2, 3).
	Richmond	Earlham College, Lilly Library (3).
		Morrison Reeves (3).
	South Bend	Indiana University (3).
	Terre Haute	Indiana State University, Cunningham Memorial Library (2, 3).
	Valparaiso	Valparaiso University, Moellering Memorial Library (2, 3).
Iowa	Ames	Iowa State University of Science and Technology (1, 2, 3).
	Cedar Falls	University of Northern Iowa (3).
	Council Bluffs	Free Public (2, 3).
	Denison	Midwestern College (3).
	Des Moines	Des Moines Public (2, 3).
		Drake University, Cowles Library (3).
		Iowa State Traveling (2, 3).
	Dubuque	Carnegie Stout Public (2, 3).
		Loras College, Wahlert Memorial Library (3).
	Fairfield	Parsons College Branch of Fairfield Public (3).
	Grinnell	Grinnell College (3).
	Iowa City	University of Iowa (1, 2, 3).
	Lamoni	Graceland College, Frederick Madison Smith Library (3).
	Mount Vernon	Cornell College, Russell D. Cole Library (1, 2, 3).
	Sioux City	Sioux City Public (3).
Kansas	Baldwin	Baker University (3).
	Emporia	Kansas State Teachers College, William Allen White Library (2, 3).

State	City	Library and Type of Publication Received
Kansas	Hays	Fort Hays Kansas State College, Forsyth Library (1, 2, 3).
	Hutchinson	Hutchinson Public (2, 3).
	Lawrence	University of Kansas (1, 2, 3).
	Manhattan	Kansas State University (1, 2, 3).
	Pittsburg	Kansas State College, Porter Library (2, 3).
	Salina	Kansas Wesleyan University, Memorial Library (1, 2, 3).
	Topeka	State Libraries of Kansas (2, 3).
		Kansas State Historical Society (3).
	Wichita	Wichita State University (1, 2, 3).
Kentucky	Ashland	Ashland Public (1, 2, 3).
	Barbourville	Union College, Abigail E. Weeks Memorial Library (3).
	Bowling Green	Western Kentucky University, Margie Helm Library (2, 3).
	Danville	Centre College (3).
	Lexington	University of Kentucky, Margaret I. King Library (1, 2, 3).
	Louisville	Louisville Free Public (1, 2, 3).
		University of Louisville (2, 3).
	Morehead	Morehead State University, Johnson Camden Library (3).
	Murray	Murray State University (3).
	Owensboro	Kentucky Wesleyan College (3).
	Pikeville	Pikeville College, O'Rear-Robinson Library (2, 3).
	Richmond	Eastern Kentucky University, John Grant Crabbe Library (3).
Louisiana	Baton Rouge	Louisiana State University (1, 2, 3).
		Southern University (1).
	Hammond	Southeastern Louisiana College, Sims Memorial Library (2, 3).
	Lafayette	University of Southwestern Louisiana (1, 2, 3).
	Monroe	Northeast Louisiana State College, Sandel Library (3).
	New Orleans	Isaac Delgado College, Moss Technical Library (1, 2, 3).
		Louisiana State University (1, 2, 3).
		Loyola University (3).
		New Orleans Public (1, 2, 3).
		Tulane University, Howard-Tilton Memorial Library (1, 2, 3).
	Ruston	Louisiana Polytechnic Institute, Prescott Memorial Library (1, 2, 3).
	Shreveport	Louisiana State University (3).
		Shreve Memorial (1, 2, 3).
	Thibodaux	F. T. Nicholls State College (2, 3).
Maine	Bangor	Bangor Public (3).
	Brunswick	Bowdoin College, Hawthorne-Longfellow Library (2, 3).
	Lewiston	Bates College (2, 3).
	Orono	University of Maine, Raymond H. Fogler Library (1, 2).
	Portland	Portland Public (1, 2, 3).
	Springvale	Nasson College (3).
	Waterville	Colby College (3).
Maryland	Annapolis	Maryland State (3).
	Baltimore	Enoch Pratt Free (1, 2, 3).
		Johns Hopkins University, Milton S. Eisenhower Library (1, 2, 3).
		Morgan State College, Soper Library (3).
	Bethesda	Montgomery County Public (3).
	College Park	Bureau of Mines, U.S. Department of the Interior (1, 2, 3).*
		University of Maryland, McKeldin Library (1, 2, 3).
	Frostburg	Frostburg State College, Jerome Frampton Library (3).
	Salisbury	Salisbury State College (2, 3).
	Towson	Goucher College, Julia Rogers Library (3).
	Westminister	Western Maryland College (3).
Massachusetts	Amherst	Amherst College (2, 3).
		University of Massachusetts, Goodell Library (2, 3).
	Boston	Boston Public (1, 2, 3).
		Northeastern University, Dodge Library (1, 2, 3).
		State Library of Massachusetts (1, 2, 3).
	Brookline	Brookline Public (3).
	Cambridge	Harvard University (2, 3).
		Massachusetts Institute of Technology (1, 2, 3).
	Chestnut Hill	Boston College, Bapst Library (3).
	Lowell	Lowell Technological Institute, Alumni Memorial Library (3).
	Medford	Tufts University (2, 3).
	New Bedford	New Bedford Free Public (3).
		Southeastern Massachusetts Technological Institute (2, 3).
	North Easton	Stonehill College, Cushing-Martin Library (3).
	Springfield	Springfield City (3).
	Waltham	Brandeis University (3).
	Wellesley	Wellesley College (3).
	Williamstown	Williams College (3).
	Worcester	Worcester Public (2, 3).

*Not a depository library.

State	City	Library and Type of Publication Received
Michigan	Albion	Albion College (1, 2, 3).
	Allendale	Grand Valley State College (1, 2, 3).
	Ann Arbor	University of Michigan (1, 2, 3).
	Battle Creek	Willard (3).
	Bloomfield Hills	Cranbrook Institute of Science (3).
	Dearborn	Henry Ford Community College (3).
	Detroit	Detroit Public (1, 2, 3).
		University of Detroit (3).
		Wayne State University (1, 2, 3).
	East Lansing	Michigan State University (1, 2, 3).
	Escanaba	Michigan State (3).
	Flint	Charles Stewart Mott (2, 3).
		Flint Public (3).
	Grand Rapids	Grand Rapids Public (1, 2, 3).
		Knollcrest Calvin (1, 2, 3).
	Houghton	Michigan Technological University (1, 2, 3).
	Jackson	Jackson Public (3).
	Kalamazoo	Kalamazoo Library System (3).
		Western Michigan University, Dwight B. Waldo Library (1, 2, 3).
	Lansing	Michigan State (1, 2, 3).
	Livonia	Schoolcraft College (3).
	Marquette	Northern Michigan University, Olson Library (1, 2, 3).
	Mt. Pleasant	Central Michigan University (1, 2, 3).
	Muskegon	Hackley Public (2, 3).
	Rochester	Oakland University, Kresge Library (3).
	Saginaw	Hoyt Public (1, 2, 3).
	Traverse City	Northwestern Michigan College, Mark Osterlin Library (3).
	University Center	Delta College (3).
	Ypsilanti	Eastern Michigan University Library (3).
Minnesota	Bemidji	Bemidji State College (2, 3).
	Collegeville	St. John's University, Alcuin Library (3).
	Duluth	Duluth Public (1, 2, 3).
	Mankato	Mankato State College (1, 2, 3).
	Minneapolis	Bureau of Mines, U.S. Department of the Interior (1, 2, 3).*
		Minneapolis Public (1, 2, 3).
		University of Minnesota, Walter Library (1, 2, 3).
	Moorhead	Moorhead State College (3).
	Morris	University of Minnesota (2, 3).
	Northfield	Carleton College (3).
		St. Olaf College, Rolvaag Memorial Library (2, 3).
	St. Cloud	St. Cloud State College (3).
	St. Paul	Minnesota Historical Society (2, 3).
		St. Paul Public (2, 3).
	St. Peter	Gustavus Adolphus College (3).
	Willmar	Kandiyohi County-Willmar Library (3).
Mississippi	Columbus	Mississippi State College for Women, J. C. Fant Memorial Library (3).
	Hattiesburg	University of Southern Mississippi (2, 3).
	Jackson	Millsaps College, Millsaps-Wilson Library (1, 2).
	State College	Mississippi State University, Mitchell Memorial Library (1, 2, 3).
	University	University of Mississippi (1, 2, 3).
Missouri	Cape Girardeau	Southeast Missouri State College, Kent Library (3).
	Columbia	University of Missouri (1, 2, 3).
	Fayette	Central Methodist College (1, 3).
	Jefferson City	Lincoln University, Inman E. Page Library (3).
		Missouri State (1, 3).
	Kansas City	Kansas City Public (1, 2, 3).
		University of Missouri (1, 2, 3).
	Kirksville	Northeast Missouri State Teachers College, Pickler Memorial Library (3).
	Rolla	Bureau of Mines, U.S. Departmento f the Interior (1, 2, 3).*
		University of Missouri (1, 2, 3).
	St. Joseph	St. Joseph Public (2, 3).
	St. Louis	St. Louis Public (1, 2, 3).
		Washington University, John M. Olin Library (2, 3).
		St. Louis University, Pius XII Memorial Library (1, 2, 3).
	Springfield	Drury College (2, 3).
		Southwest Missouri State College (1, 2, 3).
	Warrensburg	Central Missouri State College (1, 3).

*Not a depository library.

State	City	Library and Type of Publication Received
Montana	Bozeman	Montana State University (1, 2, 3).
	Butte	Montana College of Mineral Science and Technology (1, 2, 3).
	Helena	Historical Society of Montana (1, 2, 3).
	Missoula	University of Montana (1, 2, 3).
Nebraska	Crete	Doane College, Whitin Library (3).
	Kearney	Kearney State College, Calvin T. Ryan Library (1, 2, 3).
	Lincoln	University of Nebraska, D. L. Love Memorial Library (1, 2, 3).
	Omaha	Creighton University, Alumni Memorial Library (3).
		Omaha Public (1, 2, 3).
		University of Omaha, Gene Eppley Library (1, 3).
	Scottsbluff	Public (3).
Nevada	Carson City	Nevada State (1, 2, 3).
	Las Vegas	Nevada Southern University (1, 2, 3).
	Reno	University of Nevada (1, 2, 3).
New Hampshire	Concord	New Hampshire State (1, 2, 3).
	Durham	University of New Hampshire (1, 2, 3).
	Hanover	Dartmouth College, Daker Library (1, 2, 3).
	Henniker	New England College (3).
	Manchester	Manchester City (2, 3).
New Jersey	Bayonne	Bayonne Free Public (2, 3).
	Bloomfield	Bloomfield Free Public (2, 3).
	Bridgeton	Cumberland County (3).
	Camden	Rutgers Library in South Jersey (3).
	Convent Station	College of St. Elizabeth, Santa Maria Library (3).
	East Orange	East Orange Public (3).
	Elizabeth	Elizabeth Free Public (2, 3).
	Glassboro	Glassboro State College, Savitz Library (2, 3).
	Hackensack	Johnson Free Public (3).
	Irvington	Irvington Free Public (3).
	Jersey City	Jersey City Public (3).
		Jersey City State College, Forrest A. Irwin Library (3).
	Madison	Drew University, Rose Memorial Library (3).
	Mount Holly	Burlington County Area (3).
	New Brunswick	Free Public (3).
		Rutgers University (1, 2, 3).
	Newark	Newark Public (1, 2, 3).
	Passaic	Passaic Public (3).
	Princeton	Princeton University (1, 2, 3).
	Rutherford	Fairleigh Dickinson University (3).
	South Orange	Seton Hall University, McLaughlin Library (3).
	Teaneck	Fairleigh Dickinson University (3).
	Toms River	Ocean County College (3).
	Trenton	New Jersey State (3).
		Trenton Free Public (2, 3).
	Upper Montclair	Montclair State College, Harry A. Sprague Library (2, 3).
	West Long Branch	Monmouth College, Guggenheim Memorial Library (3).
	Woodbridge	Woodbridge Free Public (3).
New Mexico	Albuquerque	University of New Mexico, Zimmerman Library (1, 2, 3).
	Las Cruces	New Mexico State University (1, 2, 3).
	Portales	Eastern New Mexico University (1, 2, 3).
	Santa Fe	New Mexico State (1, 2, 3).
New York	Albany	New York State (1, 2, 3).
		State University of New York (1, 2, 3).
	Binghamton	State University of New York (3).
	Brockport	State University of New York, Drake Memorial Library (2, 3).
	Brooklyn	Brooklyn College (3).
		Brooklyn Public (1, 2, 3).
		Polytechnic Institute of Brooklyn, Spicer Library (2, 3).
		Pratt Institute (3).
	Bronx	City University of New York, Hunter College (3).
		Fordham University (3).
		State University of New York, Maritime College (3).
	Buffalo	Buffalo and Erie County Public (1, 2, 3).
		State University of New York, Lockwood Memorial Library (1, 2, 3).
	Canton	St. Lawrence University, Owen D. Young Library (1, 2, 3).
	Corning	Corning Community College, Arthur A. Houghton, Jr., Library (3).
	Cortland	State University College (3).
	Elmira	Elmira College, Hamilton Library (3).
	Farmingdale	State University of New York (2, 3).

State	City	Library and Type of Publication Received
New York	Flushing	Queens College, Paul Klapper Library (3).
	Garden City	Adelphi University (2, 3).
	Geneseo	State University College, Milne Library (2, 3).
	Greenvale	C. W. Post College (2, 3).
	Hamilton	Colgate University (2, 3).
	Hempstead	Hofstra University (2, 3).
	Huntington	Huntington Public (2, 3).
	Ithaca	Albert R. Mann (3). Cornell University (1, 2, 3).
	Jamaica	Queens Borough Public (1, 2, 3). St. Johns University (3).
	Mount Vernon	Mount Vernon Public (3).
	New Paltz	State University College (3).
	New York (Manhattan)	City University of New York, City College (1, 2, 3). Columbia University (1, 2, 3). New York Public (1, 2, 3). New York University, Gould Memorial Library (1, 2, 3).
	Oakdale	Adelphi Suffolk College (3).
	Oneonta	State University College, James M. Milne Library (2, 3).
	Oswego	State University College, Penfield Library (2, 3).
	Plattsburgh	State University College, Benjamin F. Feinberg Library (2, 3).
	Potsdam	Clarkson College of Technology, Harriet C. Burnap Memorial Library (3). State University College (1, 2, 3).
	Poughkeepsie	Vassar College (3).
	Rochester	Rochester Public (1, 2, 3). University of Rochester (1, 2, 3).
	St. Bonaventure	St. Bonaventure University, Friedsam Memorial Library (3).
	Saratoga Springs	Skidmore College (3).
	Schenectady	Union College, Schaffer Library (2, 3).
	Staten Island	Wagner College, Horrman Library (3).
	Stony Brook	State University of New York (1, 2, 3).
	Syracuse	Syracuse University (2, 3).
	Troy	Troy Public (2, 3).
	Utica	Utica Public (3).
	Yonkers	Yonkers Public (3).
North Carolina	Asheville	Asheville-Biltmore College, D. Hiden Ramsey Library (3).
	Boone	Appalachian State University, Dauphin Disco Dougherty Library (3).
	Buies Creek	Campbell College, Carrie Rich Memorial Library (3).
	Chapel Hill	University of North Carolina (2, 3).
	Charlotte	Charlotte and Mecklenburg County Public (3). University of North Carolina, Atkins Library (1, 2, 3).
	Cullowhee	Western Carolina University, Hunter Library (3).
	Davidson	Davidson College, Hugh A. and Jane Grey Memorial Library (3).
	Durham	Duke University (1, 2, 3).
	Greensboro	North Carolina Agricultural and Technical State University, F. D. Bluford Library (2, 3). University of North Carolina, Walter Clinton Jackson Library (1, 2, 3).
	Greenville	East Carolina University (1, 2, 3).
	Murfreesboro	Chowan College (3).
	Pembroke	Pembroke State College, Mary H. Livermore Library (3).
	Raleigh	North Carolina State (3). North Carolina State University, D. H. Hill Library (1, 2, 3).
	Salisbury	Catawba College (3).
	Wilmington	Wilmington College (3).
	Wilson	Atlantic Christian College, Clarence L. Hardy Library (3).
	Winston-Salem	Forsyth County Public Library System (3). Wake Forest University, Z. Smith Reynolds Library (3).
North Dakota	Bismarck	Veterans Memorial Public (3).
	Fargo	Fargo Public (3). North Dakota State University (1, 2, 3).
	Grand Forks	University of North Dakota, Chester Fritz Library (1, 2, 3).
	Minot	Minot State College, Memorial Library (3).
Ohio	Akron	Akron Public (1, 2, 3). University of Akron (3).
	Alliance	Mt. Union College (2, 3).
	Ashland	Ashland College (3).
	Athens	Ohio University (1, 2, 3).
	Bluffton	Bluffton College, Musselman Library (3).
	Bowling Green	Bowling Green State University (2, 3).
	Cincinnati	Cincinnati and Hamilton County Public (1, 2, 3). University of Cincinnati (1, 2, 3).

State	City	Library and Type of Publication Received
Ohio	Cleveland	Case Western Reserve University, Freiberger Library (1, 2, 3).
		Cleveland Public (1, 2, 3).
		Cleveland State University (2, 3).
		John Carroll University, Grasselli Library (3).
	Columbus	Columbus Public (3).
		Ohio State (1, 2, 3).
		Ohio State University (1, 2, 3).
	Dayton	Dayton and Montgomery County Public (1, 2, 3).
		Wright State University (2, 3).
	Delaware	Ohio Wesleyan University, L. A. Beeghly Library (3).
	Elyria	Elyria Public (2, 3).
	Gambier	Kenyon College (3).
	Granville	Denison University (3).
	Hiram	Hiram College, Teachout-Price Memorial Library (3).
	Kent	Kent University (1, 2, 3).
	Marietta	Marietta College, Dawes Memorial Library (1, 2, 3).
	New Concord	Muskingum College (3).
	Oberlin	Oberlin College (3).
	Oxford	Miami University (2, 3).
	Rio Grande	Rio Grande College, Jeannette Albiez Davis Library (2, 3).
	Springfield	Warder Public (3).
	Steubenville	Steubenville and Jefferson County Public (3).
	Tiffin	Heidelberg College (3).
	Toledo	Toledo Public (1, 2, 3).
		University of Toledo (1, 2, 3).
	Wooster	College of Wooster, Andrews Library (1, 2, 3).
	Youngstown	Youngstown Public (1, 2, 3).
Oklahoma	Ada	East Central State College, Linscheid Library (2, 3).
	Alva	Northwestern State College (3).
	Bartlesville	Bureau of Mines, U.S. Department of the Interior (1, 2, 3).*
	Durant	Southeastern State College (3).
	Edmond	Central State College (3).
	Langston	Langston University, G. Lamar Harrison Library (3).
	Oklahoma City	Oklahoma Department of Libraries (1, 2, 3).
		Oklahoma City University (3).
	Norman	University of Oklahoma (1, 2, 3).
	Stillwater	Oklahoma State University (1, 2, 3).
	Tahlaquah	Northeastern State College, John Vaughan Library (1, 3).
	Tulsa	Tulsa City County (1, 2, 3).
		University of Tulsa, McFarlin Library (1, 2, 3).
Oregon	Albany	Bureau of Mines, U.S. Department of the Interior (1, 2, 3).*
	Ashland	Southern Oregon College (3).
	Corvallis	Oregon State University (1, 2, 3).
	Eugene	University of Oregon (1, 2, 3).
	Forest Grove	Pacific University (3).
	La Grande	Eastern Oregon College (3).
	McMinnville	Linfield College, Northrup Library (3).
	Monmouth	Oregon College of Education (3).
	Portland	Lewis and Clark College (3).
		Library Association of Portland (1, 2, 3).
		Portland State College (1, 2, 3).
		Reed College (2, 3).
	Salem	Oregon State (1, 2, 3).
Pennsylvania	Allentown	Muhlenberg College (2, 3).
	Bethlehem	Lehigh University (1, 2, 3).
	Bradford	Carnegie Public (2, 3).
	Carlisle	Dickinson College (2, 3).
	Cheyney	Cheyney State College, Leslie Pinckney Hill Library (3).
	Collegeville	Ursinus College (3).
	East Stroudsburg	East Stroudsburg State College, Kemp Library (3).
	Erie	Erie Public (1, 2, 3).
	Greenville	Thiel College, Langenheim Memorial Library (1, 2, 3).
	Harrisburg	Pennsylvania State (1, 2, 3).
	Haverford	Haverford College (3).
	Hazleton	Hazleton Public (1, 2, 3).
	Indiana	Indiana University of Pennsylvania, Rhodes R. Stabley Library (3).
	Johnstown	Cambria Public (2).
	Lancaster	Franklin and Marshall College (1, 2, 3).
	Lewisburg	Bucknell University, Ellen Clarke Bertrand Library (1, 2, 3).
	Meadville	Allegheny College, Reis Library (1, 2, 3).
	Millersville	Millersville State College (3).
	New Castle	New Castle Free Public (2, 3).

*Not a depository library.

State	City	Library and Type of Publication Received
Pennsylvania	Philadelphia	Drexel Institute (1, 2, 3).
		Philadelphia Free (1, 2, 3).
		Temple University (2, 3).
		University of Pennsylvania (2, 3).
	Pittsburgh	Bureau of Mines, U.S. Department of the Interior (1, 2, 3).*
		Carnegie Library of Pittsburgh (1, 2, 3).
		University of Pittsburgh, Hillman Library (1, 2, 3).
	Pottsville	Pottsville Free Public (2, 3).
	Reading	Reading Public (1, 2, 3).
	Scranton	Scranton Public (1, 2, 3).
	Slippery Rock	Slippery Rock State College (3).
	Swarthmore	Swarthmore College (3).
	University Park	Pennsylvania State University (1, 2, 3).
	Warren	Warren Public (3).
	Washington	Washington and Jefferson College, Memorial Library (3).
	Waynesburg	Waynesburg College (3).
	West Chester	West Chester State College, Francis Harvey Green Library (3).
	Wilkes-Barre	King's College (2, 3).
	Williamsport	James V. Brown Library of Williamsport and Lycoming County (1, 2, 3).
	York	York Junior College (3).
Rhode Island	Kingston	University of Rhode Island (1, 2, 3).
	Providence	Brown University, John D. Rockefeller, Jr., Library (1, 2, 3).
		Providence Public (2, 3).
		Rhode Island College, James P. Adams Library (3).
	Warwick	Warwick Public (3).
	Westerly	Westerly Public (3).
South Carolina	Charleston	Baptist College (1, 2, 3).
		The Citadel (1, 3).
	Clemson	Clemson University (1, 2, 3).
	Columbia	Columbia University (3).
		South Carolina State (3).
		University of South Carolina, McKissick Memorial Library (1, 2, 3).
	Florence	Florence County (3).
	Greenville	Furman University (1, 2, 3).
		Greenville County (3).
	Greenwood	Lander College (3).
	Rock Hill	Winthrop College (3).
	Spartanburg	Spartanburg County Public (3).
South Dakota	Aberdeen	Northern State College (3).
	Brookings	South Dakota State University, Lincoln Memorial Library (1, 2, 3).
	Rapid City	South Dakota School of Mines and Technology (1, 2, 3).
	Sioux Falls	Carnegie Free Public (3).
	Spearfish	Black Hills State College (3).
	Vermillion	University of South Dakota, I. D. Weeks Library (3).
	Yankton	Yankton College, Corliss Lay Library (1, 3).
Tennessee	Chattanooga	Chattanooga Public (1, 2, 3).
	Clarksville	Austin Peay State College (3).
	Jackson	Lambuth College, Luther L. Gobbel Library (3).
	Jefferson City	Carson-Newman College, Maples Library (3).
	Johnson City	East Tennessee State University, Sherrod Library (1, 2, 3).
	Knoxville	University of Tennessee (1, 2, 3).
	Martin	University of Tennessee (3).
	Memphis	Cossitt Reference (1, 2, 3).
		Memphis State University (3).
	Murfreesboro	Middle Tennessee State University (3).
	Nashville	Fisk University (1).
		Joint University Libraries (1, 2).
		Nashville and Davidson County Public (3).
		Tennessee State Library and Archives (2, 3).
	Sewanee	University of the South, Jesse Ball Dupont Library (3).
Texas	Abilene	Hardin-Simmons University (3).
	Amarillo	Bureau of Mines, U.S. Department of the Interior (1, 2, 3).*
	Arlington	University of Texas (1, 2, 3).
	Austin	Texas State (1, 2, 3).
		University of Texas (1, 2, 3).
	Beaumont	Lamar State College of Technology (1, 2, 3).
	Brownwood	Howard Payne College, Walker Memorial Library (3).
	Canyon	West Texas State University (2, 3).
	College Station	Texas A&M University (1, 2, 3).

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State	City	Library and Type of Publication Received
Texas	Commerce	East Texas State University (2, 3).
	Corsicana	Navarro Junior College (3).
	Dallas	Dallas Baptist College (3).
		Dallas Public (1, 2, 3).
		Southern Methodist University, Fondren Library (1, 2, 3).
	Denton	North Texas State University (2, 3).
	Edinburg	Pan American College (3).
	El Paso	El Paso Public (1, 2, 3).
		University of Texas (1, 2, 3).
	Fort Worth	Fort Worth Public (1, 2, 3).
		Texas Christian University, Mary Couts Burnett Library (1, 2, 3).
	Galveston	Rosenberg (3).
	Houston	Houston Public (1, 2, 3).
		Rice University, Fondren Library (3).
		University of Houston (1, 2, 3).
	Huntsville	Sam Houston State College, Estill Library (2, 3).
	Kingsville	Texas College of Arts and Industries (1, 2, 3).
	Longview	Nicholson Memorial Public (2, 3).
	Lubbock	Texas Technological College (1, 2, 3).
	Marshall	Wiley College, Carnegie Library (3).
	Nagadoches	Stephen F. Austin State College, Paul L. Boynton Library (2, 3).
	Plainview	Wayland Baptist College, Van Howeling Memorial Library (3).
	San Angelo	Angelo State College (3).
	San Antonio	St. Mary's University (1, 2, 3).
		San Antonio Public (1, 2, 3).
		Trinity University (1, 2, 3).
	San Marcos	Southwest Texas State College (1, 3).
	Texarkana	Texarkana College (3).
	Waco	Baylor University (2, 3).
	Wichita Falls	Midwestern University, Moffett Library (1, 2, 3).
Utah	Ephraim	Snow College (2).
	Logan	Utah State University (1, 2, 3).
	Ogden	Weber State College (1, 2, 3).
	Provo	Brigham Young University (1, 2, 3).
	Salt Lake City	University of Utah (1, 2, 3).
Vermont	Burlington	University of Vermont, Bailey Library (1, 2, 3).
	Middlebury	Middlebury College, Egbert Starr Library (1, 2, 3).
	Montpelier	Vermont State (3).
	Northfield	Norwich University (3).
	Putney	Windham College, Dorothy Marvin Memorial Library (3).
Virginia	Blacksburg	Virginia Polytechnic Institute (1, 2, 3).
	Charlottesville	University of Virginia (1, 2, 3).
	Emory	Emory and Henry College (3).
	Fredericksburg	Mary Washington College, E. Lee Trinkle Library (3).
	Hampden Sydney	Hampden Sydney College, Eggleston Library (3).
	Hollins College	Hollins College, Fishburn Library (3).
	Lexington	Virginia Military Institute (2, 3).
		Washington and Lee University, Cyrus Hall McCormick Library (2, 3).
	Norfolk	Old Dominion College, Hughes Memorial Library (1, 2, 3).
		Norfolk Public (3).
	Petersburg	Virginia State College, Johnston Memorial Library (3).
	Richmond	University of Richmond, Boatwright Memorial Library (2, 3).
		Virginia State (1, 2, 3).
	Roanoke	Roanoke Public (3).
	Salem	Roanoke College (3).
	Williamsburg	College of William and Mary (1, 2, 3).
Washington	Bellingham	Western Washington State College, Wilson Library (1, 2, 3).
	Cheney	Eastern Washington State College (3).
	Ellensburg	Central Washington State College (1, 2, 3).
	Everett	Everett Public (3).
	Olympia	Washington State (1, 2, 3).
	Port Angeles	Port Angeles Public (2, 3).
	Pullman	Washington State University (1, 2, 3).
	Seattle	Seattle Public (1, 2, 3).
		University of Washington (1, 2, 3).
	Spokane	Spokane Public (1, 2, 3).
	Tacoma	Tacoma Public (1, 2, 3).
		University of Puget Sound, Collins Memorial Library (2, 3).
	Vancouver	Fort Vancouver Regional (1, 2, 3).
	Walla Walla	Whitman College, Penrose Memorial Library (2, 3).

State	City	Library and Type of Publication Received
West Virginia	Athens	Concord College (3).
	Charleston	Department of Archives and History (3).
		Kanawha County Public (3).
	Elkins	Davis and Elkins College (3).
	Fairmont	Fairmont State College (3).
	Glenville	Glenville State College, Robert F. Kidd Library (3).
	Huntington	Marshall University (1, 2, 3).
	Institute	West Virginia State College (3).
	Morgantown	West Virginia University (1, 2, 3).
	Salem	Salem College (3).
Wisconsin	Appleton	Lawrence University, Samuel Appleton Library (2, 3).
	Beloit	Beloit College (3).
	Eau Claire	Wisconsin State University, William D. McIntyre Library (2, 3).
	Fond du Lac	Fond du Lac Public (2, 3).
	La Crosse	La Crosse Public (3).
		Wisconsin State University, Florence Wing Library (3).
	Madison	Madison Public (2, 3).
		State Historical Society (1, 2, 3).
		University of Wisconsin, Memorial Library (1, 2, 3).
	Milwaukee	Milwaukee Public (1, 2, 3).
		Mount Mary College (3).
		Oklahoma (3).
		University of Wisconsin (3).
	Oshkosh	Wisconsin State University, Forrest R. Polk Library (1, 3).
	Platteville	Wisconsin State University (1, 2, 3).
	Racine	Racine Public (1, 2, 3).
	River Falls	Wisconsin State University, Chalmer Davee Library (1, 3).
	Stevens Point	Wisconsin State University (1, 2, 3).
	Superior	Superior Public (1, 3).
		Wisconsin State University, Jim Dan Hill Library (3).
	Waukesha	Waukesha Public (3).
	Whitewater	Wisconsin State University, Harold Andersen Library (1, 2, 3).
Wyoming	Casper	Natrona County Public (2, 3).
	Cheyenne	Wyoming State (1, 2, 3).
	Laramie	University of Wyoming, Coe Library (1, 2, 3).
		Bureau of Mines, U.S. Department of the Interior (1, 2, 3).*
	Sheridan	Sheridan College, Kooi Library (1, 2, 3).
Guam	Agana	Nieves M. Flores Memorial (3).
Puerto Rico	Rio Piedras	University of Puerto Rico (1, 2, 3).
	Mayaguez	University of Puerto Rico (1, 2, 3).
	Ponce	Catholic University of Puerto Rico (3).
St. Thomas, V.I.	Charlotte Amalie	Public (1).

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BULLETINS

B 615. Reduction of Coal by Lithium-Ethylenediamine and Reaction of Model Compounds With Metal-Amine Systems, by Leslie Reggel, Charles Zahn, Irving Wender, and Raphael Raymond. 1965. 57 pp. 30 figs. A series of vitrains (ranging from 67.9 to 93.1 percent C, maf) and a natural graphite were reduced on a small scale by a novel reagent—lithium-ethylenediamine at 100° C. At this low temperature, coal is very reactive and adds large amounts of hydrogen. Even a high-rank coal and graphite, which are very difficult to hydrogenate catalytically at high temperatures and pressures, were reduced by the lithium-ethylenediamine system. Studies on model compounds consisted of reduction of hydrocarbons and oxygenated compounds with lithium-ethylenediamine, isomerization of olefins and dehydrogenation of cyclic dienes by *n*-lithioethylenediamine, reductive dimerization of naphthalene by sodium-ethylamine, and formation of imidazole derivatives and cleavage of carbon-carbon bonds by *n*-lithioethylenediamine and *n*-sodioethylenediamine. Work done in cooperation with the Union Carbide Corp. (*Out of print.*)

B 620. X-Ray Diffraction Data for Aromatic, Hydroaromatic, and Tetrahedral Structures of Carbon, by Sabri Ergun, W. F. Donaldson, and R. W. Smith, Jr. 1965. 104 pp. 1 fig. Presents new theoretical data for the intensity of X-rays diffracted from randomly oriented aromatic and alicyclic molecules and diamondlike structures such as are found in coals, cokes, and carbonaceous materials. Data have been computed using the Debye interference function. Computations for the smaller molecules have been made with the Univac 120 computer; those for large structures, with either the IBM 704 or Bendix G-20 computer. A brief theoretical introduction of the Debye interference function is given, and an outline is made of the treatment of experimental data so that the experimental interference function can be obtained. (*Out of print.*)

B 621. Some Statistical Techniques for Analyzing Mine and Mineral-Deposit Sample and Assay Data, by Scott W. Hazen, Jr. 1967. 223 pp. 75 figs. A comprehensive summary is presented of the results of several years of research at the Bureau of Mines Mining Research Center at Denver, Colo., on adapting and applying techniques of statistical analysis in mine and mineral-deposit sampling and in computing grade and tonnage of ore for a mineral deposit. In addition to elementary statistical theory, the material presented in the bulletin includes (1) certain special statistical techniques that have been found useful in mining applications; (2) problems, implications, and limitations that may be encountered in applying these techniques in mine sampling and evaluation; and (3) numerous examples to demonstrate application of the theory and techniques. $1.25.

B 622. Hydrogenation of Coal in the Batch Autoclave, by C. O. Hawk and R. W. Hiteshue. 1965. 42 pp. 13 figs. Tests were made on the hydrogenation of bituminous coal by a dry method, which featured charging the autoclave with dry ingredients only—coal, catalyst, and hydrogen. This innovation limited the products to those made from the coal charged. Tin catalysts showed the highest activity in the widest variety of forms and were the easiest to disperse; dry mixing in the autoclave during the heating-up period usually sufficed. Ammonium molybdate was inactive when dry mixed, but it compared favorably with the best catalysts known when applied by impregnating the coal with a solution of a molybdenum compound. As a group, metal naphthenates were the most effective; molybdenum napththenate was the most active catalyst the tests disclosed. One-hundredth of a percent of molybdenum in this form (calculated as the metal in weight-percent of maf coal) induced 90-percent conversion of coal. However, because of their high costs, napththenates have as yet only technical significance in coal hydrogenation. Long residence time and high reaction temperatures tended to increase the amount of thermal decomposition products formed (light hydrocarbon gases and/or char). High hydrogen pressure favored the production of liquids. (*Out of print.*)

B 623. State Compensatory Provisions for Occupational Diseases, by G. G. Morgis, Lena P. Beauregard, and Earle P. Shoub. 1967. 246 pp. An occupational disease is an illness resulting from exposure to an industrial health hazard commonly regarded as peculiar to, inherent in, or a natural accompaniment of the occupation in which it arises. This report is a compilation of those portions of the workmen's compensation laws of 49 States, the District of Columbia, Puerto Rico, and Virgin Islands that deal with occupational diseases. Direct quotes are reproduced from the annotated legal codes of the States, together with references to legal history and origin of the laws. Since each State functions independently in administering its own laws, there is no general uniformity in provisions or coverage. $1.25.

B 624. Manganese-Copper Damping Alloys, by J. W. Jensen and D. F. Walsh. 1965. 55 pp. 32 figs. Extensive research and development was performed on the manganese-copper vibration-damping alloys to determine the relationship between the properties of the alloys and variations in composition, fabrication, and heat treatment. Both standard and special methods of testing were employed to obtain data on strength, elastic modulus, hardness, resistivity, dilatation, microstructure, crystal lattice, and damping capacity. The extensive tabular and graphical data on these properties are presented for alloys containing 50 to 85 percent Mn, as quenched (solid solution) and after various aging treatments. (*Out of print.*)

B 625. Studies of High-Current Metallic Arcs, by F. W. Wood and R. A. Beall. 1965. 84 pp. 46 figs. Original experimentation in specially designed arc-melting furnaces and a comprehensive review of technical literature have helped with an understanding of electric arcs as used in metallurgical applications. Results relevant to the distribution of electric potentials and currents, temperatures, pressures, consumption of electrodes, identities of particles participating in electrical conduction, and modes and mechanisms of discharge are presented and discussed. Present knowledge of high-current arcs is insufficient to test pertinent theoretical suggestions. However, the chief doubts concern the identities and the liberation or formation of current-carrying particles. It seems that either (1) novel formulations of existing concepts are needed or (2) essentially new concepts must be recognized to explain observations. An analysis of the situation has led the authors to favor the latter possibility and to suggest the existence of supplementary conducting particles. The conduction of current by the streaming of charged agglomerates is postulated. Another outgrowth of analysis is an equation for the arc potential as a function of current densities in the arc. In lieu of conclusions, the potentialities of practical applications and specific needs for fundamental clarification are summarized. Portions of the work done in cooperation with the Naval Reactors Division of the Bureau of Ships and the Pittsburgh Area Office of the U.S. Atomic Energy Commission. (*Out of print.*)

B 627. Flammability Characteristics of Combustible Gases and Vapors, by Michael G. Zabetakis. 1965. 121 pp. 131 figs. Summarizes limit of flammability, autoignition, and burning-rate data for more than 200 combustible gases and vapors in air and other oxidants; supplies empirical rules and graphs that can be used to predict similar data for thousands of other combustibles under a variety of environmental conditions. Specific data are presented on the paraffinic, unsaturated, aromatic, and alicyclic hydrocarbons, alcohols, ethers, aldehydes, ketones, and sulfur compounds, and an assortment of fuels, fuel blends, hydraulic fluids, engine oils, and miscellaneous combustible gases and vapors. 75 cents.

B 628. Sulfur Poisoning of Fixed Beds of Iron Catalysts in the Fischer-Tropsch Synthesis, by R. B. Anderson, F. S. Karn, R. E. Kelly, and J. F. Schultz. 1965. 16 pp. 6 figs. Tests of two typical iron catalysts with synthesis gas containing known concentrations of H_2S were made to determine catalyst life as a function of sulfur concentration to ascertain the type of gas purification required. One objective of the present work was to determine if synthesis gas, purified by the Bureau of Mines hot-potassium carbonate process for removing H_2S of the gas purified by this process, is in the range of concentrations used in the present work. In constant-productivity tests of nitrided fused iron oxide catalysts with synthesis gas containing 6.9 mg S/m^3, catalyst lives are nearly long enough for serious consideration of this mode of operation. However, factors relating to selectivity and stability of the catalyst indicate that this type of operation is impractical for a commercial process. (*Out of print.*)

B 629. Oilfields in the Williston Basin in Montana, North Dakota, and South Dakota, by J. R. Hamke, L. C. Marchant, and C. Q. Cupps. 1966. 487 pp. The Williston basin is the largest known sedimentary basin on the North American continent. Two-thirds of this large basin lies within the United States in Montana, North Dakota, and South Dakota. Less than 10 years after the first commercial oil discovery in North Dakota in 1951, the petroleum industry became one of the largest industries in the three-state area. Crude petroleum is now the most valuable mineral resource in the area. In 1960 the basin produced 39 million barrels of oil worth $100 million at the wellhead. Most of the 137 oil pools discovered are in Paleozoic carbonates at depths ranging from 3,000 to 13,000 feet. The major producing fields, centered on the Cedar Creek anticline in Montana and the Nesson anticline in North Dakota, produce from depths below 6,000 feet. This report presents descriptions of all phases of the Williston basin petroleum industry, including leasing, exploration, geology, drilling, production, transportation, and refining. Engineering, physical, and production data, maps, and crude petroleum analyses for 137 separate oil pools are included. Work done in cooperation with the University of Wyoming. $3.

B 630. Mineral Facts and Problems, 1965 Edition, by Staff, Bureau of Mines. 1965. 1118 pp. 55 figs. Gives up-to-date, comprehensive information on all important minerals—metals, nonmetals, and fuels. This one-volume encyclopedia discusses individual mineral commodities separately in 89 chapters under such topics as history; geology and mineralogy; prospecting and exploration; mining and processing; uses and substitutes; reserves, production, and consumption; world trade; prices, costs, and taxes; employment; transportation; and research and outlook. Previous editions were B 556, published in 1956, and B 585, published in 1960. $6.75.

B 631. Nature of the Carbides of Iron, by L. J. E. Hofer. 1966. 60 pp. 29 figs. Bureau of Mines research dealing with the preparation, properties, and reactions of iron carbides in the period 1948-60 (which was sponsored in part by Wright Air Development Laboratories) is analyzed and summarized. The inevstigations resulted in the first adequate characterization of epsilon iron carbide, which later proved to be an important intermediate in the tempering of martensite in steel. It was also found that chi iron carbide is probably an intermediate in the tempering of epsilon iron carbide to theta iron carbide as it proceeds in steels. Data from further studies indicated that epsilon iron carbide is an intermediate in the formation of chi iron carbide during its formation from carbon monoxide in the gas phase. 40 cents.

B 632. Infrared and Ultraviolet Spectrometric Techniques and Spectra-Structure Correlations, by R. A. Friedel and J. A. Queiser. 1966. 32 pp. 9 figs. The utilization by the Bureau of Mines of infrared and ultraviolet-visible spectometry in connection with coal research has led to some basic improvements in methods, including a calibration method, a quantitative assessment of infrared spectral energy sources, and the development and perfection of infrared filters and cells. The adoption of a micropipet method to flush organic samples into absorption cells permits the investigation of vapors from organic liquids and the identification of volatile organic compounds. The spectral method has been used to investigate the infrared spectra of metal chelates, the charge-transfer complexing properties of aniline and nitrobenzene, an infrared method for determining the presence of methane in coal-mine air that has been adopted for use in enforcing the regulations of the National Coal Mine Safety Act, and atmospheric pollution including smog and odor-causing oxidation and decomposition of organic materials. Correlation of spectra and structure of organic compounds, particularly aromatics, was studied. 25 cents.

B 633. Hydrogenation of Coal and Tar, by W. R. K. Wu and H. H. Storch. 1968. 95 pp. 92 figs. This bulletin traces the development of high-pressure coal and tar hydrogenation technology, based on an intensive review of the pertinent literature. The bulletin was written as a part of the Bureau of Mines research program on synthetic liquid fuels. It covers the history and economics of the process; the chemical aspect of hydrogenation of coal, tar, and middle oil; the engineering aspect of converting coal and tar to liquid fuels, principally gasoline; and the equipment for the process. The literature covered includes documents of the U.S. and British Governments, journals, and other publications. Bureau results in the hydrogenation field are also incorporated. $1.25.

B 634. Analytical Methods in Mass Spectrometry, by A. G. Sharkey, Jr., J. L. Shultz, and R. A. Friedel. 1967. 74 pp. 37 figs. The purpose of this investigation was to develop methods for analyzing coal derivatives and products from the Fischer-Tropsch synthesis. As part of this investigation it was necessary to study the mass spectral characteristics of many classes of compounds. The mass spectra of alcohols, the trimethylsilyl ether derivatives of alcohols, acetal-type compounds, ketones, esters, and naphthenes were correlated with structure, and analytical methods were formulated. A method was devised to determine the ratio of branched to normal hydrocarbons up to C_{16} in the Fischer-Tropsch product. Low-ionizing-voltage mass spectrometry was combined with type analyses to analyze tar acids and neutral oils from coal. The necessary sensitivity correlations at low-ionizing voltage were developed, particularly for phenolic compounds. Special analytical techniques were developed for the mass spectral analyses of specific compounds and compound types including (1) oxides of nitrogen, (2) hydrogen sulfide, (3) isomers of butenes and pentenes, and (4) hydrogen deuteride. An investigation was made of the effects of various hydrocarbons and oxygenated compounds on tungsten filaments in the mass spectrometer. The operating characteristics of rhenium filaments under similar conditions were studied. Several improved sample handling techniques were developed, including an automatic manometer and a self-filling micropipet. Studies were made of anomalous and negative peaks in the mass spectra of certain gases. 45 cents.

B 635. Development of the Bureau of Mines Gas-Combustion Oil-Shale Retorting Process, by Arthur Matzick, R. O. Dannenberg, J. R. Ruark, J. E. Phillips, J. D. Lankford, and Boyd Guthrie. 1966. 199 pp. 132 figs. Presents results from research and development carried out by the Bureau of Mines on the gas-combustion oil-shale retorting process. Effects of the process variables, results of gas and shale distribution studies, tests on shale particle size, and other details of experimental programs are discussed. Various auxiliary information and problems associated with the retorting process also are included. Tabulation of the retorting test data and detailed oil recovery flow diagrams for the 6-, 25-, and 150-ton-per-day retorts and drawings relating to retorting equipment are given. $1.

B 636. Characterization of the Resin Fraction From Various Low-Temperature Tar Pitches, by Clarence Karr, Jr., and Joseph R. Comberiati. 1966. 31 pp. Resins from a bituminous pitch, a bituminous coal, a lignate tar, a sub-bituminous pitch, and an electrode binder pitch were investigated by the Bureau of Mines. The compositions of these resins were determined by four independent methods of structural determination: (1) Molecular formula and ring analysis, including ring arrangement; (2) infrared and ultraviolet spectra; (3) combined pyrolysis/gas chromatography; and (4) catalytic dehydrogenation followed by spectra and pyrolysis. The resin structure was correlated wtih coal structure, and it was concluded that pitch resins probably consist of essentially unaltered coal molecules carried over with the tar vapors in low-temperature carbonization. 25 cents.

B 637. Identification of Distillable Paraffins, Olefins, Aromatic Hydrocarbons, and Neutral Heterocyclics From a Low-Temperature Bituminous Coal Tar, by Clarence Karr, Jr., Patricia A. Estep, Ta-Chuang Lo Chang, and Joseph R. Comberiati. 1967. 198 pp. 34 figs. An extensive characterization was conducted on the neutral oil components in a low-temperature bituminous coal tar. A total of 133 individual compounds was identified with respect to individual isomers, and at least 55 other compounds were indicated to be present. The amounts were determined in all instances. A comparison of isomeric distributions in the tar with thermodynamic equilibrium distributions and kinetic distributions indicated that the composition of the tar largely reflected the structure of the coal from which it was formed. Detailed descriptions are presented for the separatory and qualitative and quantitative procedures for the characterization of the neutral oil components. These include microfractional vacuum distillation, displacement liquid chromatography, gas-liquid chromatography, countercurrent distribution, and infrared and ultraviolet spectrophotometry. Descriptions are given for the synthesis of authentic specimens of alkylindenes. The ultraviolet and infrared spectra of 134 polycyclic compounds, ranging from alkylindenes to alkylphenanthrenes, either found in the distillable neutral oil or thought likely to be present, are also given. $1.

B 638. Methods of Analyzing and Testing Coal and Coke, by Staff, Office of the Director of Coal Research. 1967. 82 pp. 50 figs. This bulletin presents all analytical and test methods regularly used by Bureau of Mines laboratories for characterizing coal and coke. To provide better service to coal producers and consumers, the scope of this bulletin has been expanded to include important test methods used to evaluate coal properties for commercial processing. The methods described will prove valuable to all persons interested in analyzing and testing coal and coke. 50 cents.

B 639. Entrainment Carbonization of Texas Lignite, by W. S. Landers, Manuel Gomez, and E. O. Wagner. 1968. 44 pp. 16 figs. This bulletin is a detailed study of low-temperature, entrained-bed carbonization of a Texas lignite. The lignite studied was from the Sandow strip mine and is representative of the Rockdale Formation of the Wilcox Group. Carbonization was conducted in a continuous entrained-bed reactor at several temperatures in the 880° to 1,520° F range and at air-to-coal ratios in the 0 to 10.30 scf/1b range (moisture- and ash-free basis). Carbonization rates ranged from 97.1 to 410.0 1b/hr (as-received basis). At the higher air-to-coal ratios employed, all or most of the carbonization heat was provided by internal combustion with air in the reactor. At the lower air-to-coal ratios, part of the heat for carbonization was supplied externally. It was demonstrated that the entrained-bed carbonization of lignite is a complex reaction and that several variables, of which carbonization temperature, air-to-lignite ratio, and the average size of lignite are important, act together to influence both the carbonization yields and the properties of the resultant products. Process variables established by pilot plant tests were used to design the industrial scale carbonizer operated at Rockdale, Tex., by the Texas Power & Light Company as agents for the Aluminum Company of America. Properties of the carbonization product obtained from the industrial scale reactor were essentially the same as those obtained from the pilot plant reactor operated under the same conditions. 30 cents.

B 640. Advances in Coal Spectrometry. Absorption Spectrometry, by R. A. Friedel, H. L. Retcofsky, and J. A. Queiser. 1967. 48 pp. 26 figs. The importance of infrared and ultraviolet-visible spectrometry in studies of the structure of coal and similar substances is described. Special experimental techniques have been developed for these studies.

Thin sections of coal are preferred, but halide pellets are easier to prepare. Information obtained from infrared spectra on chemical functional groups has been discussed; the importance of both intensities and wavelengths of absorption bands has been emphasized. Functional groups assigned include aliphatic and aromatic CH, methylene and methyl groups, hydrogen-bonded hydroxyls, hydrogen-bonded and chelated carbonyls, phenolic structures, minerals, and aromatic structures that are benzenoid or polynuclear.

Infrared studies of structures of coal extracts, distillates, and reaction products of various processes, both chemical and physical, are discussed. Coallike infrared spectra of chars of model compounds have been utilized extensively in studies of coal structure.

Ultraviolet-visible absorption spectra of coals show a lack of fine structure and low spectral intensities. These results have been applied to the questions of the chemical and physical structure of coal, particularly the question of polynuclear aromaticity of coals. The color of coal is also treated. The physical-chemical origin of the color of coal may be due to free radicals, as interesting correlations of ultraviolet-visible spectra with electron paramagnetic resonance have been obtained. The optical color of coal has been explained and simulation of the color changes observed in thin sections has been carried out. The spectra and structure of coal derivatives and other carbonaceous materials are also discussed. Possible sources of error in absorption spectral measurements are pointed out.

Limited measurements of the ultraviolet-visible reflectance spectra of coal are described. 35 cents.

B 641. Optical Properties of Coals and Graphite, by J. T. McCartney and S. Ergun. 1967. 49 pp. 36 figs. Optical properties of U.S. coals of differing rank have been investigated by the Bureau of Mines for about 20 years. These investigations have been made to further the development of an objective basis for petrographic analysis of coal and to add to knowledge of the structure and composition of coal and coal components by determining their optical constants in various regions of the electromagnetic spectrum. Various experimental techniques have been used in these studies, including determination of reflectance from bulk specimens and transmittal of thin and ultrathin sections, interferometry, electron microscopy, and electron diffraction. Similar studies have also been made of graphite, the end product of coal metamorphism.

The Bureau of Mines conducted the first U.S. investigation of reflectance properties of coal components, laying the foundation for petrographic analysis based on arbitrary reflectance classes and for automated reflectance analysis of coals. Optical constants of differing rank and of graphite have been determined in the ultraviolet-visible-near infrared spectrum. Maxima in the optical constants of graphite were observed in the ultraviolet region and were interpreted to be related to transitions of electrons between the valence and conduction bands. Similar maxima for coals, especially high-rank coals, appeared to be characteristic of the presence of graphitelike layers. A special application of optical theory to absorbing, anisotropic materials like graphite and high-rank coals has been developed. Electron microscopic and electron diffraction studies of coals have revealed various ultrafine structures in coal components and have shown the evolution of an oriented, crystalline graphite structure in high-rank coals. 35 cents.

B 642. Qualitative and Quantitative Aspects of Crude Oil Composition, by Harold M. Smith. 1968. 125 pp. 65 figs. This publication summarizes the literature on the composition of petroleum with special emphasis on naphtha and gas oil, and provides a source book for the known qualitative and quantitative facts on crude oil composition. The discussion points out the known facts from supposition and suggests new research needed in various areas. $1.

B 643. Yields and Analyses of Tars and Light Oils From Carbonization of U.S. Coals, by J. G. Walters, C. Ortuglio, and J. Glaenzer. 1967. 91 pp. This bulletin presents, in collected and tabulated form, Bureau of Mines and American Gas Association (BM-AGA) carbonization data pertaining to the chemical analysis of tars and the characterization of tars and light oils obtained from U.S. coals. 50 cents.

B 644. Tunneling: Recommended Safety Rules (Revision of Bulletin 439), by Staff, Health and Safety Activity, Washington, D.C., and Health and Safety District A. 1968. 48 pp. This publication is designed to be helpful in promoting health and safety in tunneling and related operations. The format has been selected and arranged to provide a condensed guide for safety personnel, inspection and investigative agencies, design and project engineers, and others responsible for the health and safety of workmen. All the precautionary measures recommended are based on actual conditions observed, from investigations of fatal or serious accidents, and from research conducted to find ways and means of alleviating hazards and unhealthful conditions. Many of the recommended rules are included in State laws and in the general safety requirements of the construction industry. Explanatory, descriptive, and qualifying information has been largely omitted in this publication to keep basic data in more useful and compact form. Included in the appendixes are special precautions for gassy (methane atmosphere) tunnels and tunnels where petroleum products are encountered. 40 cents.

B 646. Cold-Mold Arc Melting and Casting, by R. A. Beall and others. 1968. 151 pp. 167 figs. This bulletin reviews the historical background of the cold-mold arc-melting technology, with specific references to the development that led to homogeneous zirconium ingots. Descriptions are given of modern production arc-furnaces for vacuum melting of both exotic and conventional metals. Besides zirconium, specific data are given for production of chromium, thorium, and copper. The development of the skull-casting technique for titanium is detailed, and the application of the technique to such refractory metals as molybdenum and tungsten is described. Factors of operation of the apparatus and furnace design are considered. $1.25.

B 645. Mineral Resources and Industries of Arkansas, by Raymond B. Stroud, Robert H. Arndt, Frank B. Fulkerson, and W. G. Diamond. 1969. 418 pp. 114 figs. This bulletin describes the mineral resources and industries of Arkansas. Items discussed include engineering, geological, and economic features; mineral reserves and resources; uses and markets; and the current status and future potential of mineral commodities available in the State. Data concerning the State economy, demography, mineral organizations, taxation, land resources and ownership, mining laws and regulations, transportation, and energy sources are treated briefly to assist the reader in understanding the place of mineral resources as a factor in the future economic growth of the State.

The bulletin is designed to serve the needs of industry, State and Federal agencies, and individuals and other organizations in planning and conducting effective programs for development of Arkansas minerals. $4.25.

B 647. Fluorine Micas, by Haskiel R. Shell and Kenneth H. Ivey. 1969. 291 pp. 86 figs. While the original purpose of the Bureau of Mines work on fluorine micas was to synthesize large single crystals or film suitable to replace natural muscovite or phlogopite, the objective was broadened to include development of the many possible fluorine micas as a class of new, unique materials. Several methods were developed for the synthesis of the fluorine micas at atmospheric pressure: Solid state reaction, melting in crucibles, internal resistance electric melting, and arc resistance electric melting. The latter two methods are now used commercially. A variety of fluoromicas were synthesized by isomorphic substitution including disilic, trisilic, and tetrasilic. Fluorophlogopite, $KMg_3AlSi_3O_{10}F_2$, is the fluoromica most widely used. While most of the fluoromicas are completely stable to water, many water-swelling fluoromicas and fluoromontmorrilonoids were synthesized. Single crystals or film of the fluorine micas were grown to 2 inches or more by a number of methods, but none has as yet proved economical. In the report detailed data and descriptions are given on compositions, syntheses, products, and uses and on the properties including physical, dielectric, chemical, X-ray, optical and structural. $2.75.

B 648. X-Ray Studies of Coals and Carbonaceous Materials, by Sabri Ergun. 1968. 38 pp. 28 figs. This report gives the result of investigations of coals of different rank, coal components, chemically and thermally treated and irradiated coals, and sedimented organic matter. In most studies the arbitrary parameters obtained from the usual quantitative profile analyses are not given largely because they lack physical meaning. Instead comparative interpretations are offered. X-ray patterns of high-volatile bituminous and lower rank coals are not self-sufficient for structural interpretation by the methods of analysis developed to date. The patterns of hydrogenated and dehydrogenated coals indicate that the basic change in the structure of bituminous coals with increase in rank is the conversion of alicyclic structures into aromatic layers. In low-rank anthracites the aromatic layers are about 10 A in size. The increase in rank is the result of coalescence of layers. High-rank anthracites have layer sizes of 25 to 40 A and exhibit the development of three-dimensional (hkl) reflections of graphite, indicating ordering of adjacent layers. In meta-anthracites the layers are >1000 A and the basic structure is that of defective crystalline graphite. The well-known petrographic components in low-rank coals have different structures; the differences disappear in low-volatile bituminous and higher rank coals. The patterns of sedimented organic matter, except impsonites, differ from those of coals. Their hydrogen contents are high, and their X-ray patterns are consistent with those of alicyclic structures.

In contrast to normal coals, the patterns of uranium-bearing coals show increased diffuseness with decrease in hydrogen content. The diffuseness is accompanied by increase in the uranium content of the coal. It is very likely that high uranium-bearing coals have predominantly tetrahedral structures. 45 cents.

B 649. Carbon-13 Nuclear Magnetic Resonance Spectra of Monosubstituted Pyridines, by H. L. Retcofsky and R. A. Friedel. 1969. 45 pp. 42 figs. Carbon-13 nuclear magnetic resonance (^{13}C NMR) spectra of nine 2-substituted pyridines, seven 3-substituted pyridines, and nine 4-substituted pyridines have been obtained and analyzed. Substituents included both electron-releasing groups and electron-withdrawing groups. Substituent effects on the magnetic shieldings of the ring carbons, except for those in the 2-positions of 2-substituted pyridines, were found to be quite similar to the effects reported for the monosubstituted benzenes. Thus, at least to a first approximation, the two classes of compounds have similar shielding mechanisms. Shieldings of the carbon atoms in the 5-positions of 2-substituted pyridines and those in the 6-positions of 3-substituted pyridines were found to reflect electron release or withdrawal by substituent groups. The pyridinium cation and the compounds 2,2'-dipyridyl and benzonitrile were also investigated. 60 cents.

MINERALS YEARBOOKS

The Minerals Yearbook 1964 is the second annual review to be presented in four volumes, the fourth volume giving international mineral industry statistics on a country-by-country basis. The contents of the four-volume editions follows:

Volume I, Metals and Minerals (Except Fuels), prepared by the staff of the Division of Minerals. 1965. 77 chapters. 1258 pp. 33 figs. Contains chapters on metal and nonmetal mineral commodities except mineral fuels. In addition it includes a chapter reviewing these mineral industries, a statistical summary, and chapters on mining and metallurgical technology, employment and injuries, and technologic trends. $4.75.

Volume II, Mineral Fuels, by the staffs of the Division of Anthracite, Division of Bituminous Coal, Division of Petroleum, Division of Statistics, Division of Economic Analysis, Division of Accident Prevention and Health, and Assistant Director—Helium. 12 chapters. 1965. 509 pp. 52 figs. Contains chapters on each mineral fuel and on such related products as helium, carbon black, peat, coke and coal chemicals, and natural gas liquids. Also included are data on employment and injuries in the fuel industries and a mineral-fuels review summarizing recent economic and technological developments. $2.75.

Volume III, Area Reports: Domestic, prepared by the staffs of the field offices of the Division of Mineral Resources of the Bureau of Mines. 1965. 53 chapters. 1152 pp. 56 figs. Contains geographic chapters for each State, as well as the island possessions and the Canal Zone. $4.50.

Volume IV, Area Reports: International, prepared by the staff of the Division of International Activities. 1966. 104 ch. 1350 pp. Present statistical and mineral industry information for the countries of the world (excluding the United States). $5.00.

Minerals Yearbook 1965, published in four volumes, provides a record of performance of the Nation's mineral industries during the year and a review of world mineral production, consumption, and trade on a country-by-country basis.

Volume I, Metals and Minerals (Except Fuels), prepared by the staff of the Division of Minerals. 1966. 77 ch. 1095 pp. 30 figs. Contains chapters on metal and nonmetal mineral commodities except mineral fuels. In addition it includes a chapter reviewing the mineral industries, a statistical summary, and chapters on mining and metallurgical technology, employment and injuries, and technologic trends. $4.25.

Volume II, Mineral Fuels, by the staffs of the Division of Anthracite, Division of Bituminous Coal, Division of Petroleum, Division of Statistics, Division of Economic Analysis, Division of Accident Prevention and Health, and Assistant Director—Helium. 1967. 12 ch. 465 pp. 48 figs. Contains chapters on each mineral fuel and on such related products as helium, carbon black, peat, coke and coal chemicals, and natural gas liquids. Also included are data on employment and injuries in the fuel industries and a mineral fuels review summarizing recent economic and technologic developments. $2.50.

Volume III, Area Reports: Domestic, prepared by the staffs of the field offices of the Division of Mineral Resources. 1967. 53 ch. 928 pp. 54 figs. Presents statistical data and mineral industry information for each State as well as the island possessions and the Canal Zone. Most chapters are prepared under cooperative agreements with State or island agencies for the collection of mineral data. $3.75.

Volume IV, Area Reports: International, prepared by staff of the Bureau of Mines. 1967. 105 ch. 1285 pp. Presents the latest available mineral statistics for more than 130 foreign countries and areas. A separate chapter reviews minerals in the world economy. $4.75.

Minerals Yearbook, 1966. In this edition of the Minerals Yearbook, *Volume I, Metals and Minerals*, and *Volume II, Fuels*, formerly published separately, are combined and issued as *Volume I-II, Metals, Minerals, and Fuels*. *Volume III, Area Reports: Domestic*, follows the format of previous years. *Volume IV, Area Reports: International*, will not be published for 1966. However, mineral production and trade tables for foreign countries are included in the combined Volume I-II.

Volume I-II, Metals, Minerals, and Fuels, prepared by the staffs of the Division of Anthracite, Division of Bituminous Coal, Division of Economic Analysis, Division of International Activities, Division of Minerals, Division of Petroleum, Division of Statistics, Division of Accident Prevention and Health, and Assistant Director—Helium. 1967. 1352 pp. 35 figs. In this edition of the Minerals Yearbook, covering calendar year 1966, Volume I, Metals and Minerals, and Volume II, Mineral Fuels, formerly published separately, are combined and issued as Volume I-II, Metals, Minerals, and Fuels. This volume, consisting of 225 chapters, contains all the customary statistical data on production, consumption, imports, exports, and related subjects, collected by the Bureau of Mines from sources all over the world. In addition it includes a chapter reviewing the mineral industries, a statistical summary, and a chapter on technologic trends. The review of the mineral industries chapter in this volume has been expanded and discusses the position of these basic industries in the national and international economies. $5.

Volume III, Area Reports: Domestic, prepared by the staffs of the field offices of the Division of Mineral Resources of the Bureau of Mines. 1967. 53 ch. 891 pp. 53 figs. Contains geographic chapters for each State, as well as the island possessions and the Canal Zone. Preprints of individual chapters are available at the prices listed. $3.75.

The Minerals Yearbook, 1967, published in three volumes, provides a record of performance of the Nation's mineral industries during the year and a review of world mineral production, consumption, and trade on a country-by-country basis.

Volume I-II, Metals, Minerals, and Fuels, prepared by the staff of the Division of Mineral Studies, except for the Review of the Mineral Industries, Statistical Summary, Injury Experience and Worktime in the Mineral Industries, and Helium chapters. Statistical data on the U.S. mineral industry were collected and compiled by the staff of the Division of Statistics. World production and foreign activity trade tables were compiled in the Division of International Activities. 1968. 81 ch. 1262 pp. 46 figs. Contains chapters on metal and nonmetal mineral commodities including mineral fuels. It includes a chapter reviewing the mineral industries, a statistical summary, and chapters on employment and injuries and technologic trends. $6.25.

Volume III, Area Reports: Domestic, prepared by staff of the Bureau of Mines. 1968. 53 ch. 892 pp. 53 figs. Contains chapters covering each of the 50 States, the U.S. island possessions in the Pacific Ocean and the Caribbean Sea, the Commonwealth of Puerto Rico, and the Canal Zone. This volume has a statistical summary chapter, identical with that in Volume I-II, and a chapter on employment and injuries. $5.25.

Volume IV, Area Reports: International, prepared by the staff of the Division of International Activities. 1969. This volume contains 85 chapters presenting the latest available mineral statistics for more than 130 foreign countries and areas and discusses the importance of minerals to the economies of these nations. A separate chapter reviews minerals in the world economy. $5.75.

Minerals Yearbook, 1968, published in three volumes, provides a record of performance of the Nation's mineral industries during the year and a review of world mineral production, consumption and trade on a country-by-country basis.

Volume I-II, Metals, Minerals, and Fuels, prepared by the staff of the Division of Mineral Studies, except for the Review of the Mineral Industries, Statistical Summary, Injury Fxperience and Worktime in the Mineral Industries, and Helium chapters. Statistical data on the U.S. mineral industry were collected and compiled in the Division of Statistics. World production and trade were compiled in the Division of International Activities. 1969. 80 ch. 1208 pp. 46 figs. Contains chapters on metal and nonmetal mineral commodities including mineral fuels. It includes a chapter reviewing the mineral industries, a statistical summary, and chapters on employment and injuries and technologic trends. Preprints of individual chapters are available at the prices listed. $6.25.

General reviews:

- Injury Experience and Worktime in the Mineral Industries, by Forrest T. Moyer. 14 pp. 10 cents.
- Review of the Mineral Industries, by Olman Hee and Jeannette I. Baker. 60 pp. 1 fig. 30 cents.
- Statistical Summary, by Kathleen J. D'Amico. 39 pp. 20 cents.*
- Technologic Trends in the Mineral Industries (Metals and Nonmetals Except Fuels), by John L. Morning. 24 pp. 20 cents.

Commodity reviews:

- Abrasive Materials, by J. Robert Wells. 12 pp. 1 fig. 10 cents.
- Aluminum, by John G. Parker. 20 pp. 15 cents.
- Antimony, by L. E. Davis. 8 pp. 10 cents.
- Asbestos, by Paul W. Icke. 10 pp. 1 fig. 10 cents.
- Barite, by W. Gene Diamond. 6 pp. 10 cents.
- Bauxite, by John G. Parker. 12 pp. 10 cents.
- Beryllium, by Henry C. Meeves. 5 pp. 10 cents.
- Bismuth, by Harrold J. Schroeder. 4 pp. 10 cents.
- Boron, by J. M. West. 4 pp. 10 cents.
- Bromine, by Keith S. Olson. 4 pp. 10 cents.
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- Cement, by John R. Lewis. 25 pp. 20 cents.
- Chromium, by John L. Morning. 9 pp. 10 cents.
- Clays, by J. Robert Wells. 18 pp. 3 figs. 15 cents.
- Coal—Bituminous and Lignite, by W. H. Young and J. J. Gallagher. 17 pp. 30 cents.
- Coal—Pennsylvania Anthracite, by Walter C. Lorenz. 25 pp. 1 fig. 20 cents.
- Cobalt, by Gilbert L. DeHuff. 6 pp. 10 cents.
- Coke and Coal Chemicals, by Leonard Westerstrom. 38 pp. 20 cents.
- Columbium and Tantalum, by Richard F. Stevens, Jr. 14 pp. 10 cents.
- Copper, by John W. Cole. 31 pp. 20 cents.
- Diatomite, by J. M. West. 3 pp. 10 cents.
- Feldspar, Nepheline Syenite, and Aplite, by J. Robert Wells. 6 pp. 10 cents.
- Ferroalloys, by John W. Thatcher. 10 pp. 10 cents.
- Fluorspar and Cryolite, by J. Robert Wells. 8 pp. 10 cents.
- Gem Stones, by Benjamin Petkof. 5 pp. 10 cents.
- Gold, by J. Patrick Ryan. 21 pp. 4 figs. 15 cents.
- Graphite, by Lewis K. Weaver. 7 pp. 10 cents.
- Gypsum, by Paul L. Allsman. 8 pp. 10 cents.
- Helium, by Billy J. Moore. 4 pp. 10 cents.
- Iron and Steel, by John W. Thatcher. 18 pp. 15 cents.
- Iron and Steel Scrap, by John W. Thatcher. 12 pp. 1 fig. 10 cents.
- Iron Ore, by John L. Morning. 22 pp. 1 fig. 15 cents.
- Iron Oxide Pigments, by John W. Thatcher. 4 pp. 10 cents.
- Kyanite and Related Minerals, by John W. Sweeney. 4 pp. 10 cents.
- Lead, by Donald E. Moulds. 27 pp. 1 fig. 20 cents.
- Lime, by Paul L. Allsman. 10 pp. 1 fig. 10 cents.
- Magnesium, by John W. Cole. 6 pp. 10 cents.
- Magnesium Compounds, by John W. Cole. 7 pp. 10 cents.
- Manganese, by Gilbert L. DeHuff. 10 pp. 10 cents.
- Mercury, by J. M. West. 9 pp. 1 fig. 10 cents.
- Mica, by Benjamin Petkof. 9 pp. 10 cents.

* Same chapter appears in volume III.

Volume III, Area Reports: Domestic, prepared by the staffs of the field offices of the Division of Mineral Resources. 53 ch. Contains geographic chapters for each State, as well as the island possessions and the Canal Zone. The complete volume will be published in 1970, but preprints of individual chapters are available at the prices listed.

General reviews:

*Same chapter appears in Volume I-II.

The Mineral Industry of—

Michigan, by Donald F. Klyce. 19 pp. 1 fig. 15 cents. Prepared in cooperation with the Geological Survey Division of the Michigan Department of Natural Resources.
Minnesota, by Keith S. Olson. 20 pp. 2 figs. 15 cents. Prepared in cooperation with the Minnesota Geological Survey.
Mississippi, by S. O. Wood, Jr., and William H. Moore. 13 pp. 1 fig. 10 cents. Prepared in cooperation with the Mississippi Geological, Economic, and Topographical Survey.
Missouri, by Joseph C. Arundale and James A. Martin. 15 pp. 1 fig. 15 cents. Prepared in cooperation with the Missouri Geological Survey and Water Resources.
Montana, by Fred V. Carrillo, Mary Anne McComb, and William N. Hale. 20 pp. 2 figs. 15 cents. Prepared in cooperation with the Montana Bureau of Mines and Geology.
Nebraska, by Arthur E. Falvey and William C. Henkes. 11 pp. 1 fig. 10 cents. Prepared in cooperation with the Nebraska Geological Survey.
Nevada, by Arthur C. Meisinger. 16 pp. 1 fig. 15 cents. Prepared in cooperation with the Nevada Bureau of Mines.
New Hampshire, by William Cochran. 5 pp. 10 cents. Prepared in cooperation with the New Hampshire Department of Resources and Economic Development.
New Jersey, by Richard J. Leary. 9 pp. 1 fig. 10 cents. Prepared in cooperation with the New Jersey Division of Resource Development, Bureau of Geology and Topography.
New Mexico, by Lorraine Burgin and William C. Henkes. 29 pp. 8 figs. 20 cents.
New York, by Robert G. Clark. 15 pp. 1 fig. 15 cents. Prepared in cooperation with the New York State Museum and Science Service.
North Carolina, by V. A. Danielson and Stephen G. Conrad. 12 pp. 1 fig. 10 cents. Prepared in cooperation with the Geological Survey of North Carolina.
North Dakota, by Franklin H. Persse and William C. Henkes. 9 pp. 1 fig. 10 cents. Prepared in cooperation with the State Geological Survey of North Dakota.
Ohio, by Joseph Kirickich. 20 pp. 1 fig. 15 cents.
Oklahoma, by Arel B. McMahon and William E. Ham. 17 pp. 1 fig. 15 cents. Prepared in cooperation with the Oklahoma Geological Survey.
Oregon, by Jerry J. Gray, Gary A. Kingston, and Mary Anne McComb. 13 pp. 1 fig. 10 cents. Prepared in cooperation with the Oregon Department of Geology and Mineral Industries.
Pennsylvania, by Charles C. Yeloushan. 22 pp. 2 figs. 15 cents. Prepared in cooperation with the Pennsylvania Bureau of Topographic and Geologic Survey.
Puerto Rico, the Panama Canal Zone, the Virgin Islands, Pacific Island Possessions, and Trust Territory of the Pacific Islands, by Harry F. Robertson, Eduardo Aguilar, and Roy Y. Ashizawa. 6 pp. 10 cents. Puerto Rico section of this chapter prepared in cooperation with the Mineralogy and Geology Section, Economic Development Administration, Commonwealth of Puerto Rico.
Rhode Island, by Arthur Sykes Lees. 3 pp. 10 cents.
South Carolina, by Robert C. Johnson and Henry S. Johnson, Jr. 8 pp. 1 fig. 10 cents. Prepared in cooperation with the South Carolina Division of Geology, State Development Board.
South Dakota, by M. Clair Smith and William C. Henkes. 10 pp. 1 fig. 10 cents. Prepared in cooperation with the South Dakota State Geological Survey.
Tennessee, by Doss H. White, Jr., and Robert E. Hershey. 15 pp. 2 figs. 15 cents. Prepared in cooperation with the Tennessee Division of Geology.
Texas, by F. F. Netzeband and Roselle Girard. 35 pp. 1 fig. 20 cents. Prepared in cooperation with the Bureau of Economic Geology, The University of Texas at Austin.
Utah, by Douglas H. Hileman and William C. Henkes. 21 pp. 2 figs. 15 cents. Prepared in cooperation with the Utah Geological and Mineralogical Survey.
Vermont, by Harold F. York. 6 pp. 10 cents.
Virginia, by David J. Kusler. 17 pp. 1 fig. 15 cents. Prepared in cooperation with the Virginia Division of Mineral Resources.
Washington, by William N. Hale, Mary Anne McComb, and Paul McIlroy. 13 pp. 1 fig. 15 cents. Prepared in cooperation with the Washington Division of Mines and Geology.
West Virginia, by Meherwan C. Irani. 13 pp. 1 fig. 10 cents. Work done in cooperation with the West Virginia Geological and Economic Survey.
Wisconsin, by Keith S. Olson. 14 pp. 1 fig. 15 cents. Prepared in cooperation with the Wisconsin Geological Survey.
Wyoming, by Earl F. Brauch and William C. Henkes. 20 pp. 1 fig. 10 cents. Prepared in cooperation with the Geological Survey of Wyoming.

Volume IV, Area Reports: International, prepared by the staff of the Division of International Activities. 85 ch. This volume presents the latest available mineral statistics for more than 130 countries and areas and discusses the importance of minerals to the economies of these nations. A separate chapter reviews minerals in the world economy. The complete volume will be published in 1970, but preprints of individual chapters are available at the prices listed.

Minerals in the World Economy, by E. J. Gealy and C. L. Kimbell. 49 pp. 25 cents.

The Mineral Industry of—
Algeria, by Edgar J. Gealy. 7 pp. 10 cents.
Angola, Mozambique, and Portuguese Guinea, by Eugene R. Slatick. 9 pp. 10 cents.
Argentina, by Garn Rynearson. 12 pp. 10 cents.
Australia, by Lester G. Morrell. 19 pp. 15 cents.
Austria, by Roman V. Sondermayer. 10 pp. 10 cents.
Belgium and Luxembourg, by Roman V. Sondermayer. 13 pp. 10 cents.
Bolivia, by Robert A. Whitman. 6 pp. 10 cents.
Brazil, by F. W. Wessel. 12 pp. 10 cents.
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Mainland China, by K. P. Wang. 12 pp. 10 cents.
Colombia, by Gordon W. Koelling. 9 pp. 10 cents.
Democratic Republic of the Congo (Kinshasa), by Eugene R. Slatick. 6 pp. 10 cents.

Cyprus, by Eugene R. Slatick. 4 pp. 10 cents.
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France, by L. Nahai. 29 pp. 20 cents.
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North Korea, by R. A. Pense. 7 pp. 10 cents.
South Korea, by R. A. Pense and Jean W. Pressler. 9 pp. 10 cents.
Kuwait, Kuwait-Saudi Arabia Neutral Zone, by David A. Carleton. 10 pp. 10 cents.
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Libya, by Walter C. Woodmansee. 8 pp. 10 cents.
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Other European Countries (Albania, Denmark (including Greenland), Iceland, Switzerland), by Joseph B. Huvos, Bernadette Michalski, and Roman V. Sondermayer. 17 pp. 15 cents.
Other Far Eastern and South Asian Areas, by Staff, Division of International Activities. 18 pp. 15 cents.
Other Near East Areas (Bahrain, Jordan, Lebanon, Muscat and Oman, Qatar, Southern Yemen, Syrian Arab Republic, Trucial States, and Yemen), by David A. Carleton, E. Shekarchi, Eugene R. Slatick, and Walter C. Woodmansee. 18 pp. 15 cents.
Other South American Areas (Ecuador, French Guiana, Guyana, Paraguay, Surinam, and Uruguay), by Burton E. Ashley and F. W. Wessel. 14 pp. 10 cents.
Other South Pacific Islands (British Solomon Islands, Christmas Island, Fiji Islands, Nauru and Ocean Island, New Caledonia, New Hebrides, and Papua and New Guinea), by John A. Stock. 9 pp. 10 cents.

REPORTS OF INVESTIGATIONS

RI 6573. Methods for Producing Alumina From Clay. An Evaluation of Two Ammonium Alum Processes, by Frank A. Peters, Paul W. Johnson, and Ralph C. Kirby. 1965. 47 pp. 17 figs. Evaluates the ammonium bisulfate leaching process and the ammonium sulfate baking process as methods for producing alumina from clay. Evaluations are based on published work, and the proposed plants are designed for a capacity of 1,000 tons of alumina per day. Under present economic conditions, these two processes are not competitive with the Bayer process for the production of alumina from bauxite. Future research work with these processes should be confined to areas likely to result in major cost reductions.

RI 6574. Lightweight Aggregates. Expansion Properties of Selected Indiana Shales, by John W. Sweeney and Howard P. Hamlin. 1965. 28 pp. 12 figs. Gives data on shales from 14 locations in Indiana that were sampled, tested, and evaluated to determine the feasibility of producing lightweight aggregates by rotary-kiln and sintering methods. Discusses sampling procedures and the geology of the significant shale units. Four samples from the Borden group made suitable lightweight aggregate in the laboratory rotary kiln. Four samples tested by sintering methods made unsatisfactory aggregate.

RI 6575. Synthesis and Some Properties of Aluminum Borate Whiskers, by Robert C. Johnson and John K. Alley. 1965. 23 pp. 8 figs. Describes methods of growing aluminum borate whiskers or fibers and determining their properties. Better results were obtained by vapor deposition than by molten-salt bath; whiskers exceeding 25 mm in length were produced by vapor-deposition method. Three different aluminum borates ($4.8Al_2O_3 \cdot B_2O_3$, $3.8Al_2O_3 \cdot B_2O_3$, and $2.5Al_2O_3 \cdot B_2O_3$) were identified by X-ray and chemical analyses. Optical data were obtained on the three aluminum borates. Additional whisker properties and growth factors were determined for vapor-deposition and molten-salt methods.

RI 6576. Experimental Caustic Leaching of Oxidized Zinc Ores and Minerals and the Recovery of Zinc From Leach Solutions, by C. C. Merrill and R. S. Lang. 1965. 23 pp. 4 figs. Investigates the recovery of zinc from oxidized zinc minerals by the caustic soda leach and electrolytic or chemical precipitation method. With the exception of willemite, oxidized zinc minerals were readily soluble in 180 to 240 grams per liter of NaOH solutions. Zinc can be recovered electrolytically as a high-grade zinc flake, and the solution can be recycled to the leach stage. Zinc can also be recovered from leach solutions by dilution of the solutions, carbonation of the solutions, or the addition of sulfur to boiling solutions. Carbonation of the solutions precipitated the zinc as zinc oxide, and solutions could be recausticized for recycling. Zinc precipitated as the sulfide with sulfur was easily filtered and washed. Approximately half the sulfur added to solutions was lost in the form of sodium thiosulfate.

RI 6577. Extraction and Separation of Rare-Earth Elements in Idaho Euxenite Concentrate, by Van E. Shaw and D. J. Bauer. 1965. 13 pp. 7 figs. Gives results of a study of conversion of euxenite concentrate to sulfates with sulfuric acid and solvent extraction of the yttrium-rare earth mixture with EHPA in order to determine extraction and separation characteristics. Separation of complex rare-earth mixtures into light- and heavy-group fractions is feasible, and these fractions can be further processed to isolate ytterbium, neodymium, and dysprosium by changing processing conditions to obtain separation factors greater than two between these and adjacent elements.

RI 6578. Evaluation of Electrowon Tungsten Powder, by G. H. Keith, B. D. Jones, and E. A. Rowe. 1965. 13 pp. 8 figs. Gives results of an investigation of electrowon tungsten powder with respect to particle size and shape, apparent density, flow rate, compressibility, green strength, and sintering characteristics. In addition its chemical purity, absolute density, and purification by melting were determined. Significant findings were higher flow rates and better compressibility than hydrogen-reduced tungsten powder. The large particle size peculiar to the electrowinning process effectively prevented conventional sintering to a high-density material, but a new technique of hot swaging sheathed sintered-tungsten compacts was developed, permitting the production of small compacts of high density—92 percent of theoretical.

RI 6579. Phosphorus, Chlorine, Sodium, and Potassium in U.S. Coals, by R. F. Abernethy, F. H. Gibson, and W. H. Frederic. 1965. 34 pp. Contains the quantitative values for phosphorus, chlorine, sodium, and potassium in U.S. coals. The samples tested were taken from commercial shipments and have been selected to represent the principal coal-producing areas of the country. Due to combining the analytical results from two separate surveys, values for the four elements are not available for all samples. (*Out of print.*)

RI 6580. Recovery of Scandium From Uranium Plant Iron Sludge and From Wolframite Concentrates, by J. R. Ross and C. H. Schack. 1965. 22 pp. 10 figs. Describes techniques for recovering scandium from uranium-plant iron sludges and from wolframite concentrates. The best procedure comprised (1) dissolution with sulfuric acid, (2) preliminary concentration by solvent extraction with a primary alkylamine, (3) further enrichment and purification by a combination of ion exchange, solvent extraction, chemical precipitation, and calcination. Recovery of scandium from these raw materials, which contained 0.058 and 0.14 percent scandium, ranged from 83 to 90 percent in products analyzing 99.6 to 99.9 scandium oxide.

RI 6581. Float Coal Hazard in Mines: A Progress Report, by John Nagy, Donald W. Mitchell, and Edward M. Kawenski. 1965. 15 pp. 10 figs. Gives results of initial research by the Bureau of Mines on the dust-explosion hazard of float coal and on the related factors of occurrence, rate of production, sampling techniques, transport, and deposition of float coal. Tentatively, it is suggested that where float-coal deposits prevail, a minimum of 80 percent incombustible be maintained in the top ⅛-inch layer to neutralize the explosion hazard of the surficial coal deposit.

RI 6582. Specific Conductance, pH, Density, and Viscosity of Sodium Aluminate Solutions and Some Properties of the Aluminate Ion, by R. V. Lundquist. 1965. 11 pp. 2 figs. Gives data showing that the specific conructance of solutions of sodium hydroxide and of sodium aluminate was directly proportional to the temperature. The specific conductance of sodium aluminate solutions with identical sodium ion concentration and at constant temperature decreased with increase in aluminum concentration. The aluminate ion population in solution was shown to consist of a mixture of monovalent and polyvalent ions. Aluminate ions did not influence the temperature dependence of pH in caustic solutions containing sodium aluminate. The density and viscosity of a solution was inversely proportional to the temperature and directly proportional to the concentrations of sodium and aluminate ions.

RI 6583. Heats of Formation of Lithium Chloride and Lithium Oxalate, Including Details on the Construction and Operation of a Solution Calorimeter, by B. B. Letson and A. R. Taylor, Jr. 1965. 12 pp. 4 figs. Gives heats of formation of lithium chloride and lithium oxalate determined with the aid of a Bureau-developed glass Dewar-type solution calorimeter which uses thermistors as its temperature sensing element. Values obtained at 298.15° K were —93.38 ± 0.54 kcal/mole for lithium chloride and —329.02 ± 0.79 kcal/mole for lithium oxalate, using graphite as the standard state for carbon. Work done in cooperation with the University of Alabama.

RI 6584. Reduction of Seepage Losses From Canals by Chemical Sealants (in Two Parts). I. Laboratory Research on Sodium Carbonate and Other Compounds, by W. W. Agey and B. F. Andrew. 1965. 33 pp. 2 figs. Evaluation of 74 different soluble salts revealed that several lithium and sodium salts decreased by several hundredfold the hydraulic conductivity rate of highly porous canal material under both static and dynamic test conditions. Sodium carbonate was the most effective of the salts on a basis of cost and ability to reduce waterflows.

RI 6585. Dealkylation of Tar Acids From Low-Temperature Lignite Tar, by John S. Berber and Leslie R. Little, Jr. 1965. 24 pp. 14 figs. Describes the results of a study made to test the effectiveness of 11 commercial catalysts at 700° to 1,000° F in the production of low-boiling phenols from high-boiling tar acids. While all process variables were not fully examined, data obtained indicate the relative effectiveness of the catalysts tested and are useful in selecting catalysts for optimization of the dealkylation process.

RI 6586. Distribution of Phenols in Low-Temperature Tar From Low-Rank Coals, by Manuel Gomez, W. S. Landers, Janet L. Shultz, and A. G. Sharkey, Jr. 1965. 30 pp. 8 figs. Gives carbon number distributions that were obtained for tar acid fractions from five low-temperature tars by low-ionizing voltage mass spectrometry. Quantitative data for phenols representing seven structural compound types were examined by statistical analysis. The total concentration of each structural type present was found to depend on the molecular weight and boiling point of the initial member of the group. Carbon distribution data for the tar acid fractions studied support the view that low-temperature tars contain the same chemical compounds as the parent coal but in different proportions.

RI 6587. Tin-Lode Investigations, Potato Mountain Area, Seward Peninsula, Alaska, by John J. Mulligan. 1965. 85 pp. 23 figs. Describes lode-tin deposits on Potato Mountain, Seward Peninsula, Alaska. Tin was found to occur as cassiterite associated with quartz, tourmaline, pyrite, arsenopyrite, and earthy clays, but the deposits lack the varied accessory minerals commonly found in tin districts. Sample values ranged as high as 12 percent tin, but the average grade may be about 1 percent tin.

RI 6588. Electrorefining of Titanium-Oxygen Alloys, by Oliver Q. Leone and F. S. Wartman. 1965. 20 pp. 5 figs. Studies the effect of oxygen content in the anode metal on titanium electrorefining characteristics. Increasing quantities of oxygen in the anode resulted in increased anode scale formation, decreased anode and cathode current efficiencies, lower titanium recovery efficiencies, and higher oxygen content of the cathode products. The titanium electrorefining process performed best when the anodes did not contain more than 0.5 percent oxygen, although anode dissolution was recorded for alloys containing up to 25 percent oxygen. Back emf affords a useful index of an alloy to electrorefining.

RI 6589. Anionic-Cationic Flotation of Mica Ores From Alabama and North Carolina, by James S. Browning, Frank W. Millsaps, and Paul E. Bennett. 1965. 9 pp. 1 fig. Describes a new anionic-cationic method developed for recovering mica without desliming or with a minimum of desliming to remove clay materials. In laboratory batch and continuous small-scale flotation tests, concentrates containing 98.1 percent mica were obtained from the Alabama pegmatite ore; the North Carolina pegmatite ore concentrates contained 97.2 percent mica. The recoveries were 83.8 and 81.6 percent, respectively. The process should be applicable to the commercial treatment of mica-bearing pegmatite ores and fine rejects that have been accumulated at various mica-milling operations. Work done in cooperation with the University of Alabama.

RI 6590. Conversion to Metal of Dimolybdenum Carbide Electrosynthesized From Molybdenite, by H. J. Heinen, C. L. Barber, and Don H. Baker, Jr. 1965. 14 pp. 4 figs. Describes a method consisting of two steps: (1) Electrosynthesis of pure dimolybdenum carbide (Mo_2C) from molybdenite (MoS_2) and (2) interaction of Mo_2C and molybdic oxide (MoO_3) to produce pure molybdenum metal. Two molten-salt systems were satisfactory for electrosynthesizing Mo_2C. The first was a mixture of potassium chloride (KCl), potassium fluoride (FK), and sodium metasilicate (Na_2SiO_3), and the second consisted of sodium fluoride (NaF), potassium fluoride (KF), sodium tetraborate ($Na_2B_4O_7$), and sodium carbonate (Na_2CO_3). Yields up to 0.42 gram of Mo_2C per ampere-hour were obtained. The carbide, mixed with monitored amounts of MoO_3, was converted to molybdenum metal of 99.9-percent purity by sintering at 1,500° C.

RI 6591. Effects of Substituting Cobalt for Nickel on the Corrosion Resistance of Two Types of Stainless Steel, by M. M. Tilman. 1965. 17 pp. 4 figs. Cobalt substitutes to a maximum 2.2 weight-percent were made in types 302 and 309 austenitic stainless steels. Total-immersion corrosion tests were made in 10 volume-percent hydrochloric acid, and boiling-acid tests were conducted in 65 weight-percent nitric acid and in undiluted glacial acetic acid. For modified type 309 steel in acetic acid, corrosion rates decreased for additions greater than 0.57 weight-percent cobalt. Corrosion rates increased as cobalt was increased up to about 1 weight-percent for modified type 302 steel in nitric and hydrochloric acids and for modified type 309 steel in nitric acid, but these rates decreased with a further increase in cobalt content. A gradual increase in corrosion rates with increasing cobalt content was shown for type 302 in acetic acid and for type 309 in hydrochloric acid. Cobalt substitutions in larger amounts (above a ratio of 8 Ni to 1 Co) may increase the corrosion resistance of the austenitic stainless steels.

RI 6592. High-Temperature Heat Contents and Entropies of Gallium Phosphide, Indium Phosphide, and Indium Sulfide, by L. B. Pankratz. 1965. 7 pp. 1 fig. Gives heat content measurements for $GaP_{0.986}$ and $InP_{0.996}$ over the temperature range from 298° to 1,100° K, and for $In_2S_{2.907}$ over the range from 298° to 1,200° K. Both the actual experimental data and values adjusted to conform with the stoichiometric compositions (GaP, InP, and In_2S_3) were reported. Entropy increments above 298.15° K were calculated for the stoichiometric compounds, and heat content and heat capacity equations were derived.

RI 6593. Extraction of Aluminum From $2NA_2O{\cdot}3CaO{\cdot}5Al_2O_3$ in Water and in Solutions of NaOH and Na_2CO_3, by R. V. Lundquist. 1965. 9 pp. 1 fig. About 99-percent extraction of sodium and aluminum from synthesized $2Na_2O{\cdot}3CaO{\cdot}5Al_2O_3$ was obtained in solutions of NaOH-Na_2CO_3 at leaching temperatures of 50° C and above. Extractions in water were low because insufficient NaOH was generated by hydrolysis. Extractions in NaOH solutions were limited to about 80 percent owing to the precipitation of hydrated calcium aluminates. Rapid extractions of 100 percent were obtainable in Na_2CO_3 solutions, but the subsequent rapid precipitation of alumina trihydrate caused losses in alumina recovery.

RI 6594. The Hafnium-Vanadium System, by D. K. Deardorff, M. I. Copeland, L. L. Oden, and H. Kato. 1965. 11 pp. 4 figs. The hafnium-vanadium phase diagram is of eutectic type with one intermetallic compound and a eutectoid reaction. The eutectic, peritectic, and eutectoid points occur at 1,395° C, 20 weight-percent vanadium; at 1,480° C, 36.3 weight-percent vanadium; and at 1,165° C, 6 weight-percent vanadium, respectively. The maximum solubility of vanadium was found to be 8 weight-percent in β-hafnium and 1 weight-percent in α-hafnium. The intermetallic compound has the face-centered cubic structure with $a_0 = 7.38$ A.

RI 6595. Field Testing of the Explosive-Anchored Rockbolt, by Edward W. Parsons and Lars Osen. 1965. 40 pp. 10 figs. Shows that the explosive-anchored rockbolts will produce anchorage superior in holding power to that produced by the expansion-shell and wedge bolts when placed in medium to soft and spongy ground and equal to any rocket anchorage obtained in hard rock. The strength of the explosive train and length of the anchor unit required for the explosive-anchored rockbolt to produce suitable anchorage can be determined by pull testing a few bolts installed with different length anchor units. Without additional modification and testing, the explosive-anchored rockbolt should not be used in water-filled downholes.

RI 6596. The Recovery of Manganese From Open-Hearth Slags and Low-Grade Ores by Smelting and Selective Oxidation, by R. C. Buehl, Miles B. Royer, and J. P. Morris. 1965. 33 pp. 9 figs. Slag or ore was smelted in a blast furnace to produce spiegeleisen; the spiegeleisen was then blown with air in a basic converter to give an oxide slag. This slag product contained 60 to 75 percent manganous oxide and may be considered a synthetic manganese ore. In blowing the spiegeleisen, a cyclic procedure was developed that gave nearly 90 percent recovery of manganese in the slag product (synthetic ore) yet prevented excessive contamination of the slag by phosphorus and iron. The overall recovery of manganese was about 75 percent when iron ore sinter was used with the open-hearth slag in the smelting step. Work done in cooperation with the American Iron and Steel Institute.

RI 6597. Explosibility of Carbonaceous Dusts, by John Nagy, Henry G. Dorsett, Jr., and Austin R. Cooper. 1965. 30 pp. 5 figs. Dust explosion data obtained in laboratory studies are presented for activated carbon, asphalt, charcoal, carbon black, coal, coke, gilsonite, graphite, lignite, miscellaneous carbons, pitch, tunnel dust, and mixtures of these materials with other ingredients. The explosion hazard is shown to increase as the volatile content of the dusts increases.

RI 6598. Some Generalized Probability Distributions With Special Reference to the Mineral Industries (in Five Parts). 3. Computer Programs of Distribution Moments, by Robert M. Becker. 1965. 79 pp. Presents computer programs for evaluating moments and moment relationships of the generalized probability distributions extended or developed in earlier reports (parts 1 and 2). The principal program was for evaluating the first three moments and moment relationships of the compound-multinomial distribution for finite as well as for infinite populations. This was the generalized distribution for sampling to some amount of items per sample. Another program was for evaluating the first four moments, the moments of the mean, and the moment relationships of the multinomial and generalized hypergeometric distributions. This was a general moment program in sampling to some number of items per sample or for sampling to some number of samples. This program accepted either ungrouped data, frequency data, or probability data. Part 1 of this series was published as RI 6329, Sampling to n Items per Sample; part 2, as RI 6552, Sampling to λ Amount of Items per Sample. *(Out of print.)*

RI 6599. Magnesium Reduction of Rutile, by H. Dolezal, E. C. Perkins, D. E. Kirby, and R. S. Lang. 1965. 12 pp. 2 figs. Reductions made with charges containing magnesium chloride under hydrogen yielded products with oxygen contents close to the theoretical equilibrium composition. Two reduction products made from rutile proved amenable to electrorefining. Work done in cooperation with the General Services Administration.

RI 6600. A Portable Helium Analyzer, by A. A. Sonnek, J. C. Meeks, Jr., C. L. Klingman, and C. A. Seitz. 1965. 15 pp. 9 figs. Describes a simple helium analyzer developed primarily for field use. The analyzer is based upon chromatographic principles; that is, separation of gas mixtures resulting from variable retention times of the components with respect to a separation medium (column-packing material). It uses thermistors for sensing detectors, a dry battery as source of power, and a microammeter for indicating helium concentration. The instrument requires approximately 15 minutes, after calibration, to determine the helium content of a natural gas sample.

RI 6601. Extraction and Separation of Rare-Earth Elements and Yttrium With Dodecyl Phosphoric Acid-Kerosine Solvent, by J. G. Eisele and D. J. Bauer. 1965. 16 pp. 9 figs. Solvent-extraction characteristics of dodecyl phosphoric acid (DDPA) were investigated to determine its potential as a fractional or selective extractant in a rare earth-yttrium mixture. DDPA is an effective extractant for splitting rare-earth mixtures into light and heavy subgroups. Yttrium normally extracts with the heavy rare-earth elements but may be shifted toward an extraction sequence with the light rare-earth elements by increasing the pH. Elements in the light and heavy ends of the rare-earth series can be separated from middle-group rare-earth elements by using diethylenetriaminepentaacetic acid (DTPA) as an aqueous phase counterextractant. Hydrogen-ion dependency of the distribution coefficients differs from that reported for similar systems at tracer-level concentrations.

RI 6602. Instrumental Techniques for Rapid Analysis of California Oil Well Scales, by George L. Gates and W. Hodge Caraway. 1965. 10 pp. 3 figs. Describes a rapid instrumental method of analyzing oil well scales containing primarily barium sulfate. After removal of oil and water by carbon disulfide, the scale was dissolved in strong hydrochloric acid. The cations, barium, calcium, strontium, magnesium, and iron, were determined with the flame photometer using the method of additions. Sulfate was determined colorimetrically after separation by selective adsorption on an alumina column. Phosphate was determined colorimetrically and carbonate titrimetrically.

RI 6603. Oil Recovery From 17 Water-Injection Projects in Clay, Jack, Montague, and Wise Counties, Tex., by Frank Parrish, Jr., and Paul Meadows. 1965. 101 pp. 56 figs. Describes projects producing from Pennsylvanian- and Permian-age reservoirs. Increased oil recovery resulted from injecting water in most cases; however, seven projects recovered less oil than the operators anticipated. Oil recovery by water injection ranged from 0.2 to 262 barrels per acre-foot, or 0.1 to 22.5 percent of the initial stock-tank oil in place. Major reasons suggested for poor performance include (1) adverse directional horizontal permeability, (2) channeling of injected water through fractures or zones of high permeability, and (3) lack of containment of injected water. One 330-foot-deep project is among the first successful shallow waterfloods in North Texas. Another project is the first successful Canyon sandstone waterflood reported in the area. Previous gas injection in two Cisco sandstone projects did not prevent the reservoirs from responding favorably to waterflooding. Work done in cooperation with the North Texas Oil and Gas Association.

RI 6604. Thermal Conductivity of Rock: Measurement by the Transient Line Service Method, by Robert L. Marovelli and Karl F. Veith. 1965. 19 pp. 11 figs. The thermal conductivities of six rocks were measured by the transient line source method over the temperature range of −85° to 1,500° F. Close-fitting ceramic probes were used in 0.065-inch-diameter holes drilled through 5- to 6-inch-thick rock specimens. Taconite, granite, quartzite, and basalt were used in the tests. The method yields absolute data and is applicable to both laboratory and in situ measurements.

RI 6605. Destroying the Caking Quality of Bituminous Coal by Thermal and Oxidative Treatment in a Fixed Bed on a Pilot Plant Scale, by S. J. Gasior, A. J. Forney, and J. H. Field. 1965. 18 pp. 9 figs. Coal was treated in a fixed bed by heating through its plastic range under controlled temperatures in mildly oxidative atmospheres composed of inert gas and/or steam containing about 1 volume-percent oxygen. High-volatile A and B and low-volatile bituminous coals in the size range ⅛ to 1½ inches were successfully treated at 0 (atmospheric pressure) to 300 psig in static beds 6 to 18 inches deep. Conditions of treatment ranged from 80 to 200 minutes at 350° to 510° C. Char produced in this manner from hvab coal was gasified with steam at 800° C and 100 psig in a fixed bed in one series of tests and in other tests was exposed to hydrogen in a dilute cocurrent free-falling-bed system at 750° C and 3,000 psig without agglomerating.

RI 6606. Performance Characteristics of Coal-Washing Equipment: Sand Cones, by Albert W. Deurbrouck and John Hudy, Jr. 1965. 26 pp. 6 figs. The performance of sand cones was evaluated in three preparation plants that utilized cones in various flow schemes. Three primary separations of raw coal effected between floats and sinks were excellent. The recovery efficiencies for the plus ¼-inch material ranged from 99.8 to 97.6 percent, the error areas ranged from 19 to 23 square centimeters, and the probable errors in specific gravity ranged from 0.033 to 0.024. The performance data of two secondary separations varied from excellent in one plant, where the separation was on a par with the primary separations, to somewhat inferior in another plant, where the secondary separation was effected at the middlings draw.

RI 6607. Heat Content and Specific Heat of Coals and Related Products, by Manuel Gomez, John B. Gayle, and Arthur R. Taylor, Jr. 1965. 45 pp. 23 figs. The heat contents of thermally dried lignite, subbituminous B coal, and their corresponding low-temperature chars were determined at various temperatures below the highest temperature to which these materials had been exposed before testing. Similar studies were made on high-temperature char and coke, spent shale, and ash prepared from both coal and spent shale. Heat content of the carbonaceous materials tested correlated well with temperature. Heat content results for spent shale compared well with the published results. Statistical analysis of experimental data together with published information showed moisture, volatile matter, carbon content, and temperature to be the principal variables influencing the specific heat of coal. The specific heat of devolatilized carbonaceous substances, char and coke, approached that of graphite as the carbonization temperature was increased. The elemental specific heats of coal constituents, estimated from the ultimate analysis and the specific heat of coal, compared favorably with published elemental specific heats. Work done in cooperation with the University of Alabama.

RI 6608. Entrained-Bed Carbonization of Bituminous Coal; Tests on an Australian Coal, by W. S. Landers, E. O. Wagner, Manuel Gomez, Charles C. Boley, and J. B. Goodman. 1965. 51 pp. 23 figs. Describes continuous, entrained-bed carbonization of an Australian bituminous coal containing 5.5 percent moisture and 12.6 percent ash in an 8-inch-diameter reactor at 960° to 1,300° F and at air-to-coal ratios of 6.74 to 13.16 standard cubic foot per pound of moisture- and ash-free coal charged. Carbonization rates from 138 to 287 pounds per hour (as-carbonized basis) were achieved without prior oxidation of the coal or char recirculation. Yields of char ranged from 60.2 to 68.5 percent of coal charged (as-carbonized basis), and yields of tar plus light oil ranged from 11.3 to 16.1 percent of coal charged (as-carbonized basis). Volatile matter in the char produced ranged from 8.7 to 17.9 percent. Work done in cooperation with the Joint Coal Board, New South Wales, Australia.

RI 6609. Recent Catalyst Developments in the Hot-Gas-Recycle Process, by A. J. Forney, R. J. Demski, D. Bienstock, and J. H. Field. 1965. 32 pp. 11 figs. Previous work has shown that a gas with a heating value of more than 900 Btu per cubic foot and a carbon monoxide content of 0.1 percent or less can be synthesized from hydrogen and carbon monoxide using two reactors, the first containing steel lathe turnings and the second granular Raney nickel. When in the present work assemblies of solid Raney nickel plates or plates sprayed with nickel oxide were used in the second reactor, a gas was synthesized with a heating value of 925 to 943 Btu per cubic foot, and a carbon monoxide content of 0.8 to 1.8 percent. Pressure drop was reduced 90 percent in the second stage with the plate assemblies as compared with Raney nickel granules. When catalysts of these assemblies were used in the first reactor in single-stage operation, the heating value of the product gas ranged between 856 and 941 Btu per cubic foot, and the carbon monoxide concentration was between 0.3 and 4.3 percent. The best gas, 941 Btu per cubic foot and 0.3 percent carbon monoxide, was produced with solid Raney nickel plates operating at 300 psig, 1,252 hourly space velocity, and 300° to 360° C.

RI 6610. Hydraulic Mining of Anthracite: Engineering Development Studies, by John W. Buch. 1965. 24 pp. 11 figs. Water pressure and quantity for mining Pennsylvania anthracite were arbitrarily established at 5,000 psi and 300 gpm (1,000 hp). For full-volume flow, hydraulic pressure was controlled by orifice size with the displacement pump. The hydraulic jumbo was designed for maneuvering on pitches from 0° to 20° in any direction and for a coalbed ranging in thickness from 10 feet, 6 inches, to 15 feet. All motions of the jumbo were by oil hydraulics. Jet flow was controlled at the face through an interlocked pushbutton system. From August 1961 to December 1963, 12,765 tons of bed material had been mined at an average mining-out rate of 0.821 ton per minute for chamber mining, with an average power requirement of 13.2 kilowatt-hours per ton. Work done in cooperation with the Glen Alden Coal Co. *(Out of print.)*

RI 6611. An Evaluation of the Western Phosphate Industry and Its Resources (in Five Parts). 2. Montana, by C. C. Popoff and A. L. Service. 1965. 146 pp. 62 figs. Reviews the phosphate deposits, mines, industry, and prospects in 10 districts covering most of the State's phosphate fields. Phosphate rock produced from underground mines in the Garrison district is shipped to Canada for processing to fertilizers, utilized locally for production of animal feed supplement, and pulverized and sold for direct application to the soil. Production from the Melrose district is shipped to Silver Bow and processed to elemental phosphorus. The Maxville-Philipsburg district is destined to become a major producer with the development of the Douglas Creek mine and beneficiation plant by Montana Phosphate Products Co. Montana ranks fourth in total annual production in the United States. Production has increased from about 60,000 long tons of acid-grade phosphate rock in 1940 to more than 660,000 tons of acid-, beneficiation-, and furnace-grade ore in 1961. Montana has the second largest potential resources in the Western field.

RI 6612. Extraction of Tungsten From Ore Concentrates by Chlorination, by A. W. Henderson, S. C. Rhoads, and R. R. Brown. 1965. 22 pp. 11 figs. Shows than tungsten can be extracted from scheelite by chlorination in the presence of carbon on a laboratory scale, but that operation of a large-scale chlorinator based on this reaction may be troublesome. Optimum recovery occurs at 500° C.

RI 6613. Load Relations in Preloaded Rockbolt Testing, by Lars Osen, J. L. Habberstad, E. W. Parsons, and E. R. Rodriguez. 1965. 24 pp. 17 figs. Shows that preload, the size, shape, and type of bearing plate, and the geometry of the system determine the point at which bolt load and applied load become equal. The effects on bolt load of both a theoretical solution and actual pull tests were analogous and led to similar results.

RI 6614. Lightweight Aggregates. Expansion Properties of Selected Illinois Shales and Clays, by John W. Sweeney and Howard P. Hamlin. 1965. 34 pp. 8 figs. Lightweight aggregates were produced from 16 Illinois shale samples by rotary-kiln processing under conditions which simulate those of a commercial operation. Of these 16 materials, 8 could not be considered as potential source materials for production of lightweight aggregate by commercial rotary-kiln processing because of a narrow expansion-temperature range, which would cause processing difficulties. The remaining shales had good processing characteristics and produced good-to-excellent lightweight aggregates. The compressive strength-unit weight values of the concrete made from these aggregates all met ASTM specifications.

RI 6615. Carbonizing Properties of Coals From Wyoming and Mercer Counties, W. Va., by G. W. Birge, D. E. Wolfson, J. E. Wilson, and J. H. Lynch, Jr. 1965. 21 pp. 3 figs. The coals were mostly strongly coking and low in ash and sulfur content. Dry, mineral-matter-free fixed-carbon content of the Wyoming County coals ranged from 63.0 to 83.4 percent. The Mercer County samples were all low volatile in rank. Yields of carbonization products were generally in accord with yields from similar rank coals of the Appalachian region. Because of their expanding tendencies, most of the medium- and low-volatile coals would require blending with lower rank coal for normal coke production. Fifteen coal samples from Wyoming County represented the Winifrede, Chilton, Alma, No. 2 Gas, Powellton, Eagle, Douglas, Sewell, Beckley, Pocahontas No. 4, and Pocahontas No. 3 beds, and five samples from Mercer County represented the Fire Creek, Pocahontas No. 3, and Pocahontas No. 6 beds.

RI 6616. Crystallographic Modifications and Phase Transformation Rates of Five Rare-Earth Sesquioxides. Lanthanum Oxide, Neodymium Oxide, Samarium Oxide, Europium Oxide, and Gadolinium Oxide, by Stephan Stecura. 1965. 44 pp. 13 figs. Crystallographic modifications and kinetics of solid-state phase transformations were determined for five rare-earth sesquioxides—La_2O_3, Nd_2O_3, Sm_2O_3, Eu_2O_3, and Gd_2O_3. Oxides used for crystal modification studies were prepared by thermal decomposition of the following high-purity salts of the five rare-earth elements—carbonates, chlorides, fluorides, nitrates, oxalates, and sulfates. X-ray diffraction patterns of the cubic and hexagonal oxides were indexed by a graphical method and patterns of the monoclinic oxides by Itho's method.

RI 6617. Heats of Formation of Anhydrous Sulfates of Cadmium, Cobalt, Copper, Nickel, and Zinc, by L. H. Adami and E. G. King. 1965. 10 pp. The heats of formation determined by hydrochloric acid solution calorimetry, at 298.15° K, for formation from the metal, rhombic sulfur, and oxygen gas were as follows (cal/mole): $CdSO_4$, −222.0 ±0.3; $CoSO_4$, −212.0 ±0.4; $CuSO_4$, −183.4 ±0.6; $NiSO_4$, −208.1 ±0.2; and $ZnSO_4$, −233.1 ±0.2. Corresponding heats of decomposition to form the metal oxide, sulfur dioxide, and oxygen were derived from these results; heats of decomposition to form the metal oxide and sulfur trioxide were also derived.

RI 6618. Heats of Formation of Goethite, Ferrous Vanadate, and Manganese Molybdate, by R. Barany. 1965. 10 pp. Gives the heats of formation at 298.15° K by solution calorimetry. For formation from the elements, the heat values were —133.7 ±0.3 kcal/mole for goethite, —453.8 ±0.5 kcal/mole for ferrous vanadate, and —284.8 ±0.2 kcal/mole for manganese molybdate. For formation from the oxides, the heat values were —0.9 ±0.1 kcal/mole for goethite, —19.4 ±0.3 kcal//mole for ferrous vanadate, and —14.6 ±0.1 kcal/mole for manganese molybdate.

RI 6619. Mechanism of the Monoclinic to Tetragonal Transformation of Zirconium Dioxide, by Clark F. Grain and Ronald C. Garvie. 1965. 19 pp. 9 figs. The monoclinic to tetragonal inversion of zirconium dioxide was studied by single-crystal X-ray methods, high-temperature X-ray diffractometry, and differential thermal analysis. The unusual features of the inversion, such as no definite transition temperature, hysteresis, and athermal kinetics, were confirmed for powders whose mean crystallite size was greater than 1,000 A. Samples of mean crystallite size below 1,000 A displayed classical kinetics, obeying a logarithmic rate law. A detailed mechanism based on Ubbelohde's theory of continuous phase transformations was proposed which is consistent with all the experimental facts.

RI 6620. Laboratory Investigation of the Effect of Oxidation on Coal Flotation, by J. B. Gayle, W. H. Eddy, and R. Q. Shotts. 1965. 22 pp. 11 figs. Effect of air oxidation on the recovery of float coal was studied. Both batch- and continuous-type tests were made on six bituminous coals, representing the range in rank of coals now commercially used for carbonization, and on one anthracite coal. The effects on flotation recovery of oxidation at 100° C for periods up to 50 days were investigated using an alcohol-type frother and a kerosine-pine oil reagent. Float coal recovery was adversely affected by oxidation in all tests where the alcohol-type frother was used. Conversely, a small degree of oxidation improved recovery with kerosine-pine oil frother for some of the coals in continuous tests. Prolonged oxidation (beyond about 14 days) adversely affected float coal recovery for all coals, the effect being more pronounced for batch-type tests and for tests using alcohol-type frother. Work done in cooperation with the University of Alabama.

RI 6621. Applicability of Gas Chromatographic Analysis in Thermal Oil-Recovery Tests, by T. E. Sterner. 1965. 17 pp. 13 figs. Investigates the use of a chromatographic gas analyzer in determining the concentration of combustion products in gas produced during field and laboratory thermal oil-recovery tests. Carrier-gas flow, cell current, sample size, and temperature were studied using a commercially available dual-column, dual-detector chromatographic gas analyzer which had been modified to provide close control of these variables. The apparatus made possible a much closer control of air- and gas-injection rates and provided adequate data for performing material-balance calculations and for determining oxygen utilization during the laboratory and field combustion tests. The chromatographic analysis also aided materially in evaluating and measuring bypassing and gas travel times and in detecting high-permeability zones that were present in the reservoir.

RI 6622. Analyses of Tipple and Delivered Samples of Coal Collected During the Fiscal Year 1964, by S. J. Aresco, J. B. Janus, and F. E. Walker. 1965. 38 pp. Presents results of analyses of 7,112 samples collected in connection with Government coal purchases. Heating value and proximate and ultimate analyses are given for all the samples; ash-softening temperature, free-swelling index, and Hardgrove grindability index are also shown for many samples.

RI 6623. Amenability of Coals From the Roslyn-Cle Elum (Washington) Field to the Production of High-Ash Boiler Fuel, by M. R. Geer. 1965. 16 pp. Samples of coal from six beds—Nos. 1, 2, 5, 6, 7, and 8—in the Roslyn-Cle Elum field of Washington were subjected to float-and-sink tests to determine their amenability to the production of high-ash boiler fuel for on-site power generation. Grindability tests and analyses of ash were made. All of the coals would require some degree of cleaning to insure a product of 25 percent ash. With two of the coals the entire size range would have to be washed. With the other four, it would suffice to clean only the coarse coal and bypass the raw fines. Work done in cooperation with the School of Mineral Engineering, University of Washington.

RI 6624. Electrorefining Uranium in a Chloride Electrolyte, by R. E. Campbell and T. A. Sullivan. 1965. 14 pp. 3 figs. Uranium metal of improved purity was prepared by electrorefining commercial magnesium-reduced uranium in a molten sodium chloride-uranium trichloride electrolyte. The best operating conditions for the preparation of refined metal was established as follows: An electrolyte containing 8.7 to 13.3 weight-percent uranium, initial cathode current densities from 300 to 1,500 amperes per square foot, and a molten-salt temperature of 860° C. Work done in cooperation with Lawrence Radiation Laboratory, University of California.

RI 6625. Steam-Fluidized Low-Temperature Carbonization of High Splint Bed Coal and Thermal Cracking of the Tar Vapors in a Fluidized Bed, by B. W. Naugle, C. Ortuglio, L. Mafrica, and D. E. Wolfson. 1965. 22 pp. 11 figs. Investigates the changes that occur in decomposition products when coal is carbonized in a fluidized bed with steam as the fluidizing medium and the vapors are subsequently cracked without condensation in a fluidized bed of high-temperature coke. The coal used was from the High Splint bed, High Splint mine, Harlan, Ky. Since this coal is agglomerating, it was blended with char. The integrated unit used consisted of a fluidized coal carbonizer, operated at 485° C, a cracker operated at 600°, 700°, and 800° C, and gas-cleaning and product-recovery systems. The process variables investigated were temperature, residence time, and concentration of tar vapors in the cracker. The total tar yields decreased as the temperature of the cracker increased, and at a constant cracker temperature of 600° C, the yield of paraffins, acids, aromatics, and olefins in the distillate increased directly with the tar vapor concentration in the cracker. At 700° and 800° C, only the acids and aromatics increased with increased concentration. Bases remained essentially constant regardless of the temperature and concentration. Similar results were obtained when the tar from the carbonizer was condensed prior to feeding to the cracker.

RI 6626. Use of Polyester-Type Resin To Stabilize Fractured Rock: A Progress Report, by Richard H. Oitto, Jr. 1965. 16 pp. 13 figs. A polyester-type resin and deformed-steel reinforcing bars (rebars) were used in combination to strengthen and to stabilize bolted, fractured wall rock along passageways in a western gold mine. Reinforcing bars were placed in boreholes drilled into fractured rock and then were surrounded by resin pumped under pressure into the holes and intersecting fractures until the wall rock was thoroughly impregnated. Pumping and injection equipment and infusion procedures are described. Results suggest that resin-rebar support can be used advantageously and economically in repairing fractured or broken rock when compared with rock bolting or timbering.

RI 6627. Some Generalized Probability Distributions With Special Reference to the Mineral Industries (in Five Parts). 4. Experimental Confirmation, by Robert M. Becker. 1965. 57 pp. 11 figs. Particle mixtures were sampled in the laboratory, using ordinary sampling procedures, to determine whether or not the compound-multionomial probability distribution and other developments of part 2 agreed with experimental results. The objective was accomplished by comparing the moments and moment relationships of the appropriate probability models with their corresponding experimental values over a fairly wide range. The overall agreement between the corresponding theoretical and experimental values was both good and complete. Results demonstrate that sampling to a constant amount, such as weight, of items per sample is not the same, in general, as sampling to some constant number of items per sample. Results seem to confirm all the developments of part 2 and the application of the compound-multinomial function to bulk sampling. Part 1 was published as RI 6329; part 2, as RI 6552; and part 3, as RI 6598. (*Out of print.*)

RI 6628. Properties of Vanadium-Carbon Alloys, by D. R. Mathews and E. A. Rowe. 1965. 14 pp. 8 figs. The solubility of carbon in electrorefined vanadium was determined to be approximately 0.27 weight-percent at the eutectic temperature of 1,650° C and 0.03 weight-percent at 700° C. The tensile strength and hardness of vanadium increased with carbon content to the solubility limit, but this effect was small, probably because of the narrow solubility range. Between the solubility limit and 0.3 weight-percent carbon, the second phase had essentially no strengthening effect in vanadium. The second phase contained high-carbon concentrations and was identified as V_2C by X-ray analysis. The V_2C in the grain boundaries contributed largely to the poor cold-and-hot workability of vanadium-carbon alloys. The average coefficient of thermal expansion increased slightly with increased carbon content up to the solubility limit and then remained constant for higher carbon contents. The room-temperature electrical resistivity of vanadium did not vary with carbon content within the composition range studied.

RI 6629. Exchangeability of Synthetic Gases From Solid Fuels with Pipeline Natural Gas, by Joseph Grumer and Margaret E. Harris. 1965. 15 pp. 4 figs. The range of composition of gases synthesized from solid fuels which are exchangeable with natural gas on current gas appliances was evaluated by theoretical principles. The principles consider primarily the flashback, blowoff, and yellow-tipping characteristics of air-entraining burner flames. It was found that complete identity between the synthetic and natural product is not necessary. Gases such as may be obtained by hydrogasification of coal and other solid fuels without the removal of unreacted hydrogen offer advantages in flame characteristics. Between 25 to 37 percent hydrogen can be tolerated in the sendout gas.

RI 6630. Infrared Spectra of 27 Compounds in the Regions 15-35 and 15-200 Microns, by G. A. Crowder and D. W. Scott. 1965. 37 pp. 28 figs. Far infrared spectra, most of them in the region of 15 to 200 microns and for both the liquid or solution state and for the vapor state, were obtained for 27 compounds. Work done in cooperation with the American Petroleum Institute and the Advanced Research Projects Agency.

RI 6631. Electrorefining Vanadium in a Molten Bromide Electrolyte, by T. A. Sullivan and F. R. Cattoir. 1965. 12 pp. 4 figs. Vanadium metal of about 99.95 percent vanadium was prepared by electrorefining commercial vanadium in a molten sodium bromide, potassium bromide, and vanadium dibromide electrolyte. Variables investigated were operating temperature, current densities, electrolyte composition, and condition of the anode. Iron and oxygen in the 50- to 250-ppm range were the only major impurities. Metal with hardness numbers of 50 to 60 in the Rockwell F scale was prepared from feed material with a Rockwell B hardness of 90. The arc-melted metal was highly ductile and could be cold worked into sheet or foil.

RI 6632. Spectrochemical Analysis of Tungsten, by R. C. Gabler, Jr., and M. J. Peterson. 1965. 40 pp. 5 figs. Methods for the direct spectrochemical determination of impurities at the parts-per-million level in tungsten metal and oxide are presented. Numerous modifications were made in establishing procedures with improved precision and extended lower levels of determinability. A germanium carrier-distillation procedure is applicable to the determination of 13 elements in tungsten powder, a silver chloride carrier-distillation procedure provides for the determination of 24 elements in tungstic oxide, and a sustaining ac arc method is applicable to 26 elements in tungstic oxide. The investigations were undertaken to develop direct spectrochemical methods with increased accuracy and precision to determine impurities in high-purity tungsten and tungstic oxide, and to define the lower concentration levels of detectability and measurement for common impurities in tungsten by direct spectrographic means.

RI 6633. Purification, Purity Estimation, and Spectra of Some Organic Derivatives of Fluorine, Silicon, Boron, and Aluminum, by T. C. Davis and J. C. Morris. 1965. 34 pp. 12 figs. Nine organic derivatives of fluorine, silicon, boron, and aluminum were purified for thermodynamic studies using distillation, zone melting, and gas-liquid chromatography. The unusual properties of these compounds required the development of special techniques for handling and purification. To determine purities of purified samples, new techniques for analyzing spectral data were developed. Work done in cooperation with the Advanced Research Projects Agency and the Air Force Office of Scientific Research, U.S. Department of Defense, under Contract CSO 59-9, ARPA Order 24-59, Task 3, and the University of Wyoming.

RI 6634. Design of Drill-Hole Grid Spacings for Evaluating Low-Grade Copper Deposits, by Richard F. Hewlett. 1965. 46 pp. 29 figs. Describes how a limtied number of preliminary exploration drill-hole assays from a mineral deposit can be used to design grid spacing that is both economical and efficient for subsequent evaluation drilling of that deposit. Relationships between desired precision of the estimate of grade of ore and drilling cost are used to determine the economic drill-hole spacing. The statistical concept of precision in estimating grade of ore is used to determine the efficient drill-hole spacing. Assay data from approximately 50 known copper deposits were studied, and the relationships of the statistical parameters of these deposits were computed. Drilling requirements for various precisions of the estimates of grade of ore were computed for some of these known deposits to serve as guides for drilling future copper deposits. The effect of various geologic factors on the trend in grade of ore and, therefore, on the drilling requirements is shown for certain deposits. Work done in cooperation with the Bear Creek Mining Co. and the College of Mines, University of Arizona.

RI 6635. Extraction of Tantalum and Columbium From Ores and Concentrates by Chlorination, by S. L. May and G. T. Engel. 1965. 8 pp. Shows that direct chlorination of high-grade minerals in the presence of carbon at temperatures between 500° and 800° C will extract up to 99 percent of the tantalum and columbium. Metallurgical beneficiation of low-grade source materials by carbothermic reduction produces a ferroalloy that is amenable to chlorination at a temperature of 500° C. Over 90 percent of the tantalum and columbium can be recovered.

RI 6636. Stainless Steel-Gadolinium Alloys, by M. Copeland, W. Barstow, C. Armantrout, and H. Kato. 1965. 29 pp. 14 figs. Phase relations of gadolinium alloyed, up to 40 weight-percent, with AISI 304-type stainless steel were established. Body- and face-centered cubic iron-rich solid solution phases and several intermetallic gadolinium-containing compounds of variable composition that approximated the formulas Fe_9Gd, Ni_7Gd_2, Ni_3Gd, Fe_2Gd, NiGd, and $NiGd_3$ were identified. Body-centered cubic iron solid solution was stable from 1 to 2 weight-percent gadolinium to higher contents, 30 weight-percent gadolinium or possibly more, and face-centered cubic iron, up to 12 weight-percent gadolinium below 1,200° C. The stability of these phases above 1,200° C was not resolved except for the melting points. A limited number of fabrication variables as well as mechanical and corrosion properties of alloys containing up to 5 weight-percent gadolinium were studied. Equilibrating and forming operations were best conducted at about 940° to 1,080° C. Some variability in the yield and tensile strengths of alloys was noted; however, there was a continual decrease in ductility and impact resistance with increasing gadolinium content. The resistance of gadolinium alloys to corrosion in water at 354° C was about the same as stainless steel. Work done under an agreement with the U.S. Atomic Energy Commission under Contract AT (11-1)-59.

RI 6637. Effects of Interstitial Impurities on the Mechanical Properties of Electrorefined Vanadium at Low Temperatures, by D. R. Mathews, G. H. Keith, and E. A. Loria. 1965. 23 pp. 16 figs. Electrorefined vanadium has yield strength and hardness values of about 18,500 psi and 63 DPH at 273° K. Carbon, oxygen, and nitrogen are effective strengtheners of vanadium. Nitrogen is the most potent strengthener, being approximately 1½ times more effective than carbon or oxygen. The ductile-brittle transition temperature of electrorefined vanadium was raised by at least 50° by 0.1 percent nitrogen or 0.175 percent oxygen. Electrorefined vanadium twinned profusely during tensile testing at 77° K. Twinning was completely suppressed by oxygen and nitrogen contents of 0.15 and 0.086 percent, respectively. Carbon, present as a second phase, had little effect on twinning.

RI 6638. Thermoelectric Properties of Depleted Uranium Selenides and Tellurides, by Lindsay D. Norman, Jr. 1965. 18 pp. 9 figs. The depleted uranium selenides and tellurides were semimetallic conductors exhibiting low Seebeck coefficients and electrical resistivities. Partial or complete degeneracy was in evidence, indicating a charge carrier energy distribution similar to that in a metal. Doping increased the Seebeck coefficients of the uranium monoselenides and monotellurides; however, the corresponding change in the power factor in the figure of merit was small because of the increase in electrical resistivity.

RI 6639. Calculation of Adsorption Energy, by Foster Fraas. 1965. 14 pp. 6 figs. The Bureau of Mines investigated a method for calculating values of adsorption energy. The goal was to devise an equation consistent with experimental data accumulated in the investigation of adsorption as related to ore separation processes. Numerical identification of the constants of a previously formulated equation provided an equation by which values of adsorption energy could be calculated. Values thus calculated checked with those obtained by calorimetric measurement. *(Out of print.)*

RI 6640. Heat of Formation of Europium Sesquioxide and Europium Trichloride, by J. M. Stuve. 1965. 9 pp. Provisional values for the heat of formation of europium trichloride and europium sequioxide were determined by solution calorimetry utilizing europium metal of more than 99-percent purity. The resulting values for the heats of formation of Eu_2O_3 (cubic) and $EuCl_3$ (hexagonal) were —386,970 ±1,200 cal/mole and —218,740 ±650 cal/mole, respectively, measured at 298.15° K.

RI 6641. Methods of Analyzing Oilfield Waters: Cesium and Rubidium, by A. Gene Collins. 1965. 18 pp. 3 figs. Describes a method for the detection of less than 0.01 milligram per liter of cesium and/or rubidium in a complex oilfield brine or water. Nitroethane was used for the extraction and flame spectrophometric determinations because it gave the highest sensitivity. Cesium-137 and rubidium-86 were used to determine the extraction efficiencies, which were about 87 percent and 58 percent, respectively, using a single 10-milliliter nitroethane extraction from a distilled water matrix. The standard deviation of the determination was 0.0008 milligram for cesium and 0.0007 milligram for rubidium in the 0.01-milligram range. *(Out of print.)*

RI 6642. Internal Friction as a Function of Orientation in Magnesium Single Crystals, by R. R. Nothdurft and A. E. Schwaneke. 1965. 18 pp. 10 figs. The internal friction of eight single crystals of magnesium with orientation ranging from 10° to 84° was measured at 33.5 kilocycles and 272° C, and the results were interpreted in terms of the pinned-dislocation model proposed by Granato and Lücke. Results show that the strain-amplitude-dependent decrement varies with orientation in a manner predictable by the G-L model. Different values of strain-amplitude-independent decrement were observed at different orientation angles, but correlation with the theory was not conclusive. Problems and steps for further study are discussed. Work done in cooperation with the University of Missouri at Rolla, Mo.

RI 6643. Thermal Decompositions of Siderite and Consequential Reactions, by H. E. Powell. 1965. 18 pp. 29 figs. Records basic data on the decompositions that take place during thermal decomposition of siderite ($FeCO_3$). Naturally occurring and a synthetically prepared mineral were studied by differential thermal, thermogravimetric, X-ray diffraction, and chemical (including gas) analyses. Thermal decomposition was studied in the media of dry air, moist air, dry carbon dioxide, dry helium, and dry carbon monoxide and at atmospheric and reduced pressures. Results showed the thermal decomposition of $FeCO_3$ to be an extremely complex process, dependent on environmental factors and side reactions that cannot be completely controlled. Full understanding of the reaction involved must depend on additional research with advanced evaluation techniques.

RI 6644. Sulfatization of Nickeliferous Laterites, by F. E. Joyce, Jr. 1965. 16 pp. 3 figs. Describes sulfatization of nickeliferous laterites from Puerto Rico and the Philippines for recovery of water-soluble nickel and cobalt sulfates. Temperatures ranging from 665° C to 710° C and a 10 percent sufur dioxide-air reaction gas were employed during batch-roasting tests and during continuous countercurrent treatment in a 2-inch-diameter shaft furnace. A maximum of 69 percent of the nickel and 76 percent of the cobalt was recovered from one sample of Puerto Rican laterite, and a maximum of 96 percent of the nickel and 91 percent of the cobalt was recovered from the Philippine laterite.

RI 6645. Statistical Analysis of Gamma-Ray Log Sample Data From a Uranium Deposit, Ambrosia Lake Area, McKinley County, N. Mex., by George R. Schottler. 1965. 49 pp. 20 figs. The objective was to find the extent of the range of applicability of previously developed statistical methods for determining grade and tonnage of ore to bedded uranium deposits. Uranium assays obtained from gamma-ray logs of exploratory drill holes were used to compute grade and tonnage of ore in the deposit by a standard polygonal method and by statistical analysis. The results obtained by the two methods are compared. The uranium-assay frequency distributions are shown to be lognormal and a simple transformation permits the use of standard normal curve statistics. The effects on the assay frequency distributions of stratified sampling, a required minimum mining thickness, and increased assay-interval length are investigated.

RI 6646. Evaluation of a Penetrometer for Estimating Roof-Bolt Anchorage, by Juel H. Stears. 1965. 23 pp. 10 figs. Research was done to determine if a hydraulically operated penetrometer developed by the Bureau of Mines could be used to estimate the roof-bolt anchorage capacity of mine-roof rock. Tests were conducted both in the laboratory using cement cylinders and underground in shale rock. Hardness readings were measured by the penetrometer around the periphery of the bolt holes at the anchorage horizon. Roof bolts were then installed and subjected to an anchorage test. The results showed that the penetrometer readings could be used to determine the optimum stratum for roof-bolt anchorage but could not be used to make an accurate estimate of the anchorage capacity. (*Out of print.*)

RI 6647. Removing Copper From Copper-Clad Steel by Oxidation, by R. J. Leary. 1965. 12 pp. 4 figs. Oxidation testing of copper-clad steel strip was performed in a muffle furnace to determine whether copper in contact with steel scrap could be removed by oxidation in an airstream at high temperatures. Substantially all of the copper was oxidized before any significant iron oxidation occurred. The rate of copper oxidation was not affected by contact with iron. Copper oxide scale separated spontaneously from the underlying metal during cooling. Results indicate the possibility of removing light-gage copper coatings and components from ferrous scrap by oxidation in an incineration process.

RI 6648. A Computer Program for Electron Probe Microanalysis, by James D. Brown. 1965. 28 pp. The Bureau of Mines has written a computer program in FORTRAN to facilitate the calculation of concentrations from X-ray intensities in electron-probe microanalysis. Philibert's adsorption and Castaing's secondary fluorescence corrections are used; no atomic number correction is included. Background and dead time corrections are applied to the data before calculating the relative intensities. Data from any type of electron-probe microanalyzer can be used with the program. (*Out of print.*)

RI 6649. A Study of the Chlorination Kinetics of Germanium, Silicon, Iron, Tungsten, Molybdenum, Columbium, and Tantalum, by Arne Landsberg and Frank E. Block. 1965. 26 pp. 12 figs. Gives results of a study of the chlorination kinetics of germanium, silicon, iron, trungsten, molybdenum, columbium, and tantalum to determine the effects of temperature, chlorine concentration, geometric surface area, and gamma radiation. The reaction products were volatile at the temperatures used, thus making it possible to follow the reaction rates by weight loss of the solid. Chlorination rates of germanium, silicon, and iron were found to be directly proportional to chlorine concentration while the rate for tungsten, molybdenum, columbium, and tantalum were proportional to the 0.5 to 0.6 power of chlorine concentration. A good correlation of reaction rate and geometric surface areas was not obtained because the true surface area of the samples could not be measured. Intense gamma radiation had no effect on reaction rates. The Arrhenius activation energies were determined over the temperatures used.

RI 6650. Lake Superior Iron Resources. Preliminary Sampling and Metallurgical Evaluation of Central Mesabi Nonmagnetic Taconites, by L. F. Heising and D. W. Frommer. 1965. 28 pp. 7 figs. The Bureau of Mines evaluated 191 composites from the central Mesabi range, Minn., chiefly by reductive roasting and magnetic separation. After reductive roasting and magnetic separation at minus 325 mesh, 28 composites produced concentrates that contained an average of 66.0 percent iron with less than 10 percent silica. Recovery of contained iron was over 90 percent. Natural magnetic material in excess of 5 percent was present in 142 composites. Trial flotation tests were used to evaluate three samples unresponsive to reductive roasting and magnetic separation procedures, and satisfactory concentrates having low silica contents (averaging 6.6 percent) were achieved.

RI 6651. Devitrification of Vacuum-Melted Glasses of the Lithium Metasilicate-Silica Compositional Series, by Jack I. Paige, Henry W. Harris, and Hal J. Kelly. 1965. 15 pp. 11 figs. The devitrification of lithium silicate glasses was studied to determine the effect of annealing temperature, composition, and additives on nucleation and crystallization. High-purity glasses, prepared from reagent-grade chemicals, had close to optical quality when prepared by a vacuum induction melting method developed during this research. The progress of devitrification was traced by differential thermal analysis and thermal expansion for those lithium metasilicate-silica compositions containing 80 to 90 percent silica. Microscopic studies of glasses partially devitrified at various temperatures and annealing times indicated that the primary initial mode of formation of individual crystals was from densely crystalline zones that filled in as crystallization advanced. Of the additives tested, calcium, potassium, and sodium helped promote devitrification with the least cracking or surface deformation. Tin oxide was most effective in reducing volume contraction during devitrification but was not as effective in preventing cracking as calcium or potassium additions.

RI 6652. Froth Flotation Washability Data of Various Appalachian Coals Using the Timed Release Analysis Technique, by Joseph A. Cavallaro and Albert W. Deurbrouck. 1965. 48 pp. 20 figs. Describes the timed release analysis technique that was developed to serve as a tool for assessing the froth flotation cleaning potentials of fine-size coals. Using this technique, 16 coals from 10 different coalbeds were tested. All of the coals included in this study were quite amenable to froth flotation. Float-and-sink analyses of the coals tested are shown to be of limited value in predicting froth flotation cleaning potential. The fixed carbon content of the samples collected was found to correlate with the floatability of the coals. The higher rank coals were the most readily floatable coals while the lower rank coals did not respond quite as well to flotation.

RI 6653. Stresses Induced Around Mine Development Workings by Undercutting and Caving, Climax Molybdenum Mine, Colorado (in Two Parts). 1. Use and Evaluation of Gages for Measuring Strain or Deformation, by Stephen Utter and William J. Tesch, Jr. 1965. 26 pp. 20 figs. Stresses induced by block-caving mining were estimated from in-place measurements of strain or deformation in rock and concrete around mine openings. Four types of gages were used for measurements in the Climax molybdenum mine during 1959-61. Gage performance in the laboratory was evaluated by stressing instrumented rock and concrete specimens in a universal testing machine and by comparing measurements taken by the gages and a standard gage. Gage performance in the mine was evaluated by comparing measurements taken during an 18-month test. The gage, the strain meter, and the extensometer proved suitable for the investigation; the strain cell, effective in the laboratory tests, gave erratic measurements in the mine.

RI 6654. Autoignition of Hydrocarbon Jet Fuel, by J. M. Kuchta, A. Bartkowiak, and M. G. Zabetakis. 1965. 25 pp. 14 figs. Experimental data are presented on the autoignition temperature (AIT) characteristics of the hydrocarbon jet fuel, JP-6, in various oxygen-nitrogen atmospheres under conditions of constant volume and constant pressure. AIT's of this fuel in air varied little with fuel injection pressure but increased greatly with decreasing fuel content at low fuel-air ratios. AIT's also increased with decreasing oxygen content of the fuel vapor-oxidant atmosphere. Consistent with thermal ignition theory, the ignition temperatures increased with decreasing initial pressure, ignition delay, and vessel radius; expressions are given which define the observed variation of AIT with these variables for JP-6 fuel vapor-air mixtures. The significance of autoignition temperature data obtained using various ignition criteria is discussed to show the usefulness of such data in evaluating fire and explosion hazards. In addition, data are presented on the extent of oxidation that occurs prior to autoignition of this fuel in air at various temperatures.

RI 6655. Hydrorefining Coal-Oils to Fuels for Supersonic Aircraft, by C. O. Hawk, M. D. Schlesinger, Paul Dobransky, and R. W. Hiteshue. 1965. 31 pp. 3 figs. Distillable oils derived from coal were desulfurized and hydrogenated at 2,500 psig in a two-step vapor-phase catalytic operation to give a product rich in saturated cyclic hydrocarbons. The first step was mainly a desulfurization at 400° C, the second a saturation at 300° C. One of the oils used as feed stock was from low-temperature carbonization of a bituminous coal, the other was from the liquid-phase hydrogenation of coal in the Bureau's pilot plant. The product from the saturation step was distilled to remove the light ends and high-boiling residue and to recover a fraction having acceptable properties with respect to heating value, density, freezing point, viscosity, and boiling range according to specifications suggested by the Air Force for ultra-high-speed aircraft fuel. Quantities of the fuel fraction available were too small for the thermal stability test approved by the Air Force. The experiments comprised mostly a study of the effect of varying the oil feed rate (at constant oil-to-hydrogen ratio) on the yield of the desired fuel fraction. The yield of the fuel fraction made from low-temperature carbonziation oil was a little more than 1 percent of the weight of the coal carbonized, that from coal-hydrogenation oil was about 12 percent of the weight of coal hydrogenated. Attempts to do both desulfurization and saturation in one operation with sulfur-resistant catalysts, developed for vapor-phase hydrogenation or hydroforming, were unsuccessful. By leaving the low-boiling ends in both feed stocks to desulfurization, another product was obtained: a low-sulfur aromatic cut boiling below 200° C. This material would be suitable as a solvent or a chemical raw material.

RI 6656. An Economic and Technical Evaluation of Magnesium Production Methods (in Three Parts). 1. Metallothermic, by K. C. Dean, D. A. Elkins, and S. J. Hussey. 1965. 76 pp. 6 figs. Report is the first of a series concerned with processes for producing magnesium. These reports will evaluate metallothermic, carbothermic, and electrolytic production methods and will furnish a cost basis for comparing the processes. Areas deemed most promising for future research will be delineated for each procedure. This report presents briefly the history of the metallothermic process and describes the operations of the Defense Plant Corporation (DPC) plants that employed the process. A hypothetical plant designed to produce 12,000 tons of magnesium per year, using ferrosilicon as a reductant, is described, and raw materials, energy, and major equipment requirements are estimated. Several process modifications are suggested for future research.

RI 6657. Relation of Density and Porosity Data to Structural Features of Anthracite, by Jerry W. Ramsey, G. A. Brady, and J. W. Eckerd. 1965. 24 pp. 3 figs. Reports examination of a low-, a medium-, and a high-volatile Pennsylvania anthracite by densimetric methods using four mesh sizes of each anthracite. Using high-pressure mercury porosimetry, the macropore volumes and distributions of these pore volumes were determined, densities in mercury were calculated, and specific pore volumes were obtained from these mercury densities in conjunction with helium densities. The helium densities were also used with the ultimate analyses of these anthracites in calculating structural parameters by statistical densimetric methods. The effect of 10^6 or 10^5 rads of gamma irradiation in the presence of air and in vacuum upon the properties was studied with two mesh sizes of each anthracite. Results of the statistical densimetric method seem to show some breakdown of condensed ring structural units at the lower irradiation level, with subsequent polymerization at the longer period of gamma irradiation. The structural parameters obtained also indicated that in going from high- to low-volatile anthracite, either the number of condensed rings per structural unit increased or the degree of polymerization increased.

RI 6658. Oil Well Scale Formation in Waterflood Operations Using Ocean Brines, Wilmington, Calif., by G. L. Gates and W. H. Caraway. 1965. 28 pp. 12 figs. Scales formed in producing wells in the Wilmington field, California, were studied. The scales were primarily barium sulfate and resulted from the mixing of injected sea water and formation waters; there was excess sulfate in the injection water and the formation waters contained appreciable barium. After breakthrough, the produced brines were supersaturated with barium sulfate. Laboratory tests indicated that barium sulfate precipitated quickly when the supersaturated brines were agitated with crystals of barium sulfate and fairly rapidly when more sulfate solution was added. Precipitation occurred slowly on standing or under nonturbulent conditions. Both the apparent and equilibrium solubilities of barium sulfate in these brines were determined and compared with equilibrium solubilities in distilled water and sodium chloride solutions.

RI 6659. Flammability Characteristics of Ethylene, by George S. Scott, Robert E. Kennedy, Irving Spolan, and Michael G. Zabetakis. 1965. 10 pp. 7 figs. Experiments were conducted on ignition, flammability, and decomposition of gas mixtures containing ethylene to determine its flammability characteristics at elevated pressures and ambient temperatures. Pure ethylene was found to propagate a decomposition reaction at 1,000 psig and ambient temperatures when ignited with 1 gram or more of guncotton in a 2-inch-inside-diameter bomb. The decomposition products were primarily carbon, methane, and hydrogen.

RI 6660. Foaming Agents for Removing Problem Liquids From Gas Wells, by J. L. Eakin. 1965. 14 pp. 2 figs. The Bureau of Mines determined agents that are effective in foaming heavy brines and oil from gas wells in severe concentrations of sodium chloride, in severe concentrations of calcium chloride, or in moderate oil-brine mixtures. Dynamic foam tests were designed to select the more effective foaming agents. Numerous foaming agents were tested in concentrated simulated brines, in oilfield brines having varied concentrations of ions, in heavy natural brines, and in a commercial brine generally used as a reservoir pressure-balancing fluid. Several agents were detected that could perform efficiently in the field under the most severe saline conditions. Agents that promote foaming in oil-brine mixtures were also determined. Work done in cooperation with the American Gas Association and the State of Oklahoma.

RI 6661. Electron-Beam Melting of Yttrium, by W. E. Anable and R. A. Beall. 1965. 14 pp. 4 figs. The Bureau of Mines studied the purification of commercially available yttrium by melting it in a 100-kw electron-beam furnace. Button-scale melts were made to determine the ultimate purification that could be attained by melting yttrium at 1,733° to 1,770° C at low pressure (0.05 to 0.1 micron) for 1 to 120 minutes. In addition, numerous melts were made to study the effect of doping yttrium with carbon, 17 selected metallic additions, and 3 compounds. Except for nickel and zirconium, the metallic impurities in yttrium were lowered significantly on extended treatment; silicon was lowered only slightly. The nonmetallic impurities, oxygen, nitrogen, and carbon, were not lowered except on short exposures. In isolated instances, the oxygen content was lowered from 5,860 ppm to about 5,000 ppm. In most instances the carbon content was lowered from 545 to about 220 ppm in 20 minutes and then increased again. It was concluded that yttrium cannot be purified by direct heating or by the doping technique employed. Work done under agreement with the U.S. Atomic Energy Commission.

RI 6662. Hydrogen Reduction of Galena and Sphalerite, by J. D. Spagnola. 1965. 17 pp. 10 figs. The Bureau of Mines conducted research to obtain comparative data on the extent of reduction of galena and sphalerite with molecular hydrogen and with hydrogen from the thermal cracking of ammonia and methane at various time intervals. Galena reductions of 95 to 99 percent were obtained with H_2 and with decomposed NH_3, while reductions of 70 to 80 percent were obtained with cracked CH_4. Sphalerite reductions of 99 percent were obtained at 1,000° C with H_2 and with decomposed NH_3; however, complete volatilization of the free zinc from the remaining concentrate and the subsequent recombination of zinc and sulfur vapors resulted. A promoted iron catalyst brought about a decrease of 100° C in the temperature required for complete decomposition of ammonia. It was found that H_2S retards NH_3 decomposition and that nitrogen retards the reduction of galena by H_2. A mixture of N_2 and H_2 in about the same ratio as that obtained by the thermal cracking of NH_3 gave about 15 percent less reduction of galena than was obtained with decomposed NH_3; this indicates that a portion of the hydrogen obtained by NH_3 decomposition is in an active form.

RI 6663. Heat of Formation of Tantalum Carbide, by Alla D. Mah. 1965. 5 pp. The heat of combustion of $TaC_{0.996}$ was determined by oxygen bomb calorimetry to be —302.8 ±0.4 kcal/mole. The corresponding heat of formation of $TaC_{0.996}$ is —35.4 ±0.5 kcal/mole, and the calculated heat of formation of $TaC_{1.00}$ is —35.5 ±0.5 kcal/mole.

RI 6664. Some Thermal Properties of Beryllium Fluoride From 8° to 1,200° K, by A. R. Taylor, Jr., and T. Estelle Gardner. 1965. 15 pp. 8 figs. The heat capacities of α-quartz from beryllium fluoride were measured at approximately 3-degree intervals from 8° to 300° K, using an adiabatic calorimeter. At 298.15° K the heat capacity and entropy were 12.39 cal/deg mole and 12.75 $\pm$0.04 eu, respectively. Enthalpy measurements were made with an ice calorimeter at approximately 30-degree intervals on the quartz and glassy forms of beryllium fluoride between 300° and 1,200° K. A melting point of 825° K and an α-β type transition at 500° K with a heat effect of 75 cal/mole were determined from the enthalpy data for the quartz-type sample. Bryllium fluoride glass crystallized spontaneously into the quartz modification at 500° K. The heat of the reaction, BeF_2 (α-quartz) BeF_2 (glass), was found to be 1,125 $\pm$ 16 cal/mole at 298° K by solution calorimetry. This value, when corrected to 273° K, was used to correct for the heat absorbed by the formation of glassy BeF_2 when the sample was dropped into the ice calorimeter from temperatures above the melting point. Using corrected enthalpy measurements, the heat of fusion was determined to be 1.13 kcal/mole at 825° K. Work done in cooperation with the University of Alabama.

RI 6665. Preparation Characteristics of Coal From Fayette County, W. Va., by Albert W. Deurbrouck. 1965. 52 pp. 3 figs. Describes the preparation characteristics of 23 coal samples collected from nine of the more significant coalbeds of Fayette County, W. Va., Coalburg, Fire Creek, Gilbert, Little Eagle, No. 2 Gas, Pocahontas No. 6, Powellton, Sewell, and Winefrede beds. Of the 23 coal samples collected, 11 would require some upgrading to provide metallurgical quality products, 11 were acceptable as received, and 1 was a noncaking coal. Cleaning these coals to metallurgical standards would require only the removal of the sink 1.58 specific gravity material which would be quite easy as very little near-separating-gravity material was present at this gravity.

RI 6666. Stresses Induced Around Mine Development Workings by Undercutting and Caving, Climax Molybdenum Mine, Colorado (in Two Parts). 2. Strain and Deformation Measurement, by R. L. Bolmer. 1965. 27 pp. 19 figs. During 1959-61 the Bureau of Mines investigated the strain and deformation induced in rock and concrete linings around mine openings by retreat panel caving at the Climax molybdenum mine. Two concrete-lined slusher drifts on the Phillipson level of the mine were instrumented with both electrical strain gages and extensometers. Changes in strain and deformation were recorded over an 18-month period during the undercutting and caving of the mining panel. General agreement was found between the strain and deformation measurements and the hypothesis that the vertical component of the stress field on the openings is almost completely removed by undercutting. This phenomenon is a possible explanation for the structural failures that occur in the slusher drifts during the undercutting cycle.

RI 6667. Growth and Properties of Zirconia and Titania Whiskers From Fused Salt Baths, by Robert C. Johnson and John K. Alley. 1965. 15 pp. 3 figs. Single crystal whiskers of ZrO_2 and TiO_2 were grown by solution and crystallization of these oxides in molten baths. Mixtures of $Na_2B_4O_7$ and LiCl were the most suitable growth media for zirconia. Sodium borate alone and Na_2CO_3 plus SiO_2 were best suited for titania. The solubilities of zirconia and titania in molten sodium borate were determined. Whether zirconia whiskers were dendritic or nondendritic depended on the temperature used. The best crystal whiskers were grown below 1,100° C. Titania whiskers always grew as single crystals. The tensile strengths of zirconia and titania whiskers were about 15,000 psi and 50,000 psi, respectively. Modulus of rupture was about 49,000 psi for zirconia whiskers and 75,000 psi for titania whiskers. Chemical analyses showed the zirconia and titania whiskers to be pure. The zirconia and titania whiskers were shown by X-ray analysis to be, respectively, baddeleyite and rutile.

RI 6668. Flotation of California Mica Ore, by James S. Browning and Paul E. Bennett. 1965. 7 pp. 1 fig. The Bureau of Mines conducted laboratory batch and pilot plant flotation tests to determine the technical feasibility of recovering commercial-grade mica from a California micaceous schist. Best results in the laboratory batch tests were obtained using sodium carbonate and sodium silicate for pH control and quartz depression, and a combination of fatty acid and cationic reagents as the mica collector. In continuous pilot plant flotation tests, an alkaline-fatty acid-cationic method recovered about 70 percent of the mica in a concentrate analyzing 95.6 percent mica. Work done in cooperation with the University of Alabama and Kelly-Moore Paint Co., Inc.

RI 6669. Low-Temperature Heat Capacities and Entropies at 298.15° K of Anhydrous Sulfates of Cobalt, Copper, Nickel, and Zinc, by W. W. Weller. 1965. 6 pp. Heat capacity measurements of anhydrous cobalt sulfate ($CoSO_4$), copper sulfate ($CuSO_4$), nickel sulfate ($NiSO_4$) and zinc sulfate ($ZnSO_4$) were conducted over the temperature range 51° to 298° K. The results were used to evaluate the following entropies at 298.15° K (cal/deg mole): $CoSO_4$, 28.1; $CuSO_4$, 26.8; $NiSO_4$, 24.8; and $ZnSO_4$, 26.4. Entropies were combined with heats of formation to give free energies of formation.

RI 6670. Vertical Flow of Oil and Gas Mixtures in Small-Diameter Siphon-Type Flowstrings, by G. E. Rennick and R. L. Rough. 1965. 50 pp. 21 figs. A siphon-type laboratory airlift well was designed and operated to study the concurrent flow of air and oil in small-diameter pipes. Glass flowstrings ranging from ¼ to 1 inch in diameter and from 14 to 64 feet in length were equipped with various-sized air-entry jets. Liquid holdup volumes were used to correlate vertical-flow data, and empirical equations for computing gas requirements were derived. The effect of flowstring length on flow efficiency, oil- and gas-production rates, and gas-oil ratios was relatively minor at all flowing pressures. Air-jet sizes and flowstring diameters, however, had a marked effect on flow efficiency and oil- and gas-production rates. The small air-jet sizes increased maximum flow efficiency and its associated flowing pressures but decreased oil- and gas-production rates. An increase in flowstring diameter increased maximum flow efficiency with its associated flowing pressure and also increased the production rates of oil and gas.

RI 6671. The Mass Spectra and Correlations With Structure for 14 Alkylthiophenes, by Norman G. Foster, D. E. Hirsch, R. F. Kendall, and B. H. Eccleston. 1965. 31 pp. 5 figs. The mass spectra of 14 previously unreported alkylthiophenes are presented. Low-ionization-voltage data of selected compounds from these 14 and 23 previously reported alkylthiophenes are presented and discussed for their value in supporting fragmentation mechanisms and analytical correlations. A comparison with and corroboration of earlier correlations is made. Additional correlations concerning detection of side chain branching and the detection of ethyl-alkyl and propyl-alkylthiophenes are made. A discussion of the possible fragmentation routes and mechanism of fragmentation is given. Speculative structures are inferred about some of the ions and hence this work provides a basis for suggesting fragmentation mechanisms for the alkylthiophenes according to modern theories of mass spectrometry. Verification of these mechanisms must await the availability of isotopically labeled molecules which are labeled in specific locations that permit the definition of the paths of fragmentation. Some suggestions for further work to generalize on the correlations and studies made to this point are presented.

RI 6672. The Thermodynamics of Combustion Gases. Computed Compositions of Methane-Air, Propane-Air, and Ethylene-Air Flames, by Robert W. Smith, Jr., and Edwin B. Cook. 1965. 30 pp. Reports the equilibrium compositions of product gases for mixtures of air with methane, propane, or ethylene at and around flame temperatures. For each hydrocarbon, compositions are given for five fuel-to-air ratios—two lean, two rich, and one stoichiometric—at five pressures, from 1 to 20 atmospheres, and at an ambient temperature of 25° C.

RI 6673. Determination of a Part of the Magnesium-Zirconium Liquidus, by R. L. Crosby and K. A. Fowler. 1965. 19 pp. 8 figs. A part of the liquidus of the magnesium-zirconium system was determined by chemical analysis of suction samples taken from the melt in the approximate temperature range of 850° to 1,450° C. The melt was prepared in a furnace pressurized with an inert gas. The average zirconium value in weight-percent of the liquidus composition at each sampling temperature was 0.96 at 867° C, 1.40 at 1,062° C, and 2.96 at 1,402° C. The equilibrium solid phase was zirconium.

RI 6674. Preparation of Primary Standard Gas Mixtures for Analytical Instruments, by J. E. Miller, A. J. Carroll, and D. E. Emerson. 1965. 10 pp. 1 fig. Primary standard gas mixtures were developed for more accurate calibration of analytical instruments and for calibration of analytical instruments used in the helium conservation program. A 10-kilogram-capacity balance is used to weigh a 4-kilogram metal cylinder filled to high pressure (1,800 psi maximum) with the component gases of the desired mixture. At 1,800 psi, a cylinder contains about 60 grams of helium, or 420 grams of nitrogen. An accuracy of ±0.05 mole-percent or better is claimed for each component in the mixtures.

RI 6675. Distribution of Stress in the Westvaco Trona Mine, Westvaco, Wyo., by Thomas A. Morgan, William G. Fischer, and William J. Sturgis. 1965. 58 pp. 44 figs. Gives the distribution of stress adjacent to each of 25 mine openings determined by the borehole stress-relief method in the FMC Corp. Westvaco trona mine. The purpose of the stress determination was twofold: First, to study the effect on the distribution of various factors such as opening shape, stress level, and loading history; and, second, to estimate the distribution of stresses adjacent to extensive high-extraction (85 to 100 percent) extraction areas. Stress distributions in areas of low average stress correspond closely to the theoretical distributions based on elastic theory. However, in areas of high average stress, the stress distributions are of a type associated with plastic failure. The stresses adjacent to a mined-out area supported by remnant pillars were significantly higher than the stresses adjacent to another area in which the remnant pillars were removed. (*Out of print.*)

RI 6676. Automated Modified Fischer Retorts for Assaying Oil Shale and Bituminous Materials, by Arnold B. Hubbard. 1965. 19 pp. 12 figs. Automatic control instruments were utilized for routine assays of large numbers of oil shale samples and other bituminous materials. The standard Fischer assay method was automated by automatically controlling the heating cycles of a battery of 12 electric heaters with electronic controllers and programers. The condensers were cooled with a modified automatically controlled refrigeration bath. The complete assembly consisted of 12 retort units, necessary control instruments, and the refrigeration bath. This equipment was capable of producing more consistent results than those previously obtained with the gas-heated retorts and of increasing the output of assays substantially with no increase in operating personnel. Work done in cooperation with the University of Wyoming.

RI 6677. Freezeproofing Lignite, by Robert C. Ellman, John W. Belter, and Leroy Dockter. 1965. 28 pp. 9 figs. Investigates the factors that cause agglomeration of lignite by freezing during winter shipment to find methods of avoiding it. Tests showed that lignite may be freezeproofed by removal of the relatively small quantity of moisture involved in forming the frost crystals which cement particles together, or by controlling the crystal characteristics. Adding dried lignite fines proved to be an effective and superior freezproofing method. Commercial adoption of this method has been successful.

RI 6678. Blast Furnace Operations With Very Low Slag Rates, by P. L. Woolf, J. F. Pearce, W. M. Mahan, and J. A. Basso. 1965. 14 pp. 3 figs. Two blast furnaces, one a commercial furnace and the other the Bureau of Mines experimental furnace, were successfully operated with extremely low slag volumes. The lowest slag rate obtained on the industrial furnace was 335 pounds per ton of metal. Using the same burden materials a 245-pound slag volume was achieved on the small furnace. The coke-rate saving and increase in productivity resulting from lowered slag rates are discussed as well as the factors limiting a low slag practice. Work done in cooperation with Wabush Mines.

RI 6679. Effects of Decoupling and Type of Stemming on Explosion-Generated Pulses in Mortar: A Laboratory Study, by D. E. Fogelson, D. V. D'Andrea, and R. L. Fischer. 1965. 18 pp. 12 figs. In a factorial experiment, blasting caps were detonated in three sizes of shotholes in mortar with three types of stemming—dry sand, wet sand, and hydrostone. Free-surface displacement pulses were recorded with a capacitive-displacement gage at a distance of 15 inches. The effects of decouping and the type of stemming on the amplitude and the duration of the displacement pulse were significantly decreased by increasing the decoupling, but they were little affected by the type of stemming.

RI 6680. Stress Corrosion Cracking of Vanadium, Molybdenum, and a Titanium-Vanadium Alloy, by J. P. Carter, C. B. Kenahan, and David Schlain. 1965. 18 pp. 10 figs. Vanadium, molybdenum, and a titanium-10 percent vanadium alloy were evaluated for their susceptibility to stress-corrosion cracking in a number of corrodents. Tests were conducted utilizing conventional U-bend techniques with subsequent evaluation in a pneumatic constant-load apparatus. Vanadium and molybdenum were generally resistant to stress-corrosion cracking in the media studied. U-bend specimens of vanadium showed evidence of stress-corrosion cracking in 6 N hydrochloric and 18 N sulfuric acids; however, tensile stress specimens exposed to these solutions did not exhibit stress cracking. Similar results were obtained when U-bend specimens of molybdenum were immersed in 10 percent formic acid. Titanium-10 percent vanadium alloy was susceptible to stress-corrosion cracking in 10-percent (2.85 N) hydrochloric acid solution. Heat treating the alloy greatly reduced its corrosion rate and its susceptibility to stress-corrosion cracking in this medium.

RI 6681. Measurement of Backscattered Electrons in an Electron Probe Microanalyzer, by Philip G. Burkhalter. 1965. 22 pp. 10 figs. Total yield and backscattered electron coefficients were measured in this study in an electron-probe microanalyzer as a function of atomic number and of primary energy in the 15- to 35-kilovolt range. The electron coefficients were obtained indirectly from measurements of the specimen electron current and the primary beam current collected in a Faraday cage and were measured with a precision better than 0.5 percent. Secondary electron emission was suppressed with an opposing potential applied to a screen grid surrounding the specimen. The values of the backscattered electron coefficients agreed with published values within 5 percent.

RI 6682. A Torsion Effusion Apparatus for Vapor Pressure Measurement. Vapor Pressure of Silver From 1,200° to 1,500° K, by Larry A. Haas and C. W. Schultz. 1965. 18 pp. 7 figs. The Bureau of Mines constructed a torsion effusion apparatus to measure the equilibrium vapor pressure of pure metals, alloys, and compounds at temperatures up to 1,500° K. The reliability of the apparatus was established by determining the vapor pressure of silver. The data obtained on solid and liquid silver in the temperature range 1,200° to 1,500° K can be expressed by the following equations:

$$\text{Solid, } \log P_{mm} = -\frac{14{,}938 \pm 818}{T} + 9.666 \pm 0.679,$$

$$\text{Liquid, } \log P_{mm} = -\frac{14{,}203 \pm 145}{T} + 9.115 \pm 0.077.$$

The heat of sublimation at 298° K of 66.76 ± 0.19 was calculated by the third-law method.

RI 6683. Oil-Reservoir Analysis and Predicted Recovery by Waterflooding, Clinton Sand, Logan Hocking Oilfield, Hocking County, Ohio, by D. W. Boley, H. R. Johnson, and W. K. Overbey, Jr. 1965. 43 pp. 23 figs. Contains the results of an analysis of the Logan oilfield, Hocking County, Ohio, and predicts the recovery of oil from the Clinton sand by waterflooding. Core analyses, electrical and radioactivity well-survey logs, reservoir-fluid analysis, and geologic and production data were used for this study. Considered in the evaluation were the reservoir geometry, depth, lithology, continuity of the rock properties, fluid saturations, fluid characteristics, rock wettability, and relative permeability-fluid saturation relationships. The study indicates that a properly engineered waterflood should recover approximately 135 barrels per acre-foot of effective sand. The predicted recovery warrants the initiation of a pilot waterflood in this field.

RI 6684. A Study of Radioactive Contamination Resulting From the Use of Nuclear Explosives for Stimulating Petroleum Production, by C. E. Arthur and F. E. Armstrong. 1965. 11 pp. 2 figs. Investigates the problem of radioactive contamination using nuclear explosives to fracture petroleum reservoirs in an attempt to stimulate production. It was concluded that some contamination of petroleum products will almost certainly occur. However, the degree of contamination cannot be predicted except by a full-scale experiment, since simulating the problem in the laboratory is economically impossible because of the extremely high temperatures and pressures that must be reached in extremely short time intervals if a reasonable analog is to result. Work done under an agreement with the U.S. Atomic Energy Commission.

RI 6685. Hydraulic Coal Mining Research. Development Mining in a Steeply Pitching Coalbed, Roslyn, Wash., by George C. Price and Frank Badda. 1965. 16 pp. 8 figs. Gives results of a study in the Roslyn No. 5 coalbed to determine the feasibility of mining hydraulically the portion of the coalbed that was steeply pitching. All of the experimental mining was done while advancing raises and rooms. A Bureau-developed hydraulic mining machine was used successfully in the pitching coalbed. It consisted of a remotely controlled monitor mounted on a self-advancing roof-support unit of the type commonly used for roof support in longwall mining systems. The coal-cutting rates averaged 0.73 and 0.54 tons per minute in raise and roof mining, respectively, while using water volumes up to 230 gpm at a pressure of 4,000 psig. Productivity averaged 4.7 and 5.2 tons per man-shift for raise and room mining, respectively, compared with 7.5 and 8.5 tons per man-shift, respectively, by conventional hand-mining methods. Two previous publications, RI 5915, published in 1961, and RI 6276, published in 1963, described the equipment and gave the results of mining in a flat-lying coalbed and a steeply pitching coalbed. Work done in cooperation with the Northern Pacific Railway Co.

RI 6686. Prerefining Pig Iron With a Vortex Cone. Improvements in Desiliconizing Techniques, by F. X. Tartaron. 1965. 12 pp. 4 figs. Describes work done by the Bureau to simplify the design and operation of the vortex cone, a new device for prerefining blast-furnace iron. Three new apparatus arrangements were tested. Results with one of these arrangements averaged 74.2 percent silicon removal and 61 percent oxygen efficiency (disregarding removal of carbon and manganese). A previous report, RI 6388, published in 1964, described the design and operation of the vortex cone.

RI 6687. Heats of Formation of Anhydrous Ferric Sulfate and Indium Sulfate, by R. Barany and L. H. Adami. 1965. 8 pp. The heats of formation of anhydrous ferric sulfate and indium sulfate were determined by solution calorimetry. At 298.15° K the heats of formation from the metal, rhombic sulfur, and oxygen were −615.6 ±0.7 kcal/mole for ferric sulfate and −649.6 ±0.6 kcal/mole for indium sulfate. Heats of decomposition at 298.15° K are given for the reaction that forms metal oxide, sulfur dioxide, and oxygen and for the reaction that forms the metal oxide and sulfur trioxide.

RI 6688. Removal of Waterblocks From Gas-Producing Formations, by J. L. Eakin, J. S. Miller, and W. E. Eckard. 1965. 24 pp. 1 fig. Describes a method developed in the laboratory and in the field to relieve capillary waterblocks in gas wells. Impaired gas permeability was improved by this inexpensive chemical treatment which lowers the surface tension of the water held in the capillaries of the formation. Effectiveness of the alcohol-surfactant treatment was tested with a variety of chemicals and with sandstone cores cut from rocks having relatively low permeability. Field tests on 20 gas-producing and storage wells demonstrated the effectiveness and limitations of the method. The productive capacity of some wells was doubled by the treatment. The final test was evaluated by the neutron logging technique for measuring changes in apparent liquid saturation. Maximum apparent liquid saturation was reduced by 52 percent; gas production rate increased from 2.3 to 3.5 million cubic feet per day. Work done in cooperation with the Pipeline Research Committee, American Gas Association.

RI 6689. Instrumentation for Primary and Secondary Excitation of Low-Energy X-Ray Spectral Lines, by John W. Thatcher and William J. Campbell. 1965. 29 pp. 17 figs. A demountable X-ray tube vacuum spectrograph was designed by the Bureau for the determination of long-wavelength X-ray spectra from the light elements. This instrument was operated for both secondary and combined primary-secondary excitation of the aluminum K-series. There was an increased analytical sensitivity for elements in period 3, and an indication that with improved X-ray tubes or direct electron excitation of the sample, X-ray determination of elements in period 2 is also possible.

RI 6690. Thermal Expansion Anistotropy and Preferred Orientation in Rolled Zinc Alloys Containing Copper and Titanium, by J. T. Dunham, L. E. D. Pease, Jr., and P. G. Barnard. 1965. 16 pp. 6 figs. Gives results of study by dilatometry of the effect of titanium on the thermal expansivity of hot-rolled zinc and Zn-1 percent Cu alloy. The titanium content of the alloys was varied up to 0.3 percent. Expansion coefficients were determined from measurements made both parallel and perpendicular to the plane of the rolled sheet. Titanium reduced expansion parallel to the plane of the sheet, especially in the rolling direction, but increased expansion perpendicular to the sheet. Basal-plane pole figures showed that the degree of preferred orientation increased with the titanium content in the alloy and that anisotropic expansion can be correlated to sheet texture.

RI 6691. Diborides in the Pseudobinary System TiB_2-CrB_2: Electrical Properties, by Gilbert M. Farrior. 1965. 26 pp. 14 figs. The electrical resistivity, the coefficient of electrical resistivity, the Hall coefficient, and the absolute thermoelectric power were determined in this investigation for nine compositions of the TiB_2-CrB_2 subsystem. The numerical values of the electrical resistivity and the thermoelectric power were greater for the intermediate compositions than for the end members. The absolute values of the Hall coefficients and the coefficients of electrical resistivity were less for the intermediate compositions than for the end members. The electrical resistivities and Hall coefficients were about the order of magnitude of most metals—from 34 to 202 microhm-cm and from about 0 to -23.3×10^{-4} cm^3/coulomb. The thermoelectric power was somewhat greater than that of most metals—up to 15.6 microvolts per ° C.

RI 6692. Extraction of Manganese From Georgia Umber Ore by a Sulfuric Acid-Ferrous Sulfate Process (in Two Parts). 1. Countercurrent-Decantation Extraction and Agglomeration of Leached Residue Tests, by H. P. LeVan, E. G. Davis, and F. E. Brantley. 1965. 21 pp. 7 figs. Research was conducted to examine the feasibility of extracting manganese from Georgia umber ore by a three-stage continuous sulfuric acid-ferrous sulfate pickle liquor leaching process. A continuous cyclic process for treating the umber was operated successfully, using a synthetic solution simulating a ferrous sulfate fortified anolyte solution discharged from a manganese electrolytic cell as the leaching medium. Leaching efficiency based on removal of the manganese from the ore ranged from 83 to 89 percent for all systems tested. Work done in cooperation with the University of Alabama.

RI 6693. Comparative Study of Explosives in Granite. Third Series of Tests, by Harry R. Nicholls and Verne E. Hooker. 1965. 46 pp. 19 figs. Six different chemical explosives were detonated in a test series to compare their relative performance in granite. From 5 to 255 feet from the detonation point, strain, acceleration, and particle velocity were recorded and analyzed for amplitude and pulse shape. Strain energy was calculated from strain data, and displacement data were obtained from particle velocity data by integration. Results show that explosives which have a characteristic impedance more closely matching that of the rock generate larger peak amplitudes than explosives with a lower characteristic impedance. The results also show that as the ratio of characteristic impedance of explosive-to-rock approaches unity, more rock is crushed and a larger percentage of the available explosive energy is transferred to the rock as seismic energy. The effect of characteristic impedance is shown to be greater than the effect predicted from acoustic theory and is believed to be indicative of shock wave effects at the explosive-rock boundary.

RI 6694. Continuous Attrition Grinding of Coarse Kaolin (in Two Parts). 2. Closed-Circuit Tests, by Martin H. Stanczyk and I. L. Feld. 1965. 13 pp. 3 figs. The Bureau of Mines studied continuous closed-circuit attrition grinding of a coarse commercial filler-grade kaolin to produce paper-coating-grade clay having a particle size analysis of at least 70 percent minus 2-micron equivalent sperical diameter (esd). The coarse clay, containing about 12 percent minus 2-micron-esd material, was ground in a Bureau-developed 10-inch-diameter attrition grinder in closed circuit with a 5-foot-diameter bowl classifier. In the best test, a finished product containing 82.7 percent minus 2-micron-esd material was obtained when grinding 20 pounds of raw clay per hour at 45 percent solids with a 100-percent circulating load. Energy consumption was about 341 kilowatt-hours per ton of clay feed, or 487 kilowatt-hours per ton of minus 2-micron-esd material produced. Closed-circuit grinding gave somewhat greater particle size reduction and lower energy consumption than either batch or continuous open-circuit grinding. Work done in cooperation with the University of Alabama.

RI 6695. Vibration Levels Transmitted Across a Presplit Fracture Plane, by James F. Devine, Richard H. Beck, Alfred V. C. Meyer, and Wilbur I. Duvall. 1965. 29 pp. 16 figs. Describes tests conducted at three sites to determine if, and to what extent, a vertical presplit fracture plane placed between a blast point and detection point will reduce vibration levels. Statistical analyses indicate that the presplit fracture plane did not reduce the vibration level.

RI 6696. Variables in the Use of Hot-Finished Mild Steel Coupons for Corrosion Inhibitor Testing, by Jerry B. F. Champlin and Don R. Thompson. 1965. 17 pp. 5 figs. Describes an accelerated testing procedure developed for evaluating commercially available corrosion inhibitors. Ultrasonic agitation of the corrodent solutions and the hot-finished mild stel test coupons was used to evaluate the effects of several variables on the effectiveness of two corrosion inhibitors. Small changes in the weight of the test coupons in both controlled and inhibited corrodents, before and after exposure, affected the precision and accuracy of the results. Minute amounts of oxygen in the systems were found to be causing the relatively large deviations in the corrosion developed in the controlled tests. Microscopic examination of the test coupons revealed that both surface preparation and internal strains resulting from fabrication methods materially affect corrosion behavior. Work done in cooperation with the State of Oklahoma.

RI 6697. Heat of Formation of Neodymium Trichloride, by J. M. Stuve. 1965. 4 pp. Heat of solution measurements of high-purity neodymium metal and neodymium trichloride ($NdCl_3$) in 4.360 molal hydrochloric acid (HCl) were used to determine the standard heat of formation (ΔH_f^0) of $NdCl_3$. From solution data obtained, the heat of formation of $NdCl_3$ (c) was computed as $-248,970 \pm 260$ cal/mole at 298.15° K.

RI 6698. Mass Spectra of Organic Sulfur Compounds, by Glenn L. Cook and G. U. Dinneen. 1965. 86 pp. Correlations between mass spectra and molecular structures of 186 organic sulfur compounds are discussed. The olefinic ions, the alkyl ions, the $C_nH_{2n+1}S$ ions, the m/e 61 ions, and the m/e 35 ions in the spectra of thiols are related to molecular structure. In the spectra of sulfides, the olefinic ions, the m/e 61 ions, the m/e 35 ions, the $C_nH_{2n+1}SH$ ions, and the $C_nH_{2n+1}SH_2$ ions are correlated with molecular structure. For disulfides, the correlations relate HSSH and RSSH ions to molecular structure. Base peaks of alkylthiophenes are correlated to their molecular structures. Some unimolecular reactions of sulfur compounds in the mass spectrometer are considered. A cyclic intermediate is suggested for the reaction which produces m/e 47, CH_3S^+, and m/e 48, CH_4S^+, ions in the spectra of sulfides. An expanded ring is suggested as a possible intermediate in the reactions of thiophenes. Heats of formation of sulfur-containing ions and their appearance potentials are presented in tabular form. Ionization potentials for sulfur-containing radicals and molecules are also given. Discussion of the spectra, tabulated in the appendixes, provides an insight into the relationship of the molecular structure of a compound to the mass-to-charge ratios and the intensities of the ions in its mass spectrum. Correlations of the mass spectra with molecular structures are empirically developed by observing regularities in the spectra of the reference compounds. Correlations extend the usefulness of mass spectra because they can be employed to determine the molecular structure of an unknown compound. Work done in cooperation with the University of Wyoming and the American Petroleum Institute, Research Project 48.

RI 6699. Adsorption Phenomena and the Reduction of Iron Oxides. Relation of Heat of Adsorption to Heat of Activation for the Reduction of Wustite and Magnetite, by S. E. Khalafalla, C. W. Schultz, and T. N. Rushton. 1965. 18 pp. 8 figs. The Bureau of Mines investigated variations in the activation energy for the carbon monoxide reduction of magnetite and ferrous oxide with respect to the state of aggregation of the oxide material. Reduction phenomena can only be satisfactorily explained by including an adsorption step in the reduction process. Summation of the values of the exothermic heat of chemisorption and the variable apparent activation energy for reduction yields a nearly constant value of about 50 kcal for either ferrous oxide or magnetite regardless of whether they are aggregated in pelletized form or coarsely crystalline particles.

RI 6700. Comparison Between End and Axial Methods of Detonating an Explosive in Granite, by Wilbur I. Duvall and Joseph M. Pugliese. 1965. 11 pp. 7 figs. A linear array of shot and gage holes 30 feet deep in a granite outcrop was used to compare the size and shape of radial strain pulses produced in the rock when short cylindrical charges of cast composition B were detonated axially or at one end. The axially detonated charges produced radial strain pulses that had shorter rise times and larger peak strain than the strain pulses produced by end detonated charges.

RI 6701. Measurement of Lateral Pressure Generated From Cylindrical Explosive Charges, by Lippe D. Sadwin and Norman M. Junk. 1965. 8 pp. 4 figs. Describes a high-speed streak camera technique for measuring the lateral shock pressure generated by a cylindrical explosive charge detonated from one end. Experimental data show that the magnitude of the lateral pressure is approximately 50 percent that of the pressure generated from the terminal end of the charge for the three explosives studied.

RI 6702. Prediction of Compressive Strength From Other Rock Properties, by D. V. D'Andrea, R. L. Fischer, and D. E. Fogelson. 1965. 23 pp. 13 figs. Nine rock properties were determined for rocks coming from 49 locations and having a wide range of compressive strengths. Plots of the nine rock properties versus each other were prepared. A stepwise multiple linear regression analysis was performed to obtain several equations for predicting compressive strength. Both linear and curvilinear relationships were assumed between compressive strength and the other rock properties. The prediction equations had multiple correlations coefficients ranging from 0.947 for an equation with 1 variable (point load tensile strength) to 0.986 for an equation with 25 variables. Of the properties tested only point load tensile strength could be used alone to estimate compressive strength with fair accuracy.

RI 6703. Creep in Model Pillars, by Leonard Obert. 1965. 23 pp. 25 figs. Considers the deformational behavior (creep) of pillars made from three quasi-plastic rocks—salt, trona, and potash ore. The first phase of this study considers the design of a model pillar suitable for creep tests; in the second phase, six model pillars were prepared from salt from two sources, from trona, and from potash ore. The pillars in each group were subjected to a different but constant axial stress, and the axial strain was measured for 1,000 hours.

RI 6704. Explosive-Expansion Center-Hole Anchor, by Edward W. Parsons and Lars Osen. 1965. 14 pp. 11 figs. The explosive-expansion center-hole anchor was designed and developed for use as a component of an instrument system that measures differential ground movement within a small drill hole in rock. The anchor has a thick-walled center tube and a thin-walled outer tube. Low-energy detonating cord, wrapped around the center tube and detonated with a mild end primer, expands the outer tube to produce anchorage. The explosive-expansion center-hole anchor can be installed easily in drill holes of any inclination but cannot be installed under water. Centering of the anchor is critical with regard to its subsequent holding power. The anchor is safe to make and handle.

RI 6705. Heat of Formation of Scandium Trichloride, by J. M. Stuve. 1965. 5 pp. Calorimetric data for the dissolution of scandium sesquioxide and scandium trichloride in 4.360 molal hydrochloric acid were used to evaluate the standard heat of formation of $ScCl_3(c)$. The heat of reaction for $Sc(c) + 1.5Cl_2(g) = ScCl_3(c)$ at 298.15° K was computed as $-225{,}440 \pm 340$ cal/mole.

RI 6706. Flow Properties of Powdered Coal-Water Slurries, by W. R. Huff, J. H. Holden, and Jack A. Phillips. 1965. 15 pp. 10 figs. Yield stress and plastic viscosity values, determined from shear rate-shear stress relationships, were found to be a linear function of coal concentration for coal-water slurries containing 40, 45, 50, and 55 weight-percent of powdered coal. In the laminar region, the flow is described by an equation derived from the fact that the square root of the shear stress varied linearly with the square root of the shear rate. In the turbulent region, the friction factor was found to be inversely proportional to the velocity to the 0.12 power.

RI 6707. Preparation Characteristics of Coal From Barbour County, W. Va., by Albert W. Deurbrouck. 1965. 32 pp. 3 figs. Twelve samples from six Barbour County coalbeds—Bakerstown, Pittsburgh, Redstone, and Upper, Middle, and Lower Kittanning—were analyzed for this report. The samples collected were generally high sulfur content coals, frequently exceeding 3 percent in the raw-coal sample. Many of them could not be upgraded to acceptable metallurgical standards even by rigorous preparation procedures. The production of coal in the county in 1963 amounted to almost 3 million tons of which 44 percent was mechanically cleaned.

RI 6708. High-Temperature Heat Contents and Entropies of Two Zinc Sulfides and Four Solid Solutions of Zinc and Iron Sulfides, by L. B. Pankratz and E. G. King. 1965. 8 pp. Heat contents, measured above 298.15° K, and derived entropy increments are presented in tabular and equation form for the two crystalline forms of zinc sulfide (sphalerite and wurtzite) and for four solid solutions of iron and zinc sulfides having the compositions $Zn_{0.[illegible]}Fe_{0.[illegible]}S$, $Zn_{0.75}Fe_{0.250}S$, $Zn_{0.[illegible]}Fe_{0.[illegible]}S$, and $Zn_{0.[illegible]}Fe_{0.[illegible]}S$.

RI 6709. Analysis of Light Oils From Fluidized Carbonization, by J. G. Walters and C. Ortuglio. 1966. 25 pp. 4 figs. Analyses of light oils produced from the fluidized carbonization of coal at 485°, 550°, 600°, and 660° C are presented. Tar vapors from 485° C fluidized carbonization were thermally treated at 600°, 700°, and 800° C, and the analyses of light oils produced by this treatment are also presented. Procedures were developed for analysis of coal carbonization light oil by gas chromatography to permit a more definitive analysis than can be obtained by the conventional distillation procedure. An increase in low-oiling olefins, benzene, and toluene, a decrease in low-boiling paraffins, and little change in the remainder of the aromatics were observed with increased temperature of carbonization.

RI 6710. Stoppings for Ventilating Coal Mines, by Edward M. Kawenski, Donald W. Mitchell, George R. Bercik, and Angelo Frances. 1965. 20 pp. 15 figs. Tests were made in the Bureau's Experimental Coal Mine on stoppings similar to those used in operating coal mines to obtain information on air leakage through the face and the rupture strength of a stopping subjected to a pressure differential. Block stoppings were made from cinder, slag, and gravel aggregates with and without mortared joints and coatings. Sheet stoppings were uncoated brattice cloth and nylon or brattice cloth and expanded-metal-lath coated with asphalt, latex, mortar, or rigid urethane foam. Limited data were obtained on air leakage through stoppings subjected to simulated roof convergence and to shock forces created by the firing of an adjacent charge of explosive. The pressure differential required to rupture stoppings was determined. The research shows that coating the face of a stopping effectively reduces air leakage. Block stoppings, particularly those with mortared joints, are more resistant to pressure and shock forces than are sheet stoppings. Where ground movement is a factor, sheet stoppings leak less air than block stoppings.

RI 6711. Devitrification of a Lithium Disilicate Glass, by Henry M. Harris, John E. Kelley, and Hal J. Kelly. 1965. 14 pp. 7 figs. A glass containing approximately 17 percent lithia and 83 percent silica was investigated to establish a method of devitrifying cast and rolled shapes. Glass shapes with high strength were made by melting, forming, and rapid cooling of the composition, and the shapes subsequently were converted to a crystalline condition by heat treatment. The best devitrification schedule included rapid cooling of the glass to below 300° C, followed by reheating at a rate of 50° to 400° C per hour, depending on the size of the shape, followed by a dwell of 60 to 70 hours at 500° C and another cooling period of 15 hours at 800° C. Attempts to use faster heating rates or slow cooling to accomplish devitrification resulted in deformation of the shapes. The crystalline shapes had flexural strengths that averaged over 33,000 psi, achieved with an annealing time of 60 to 70 hours at 500° C.

RI 6712. Reduction of Ferrous Oxide (Wustite) at High Temperatures, by J. P. Hansen, T. N. Rushton, and S. E. Khalafalla. 1966. 25 pp. 12 figs. Wustite beds were reduced with carbon monoxide and mixtures of hydrogen and nitrogen in the temperature range 900° to 1,300° C to determine the effect of temperature, gas flow, and surface area on the rate of reduction to iron. The composition of the gas stream as it passed through the wustite bed was continuously measured. The change in composition was used to calculate the reaction rates. The velocity of reduction is dependent on the area of reacting interface and the driving potential of the gas as well as the exponential temperature effect. The reaction rate was independent of the gas velocity over the range of conditions studied.

RI 6713. Vapor Deposition of Cobalt-Tungsten Alloys, by J. G. Donaldson. 1965. 15 pp. 7 figs. Cobalt-tungsten binary deposits were formed in laboratory experiments by hydrogen reduction of the anhydrous mixed vapors of cobaltous chloride and tungsten hexachloride. The materials were sublimed in separately heated zones of a reaction tube and were transported in a stream of purified helium into the deposition section of the tube where the chloride gases were reduced to metal by a countercurrent flow of hydrogen. Heat treating of the near stoichiometric binary metallic deposits converted nearly all to the intermetallic compound Co_3W, however, small quantities of both cobalt and tungsten remained. Mechanical tests showed that the tensile strength of heat-treated 75 percent cobalt-25 percent tungsten deposits was twice as high as that of similarly treated deposits of cobalt.

RI 6714. Copper Extraction From a Low-Grade Ore by *Ferrobacillus Ferrooxidans*. Effect of Environmental and Nutritional Factors, by John D. Corrick and Joseph A. Sutton. 1965. 21 pp. 11 figs. The environmental and nutritional characteristics necessary for maximum copper extraction from a low-grade ore by *Ferrobacillus ferrooxidans* have been explored as have many of the limiting parameters. Criteria considered were oxygen consumption, copper extracted, soluble copper concentration, temperature, pH, particle size, nutrients, and other inorganic salt concentrations. A set of environmental and nutritional conditions were developed for *F. ferrooxidans* which supported cell reproduction and maximum microbial oxidation of a low-grade copper sulfide ore. Percolator tests conducted under these optimum conditions resulted in an 18-percent increase in the quantity of copper microbially extracted over that extracted under conditions considered to be standard. Manometric tests determined those extremes of environmental conditions and nutritional factors which were detrimental to the extraction of copper by *F. ferrooxidans.*

RI 6715. Corrosion Properties of Molybdenum, Tungsten, Vanadium, and Some Vanadium Alloys, by W. L. Acherman, J. P. Carter, C. B. Kenahan, and David Schlain. 1966. 59 pp. 17 figs. Molybdenum, tungsten, and vanadium were found to possess generally superior chemical and galvanic corrosion properties in many aqueous corrosive media at temperatures up to the boiling point. The corrosion resistance of vanadium in certain solutions was further improved by alloying it with such metals as columbium, tantalum, and titanium. Tungsten was susceptible to a type of crevice corrosion in mercuric chloride solutions, but no other instances of crevice corrosion were encountered. With few exceptions, molybdenum, tungsten, and vanadium were not adversely affected when coupled with dissimilar metals in galvanic corrosion experiments; in some cases one or both members of a couple were protected by contract. When exposed to aqueous ammonia spray at 60° C, all three metals were moderately attacked, but they were resistant in spray environments of substitute ocean water and ammonium dihydrogen phosphate.

RI 6716. Correlation of Yield Behavior in Electrorefined Vanadium With Interstitial Impurities, by E. A. Loria, G. H. Keith, and E. A. Rowe. 1965. 31 pp. 19 figs. The Bureau analyzed the effects of oxygen, nitrogen, and carbon on the tensile properties of electrorefined vanadium in terms of the Petch equation. The effects of the different impurities and grain sizes on the yield and flow stress between 273° and 77° K were studied.

RI 6717. Evaluation of a Formcoke for Blast Furnace Use, by P. L. Woolf. 1966. 6 pp. An investigation was conducted to evaluate the use of a formcoke as the total fuel in the Bureau of Mines experimental blast furnace. The formcoke performed very satisfactorily, and comparisons made with a metallurgical coke showed that the performance with the formcoke was somewhat superior under the experimental conditions used. Work done in cooperation with Blast Furnace Research, Inc.

RI 6718. Steam as a Coal Dewatering Aid During Vacuum Filtration: A Pilot Plant Study, by A. W. Deurbrouck. 1966. 8 pp. 3 figs. Four samples of Pittsburgh-bed coal, of various size consist and ash content, were dewatered in a pilot-size vacuum-disk filter partially enclosed with a steam jacket. Steam fed at 2.5 to 12.5 pounds per minute reduced the moisture content of the filter cakes from 2.8 to 13.8 percentage points more than normal vacuum dewatering. Approximately 1.5 pounds of steam was required to remove 1 pound of water.

RI 6719. Pilot Plant Flotation of Nonmagnetic Taconite and Semitaconite, by R. T. Sorensen and D. W. Frommer. 1966. 46 pp. 17 figs. Research and testing in a small-scale equivalent of a commercial flotation plant were completed on four low-grade, iron-bearing materials from the western Mesabi range. Closed circuit flotation of calcium-activated silica with fatty acid collector developed data for comparison with the batch process and highlighted problems not evident from previous bench testing. The four ore samples, containing from 27 to 39 percent Fe, were equally represented by nonmagnetic taconite and semitaconite type materials. Iron concentrates containing 6.0 percent, or less, SiO_2 were made from all four samples. Of the two material types the semitaconite was the more amenable to treatment, yielding iron recoveries of about 90 percent as compared with 70 to 80 percent for the other. Work done in cooperation with the Hanna Mining Co.

RI 6720. Thermal Reactions of Shale-Oil Components: Methylpyrroles, Butylpyrroles, and Isopropylpyrroles, by I. A. Jacobson, Jr., and H. B. Jensen. 1966. 50 pp. 13 figs. Thermal reactions of 1-methylpyrrole, 1-butylpyrrole, and 1-isopropylpyrrole were investigated by a flow method in the temperature range of 450° to 575° C. Those of 1-butylpyrrole and 1-isopropylpyrrole were also investigated in the 340° to 400° C range in a static system. The 1-substituted pyrroles isomerize by an irreversible reaction to 2-substituted pyrroles. A reversible isomerization reaction shifted the alkyl group from the 2- to the 3-position on the pyrrole ring. All of the isomerization reactions were homogeneous, unimolecular, nonchain, first-order reactions having similar mechanisms and transition states. There is decomposition and cleavage of the longer alkyl side chain when it is in either the 2- and 3-position giving, as products, pyrrole, 2- and 3-methylpyrrole, 2- and 3-ethylpyrrole, pyridines, and hydrocarbons. The decomposition reactions appear to be by free-radical mechanisms. Pyridine homologs are formed by the expansion of the alkylpyrrole: butylpyrrole produces pyridine, and isopropylpyrrole produces 3-methylpyridine. Approximate Arrhenius equations are given for the formation of the decomposition products. Work done in cooperation with the University of Wyoming.

RI 6721. Lurgi-Gasifier Tests of Pittsburgh-Bed Coal, by W. H. Oppelt, H. Perry, J. L. MacPherson, and E. J. Vitt. 1966. 31 pp. 1 fig. Two exploratory gasification tests of limited duration were made at Dorsten, Germany, with strongly coking Pittsburgh-bed coal in a fixed-bed pressure gasifier. To reduce the coking potential of the Arkwright coal, ash refuse from the gasification of Dorsten (Leopold) coal was added to prepare coal-ash mixtures which contained nominal 20 and 30 percent ash. Major adjustments in principal process variables at the beginning of the tests resulted in wide fluctuations in the rate of gas production, gas offtake temperature, and carbon dioxide concentration in the gas. Because a higher steam-to-oxygen ratio was used in the tests than was customarily employed for routine operation, gas production was lower, and steam and oxygen consumption was higher. After operating conditions had been improved, the results of a 12½-hour-long test with addition of sufficient ash refuse to obtain a nominal 30-percent ash concentration indicated that operation is feasible with this coal mixture using a fixed-bed pressure gasifier equipped with a rotating coal distributor and stirrer. Work done in cooperation with the Blaw-Knox Co.

RI 6722. The Matrix-Type Magnetic Separator, by Foster Fraas. 1966. 11 pp. 6 figs. A separator for minerals of low magnetic susceptibility and fine particle size in a water suspension is described. A ring-shaped matrix of ferromagnetic fragments rotating so as to pass successively through magnetic-field and field-free regions provides for the separation. Application is illustrated in the separation of hematite and ilmenite from quartz.

RI 6723. Use of a Diphenyl Ether Calorimeter in Determining the Heat of Fusion of Iron, by J. P. Morris, E. F. Foerster, C. W. Schultz, and G. R. Zellars. 1966. 14 pp. 5 figs. A diphenyl ether calorimeter for measuring high-temperature heat contents of ferrous alloys and iron- and steelmaking slags was constructed and calibrated with specimens of molybdenum, alumina, and platinum that were heated to temperatures ranging from 1,720° to 1,875° K. The standard deviation of the calibration measurements was 0.37 percent. By measurements of the enthalpy of delta and liquid iron, the heat of fusion of iron was found to be 3,298 ±100 cal per mole.

RI 6724. Heats of Formation of Beryllium Sulfate and Its Hydrates, by A. R. Taylor, Jr., B. B. Letson, and D. F. Smith. 1966. 8 pp. Heats of formation of beryllium sulfate and its hydrates at 298° K were $BeSO_4$, -287.55 ± 0.13 kcal/mole; $BeSO_4\cdot2H_2O$, -435.25 ± 0.13 kcal/mole; and $BeSO_4\cdot4H_2O$, -578.80 ± 0.13 kcal/mole. Previously existing values for the heats of formation of these compounds were based on rather old and somewhat uncertain measurements.

RI 6725. Face Ventilation in Underground Bituminous Coal Mines. Performance Characteristics of Common Jute Line Brattice, by R. W. Dalzell. 1966. 30 pp. 23 figs. The performance characteristics, efficiency, and operating pressure of jute line-brattice systems were studied under varying underground conditions; various fabric grades and installation methods were used. The test results indicate that line-brattice system efficiency is dependent upon the method of ventilation, the method of installation, porosity of fabric, and size of tight rib area.

RI 6726. Analysis of the Coal Industry in Boulder-Weld Coalfield, Colorado, by Raymond L. Lowrie. 1966. 79 pp. 25 figs. Coal deposits in the Boulder-Weld County coalfield in Colorado are analyzed in relation to economic factors governing the growth, stability, and competitive potential of the coal industry. Recoverable reserves, estimated to be 571 million tons, are discussed in detail, particularly those in the Erie and Frederick Quadrangles. Geology of the coal measures, quantity and quality of water resources, and chemical and physical properties of the coal are described. Coal production factors, including mining techniques and equipment, labor requirements, transportation facilities and rates, and markets, are considered for coal's position in competition with alternate fuels. Growth of the fuels market, through increasing thermal-electric power generation in the Denver Metropolitan Area, will stimulate coal production in Colorado. Reserves of the contiguous Boulder-Weld coalfield, if mined in a sustained, year-round, high-tonnage operation, could be used to supply much of that fuel demand.

RI 6727. Thermodynamic Properties of Vanadium and Its Compounds, by Alla D. Mah. 1966. 84 pp. The subject matter is divided into three main sections. The first summarizes basic metallurgical thermodynamic data for vanadium and its compounds. Included are heat capacities, entropies, heat contents, heats of vaporization, free energies of vaporization, vapor pressures, temperatures of phase changes, heats of phase changes, heats of formation, and free energies of formation. The second section, application of the basic data, contains heats, free energies, equilibrium pressures, and equilibrium constants of reactions of vanadium compounds with special emphasis on metallurgical reactions. The third section supplies basic thermodynamic data for elements and compounds associated with metallurgical reactions of vanadium. Sufficient auxiliary data have been included so that the calculated values contained in this paper may be followed or new calculations made for related metallurgical reactions.

RI 6728. Recovery of Manganese From Slag Formed by Selective Oxidation of High-Manganese Pig Iron, by E. G. Davis, F. E. Brantley, and E. C. Wright. 1966. 16 pp. 4 figs. Describes laboratory-scale experiments made to examine technical possibilities of reclaiming manganese from slags produced by oxygen lancing of high-manganese pig iron. Ferromanganese was added to molten pig iron to yield a 4- to 5-percent manganese hot metal, which simulated a product obtainable from the blast furnace. This was injected with oxygen to reduce the metal to 1 percent or less manganese and form a slag containing about 40 percent manganese. The molten slag was water quenched, treated with H_2SO_4, roasted at 660° C, and water leached to give soluble manganese and iron sulfates. The sulfates were precipitated as hydroxides, converted to the oxide form, and smelted to produce a standard ferromanganese containing 74.6 percent Mn and 0.01 percent P. As an alternate method of manganese recovery, a manganese cell feed was prepared from the leach solutions and electrolytic manganese was produced. Direct smelting of the high-manganese slag resulted in 74.2 percent ferromanganese meeting ASTM specifications except for phosphorus content. The high phosphorus content of the metal and high slag-to-metal ratio obtained made this approach unattractive. Work done in cooperation with the University of Alabama.

RI 6729. Laboratory Processes for Washing Tetrabromoethane From Mineral Particles, by James S. Browning, R. B. Tippin, and Thomas L. McVay. 1966. 10 pp. Organic heavy liquid adhering to or adsorbed on fine mineral particles can be effectively removed by a novel method embracing pulping or displacement washing with hot water alone or in combination with a detergent. Displacement washing with steam alone or in combination with a detergent also was effective for removing the heavy liquid. In tests of sized minus 48- plus 200-mesh mineral charges, both the hot water washing with detergents and detergent steaming effectively reduced the heavy liquid losses on the particles to about 0.2 pound per ton of mineral or less. Centrifuging of the wash solution permitted an almost complete recovery of heavy liquid from the solution as a pure heavy liquid product. Work done in cooperation with the University of Alabama.

RI 6730. A Cost Estimate of the Bayer Process for Producing Alumina, by Frank A. Peters, Paul W. Johnson, and Ralph C. Kirby. 1966. 23 pp. 7 figs. The Bayer process for treating Jamaican bauxite was evaluated from an economic standpoint, using standard estimating methods and published data, to present a reference point for cost estimates for nonbauxite alumina processes. The estimated operating cost for a plant producing 1,000 tons of alumina a day is $47.96 per ton of alumina when charging $8 per ton for bauxite and $2.30 per hour for direct labor. The estimated fixed capital cost is $46 million.

RI 6731. Effect of Certain Process Variables on Vapor Deposited Tungsten, by F. W. Hoertel. 1966. 15 pp. 17 figs. The effects of certain process variables on the grain size, grain type, and microhardness of vapor-deposited tungsten were established, and the near-optimum parameters and the efficacy for the vapor deposition process were determined. No significant change in the grain size or microstructure resulted from ultrasonic vibrations of the substrate during deposition, from variations in the hydrogen to tungsten hexafluoride ratio, or from small increases in reaction-chamber pressure. Near-optimum conditions were continuous deposition at atmospheric pressure, a deposition rate of 2-mils thickness/square inch of substrate area/hour, a temperature of 550° C, and a hydrogen to WF_6 ratio of 4:1. The addition, individually, of about 2 volume-percent of butane, 24 volume-percent of carbon dioxide, or 4 volume-percent of propane to the hydrogen and WF_6 mixture produced deposits with the finest grain size for each gas. A corresponding increase in microhardness accompanied the decrease in grain size. The addition of these gases did not alter the columnar microstructure found in vapor-deposited tungsten.

RI 6732. Calculation of the Average Ground Stress Components From Measurements of the Diametral Deformation of a Drill Hole, by Louis A. Panek. 1966. 41 pp. 3 figs. Describes a method of determining the existing stresses in a rock medium, by cutting free (core drilling) an annulus containing the drill hole. Expressions are derived from which one can calculate the stress ellipsoid—the three-dimensional change of stress, or the existing three-dimensional stress field, as the case may be. Study of these equations shows that the stress components in three dimensions can be determined by measurements in only two drill holes, and yields general principles that are useful in planning an efficient program of drilling and measurement.

RI 6733. Changing Water-Injection Profiles by Selective Plugging. A Field Study, by Thomas M. Garland. 1966. 46 pp. 30 figs. A study was made to determine the feasibility of changing the injection profile of water-input wells after water breakthrough at producing oil wells. A secondary objective was to study the particle size and quantity of plugging material required to change the input profile and the methods of applying these materials. Fifty-three injection wells were treated with various amounts and types of plugging materials, and the injection profile was definitely changed in most of the wells treated. Increased efficiency of water injection after treatment was indicated by tracer surveys and injection-well performance. There were some indications that the rate of water production was reduced and the rate of oil production was increased as a result of selective-plugging treatments, but it was found that an immediate change in the rate of oil and water production did not normally occur. In many cases, beneficial results from a treatment may never be observed in the rate of oil or water production due to the many factors that affect the performance of producing and injection wells. Work done in cooperation with the North Texas Oil and Gas Association.

RI 6734. Electric-Arc Furnace Reduction of Tin Slag for Production of Columbium-Tantalum-Bearing Alloy, by Willard L. Hunter and Oliver C. Fursman. 1966. 19 pp. 1 fig. Tin slags from Malaya and the Congo (Geomines) were reduced by carbon in a small, single-phase, steelmaking furnace, a larger three-phase, steelmaking furnace, and a three-phase, submerged-arc furnace. In all cases depleted slags were fluid and easily tapped from the furnace. However, unless diluted by iron additions, the metal product was a viscous, high-melting, heterogeneous mixture that could be removed from the furnace only by hand rabbling. In batch operations in the steelmaking furnaces, 90 percent of the columbium and 85 percent of the tantalum were recovered in the alloy. Although more than 90 percent of the columbium and tantalum were recovered by smelting tin slag in a submerged-arc, ferroalloy furnace, removal of alloy from the furnace hearth was extremely difficult. Alloy produced when smelting tin slag in either type of furnace, without iron addition, possessed both physical and chemical properties required for further processing.

RI 6735. Efficiency of Gas Displacement From a Water-Drive Reservoir, by D. C. Crowell, G. W. Dean, and A. G. Loomis. 1966. 29 pp. 6 figs. Presents the results of a laboratory investigation of displacement of gas by injection or imbibition of water into sandstone models under essentially isobaric conditions. A brief discussion of scaling requirements is included. The influence on residual gas saturation of independently varying the parameters of dimensional ratios of the porous media, rates and methods of flooding, surface tension, initial water saturation, and permeability is shown. Of these variables, increased initial water saturation and decreased surface tension reduced residual gas saturation significantly, whereas variations in flooding rate and dimensional ratios had no apparent effect. No correlation was evident between absolute permeability and residual gas saturation.

RI 6736. Reaction Rate of Uranium Metal With Uranium Tetrafluoride in Molten Fluoride Solutions, by Bernard Porter, R. E. Meaker, and T. A. Henrie. 1966. 11 pp. 4 figs. The rate of the heterogeneous reaction between high-purity uranium metal and uranium tetrafluoride in molten lithium fluoride was measured. The apparent heat of activation for the reaction is 16.91 kilocalories per mole of UF_4. A surface-controlled mechanism is suggested in which UF_4 is adsorbed on the uranium metal surface. Additional UF_4 reacts with adsorbed species and the metal site to form an activated complex that decomposes to the product UF_3. The reaction is an important source of metal loss in the electrowinning of uranium metal.

RI 6737. Tin-Lode Investigations, Cape Mountain Area, Seward Peninsula, Alaska, by John J. Mulligan (with Section on Petrography by Walter L. Gnagy). 1966. 43 pp. 9 figs. The Bureau investigated the tin deposits of the Cape Mountain area during July and August 1962 to test the effectiveness of detrital-cover sampling in permafrost areas as a relatively cheap and simple means of guiding mine development and exploration. Results indicate that systematic detrital-cover sampling can be used effectively to delineate obscure deposits with sufficient accuracy to permit sampling with minimum of trenching or drilling. Extensions of known outcroppings were traced in sufficient detail to guide lode sampling and several previously unknown tin-bearing lodes were found and sampled. Lode sampling was limited to the minimum needed to establish the reliability of detrital-cover sampling results. The results of previous lode and placer investigations are summarized and detrital-cover sampling methods and results are described in detail.

RI 6738. Reduction-Volatilization Processes for Recovery of Manganese From Ores, by W. L. Falke and A. A. Cochran. 1966. 19 pp. 11 figs. Procedures in which manganese compounds are reduced and the metal is volatilized and selectively condensed were investigated. More than 95 percent of the manganese was recovered from high-melting-point ores whether vacuum volatilization or atmospheric pressure volatilization was used, but neither process is economically attractive under present price-cost conditions.

RI 6739. Critical Path Planning and Scheduling Applied to Mining Operations, by Adrian J. Mathias and Donald E. Redmon. 1966. 48 pp. 18 figs. Illustrates critical path planning and scheduling techniques as applied to typical mining operations. Detailed examples of arrow diagraming and computer-oriented applications of critical path methods are given. Program Evaluation and Review Technique (PERT) is discussed briefly in comparison to the Critical Path Method (CPM).

RI 6740. Preparation Characteristics of Coal From Buchanan County, Va., by Albert W. Deurbrouck. 1966. 49 pp. 3 figs. Twenty-one samples were collected from 9 coalbeds in the county. Of these samples 13 were of metallurgical quality as received, and 8 required some upgrading to provide acceptable products. In general, the coals were of low to medium ash and sulfur content and ranked as medium- to high-volatile bituminous. In 1963, production in the county was in excess of 13 million tons, of which 2.2 million tons were mechanically cleaned.

RI 6741. The Mass Spectra and Correlations With Structure for 2-*t*-Butyl-, 3-*t*-Butyl-, 2,5-di-*t*-Butyl-, and 2,4-di-*t*-Butylthiophenes, by Norman G. Foster. 1966. 30 pp. 9 figs. The mass spectra of four tertiary butyl substituted thiophenes are reported. A comparison and contrast with earlier structure correlations made by ARI-RP48 mass spectroscopists is presented. The fragmentation routes of these types of molecules are discussed and explained in terms of existing theories in mass spectrometry. Low ionization voltage data are presented to support the mechanistic picture developed. Structures are inferred about some of the ions, and these are correlated with existing theories. Metastable peaks in the spectra are used to support the fragmentation paths. The presence of doubly charged ions in the spectra is noted and the possible implications toward mechanisms discussed. The general picture of simple, small fragments leaving the ion moiety upon further fragmentation is developed in detail. Some suggestions are presented for further work utilizing isotopically labeled molecules to establish firmly the general picture of fragmentations of the alkylthiophenes.

RI 6742. Electrowinning Tungsten in Halide and Phosphate Electrolytes, by John M. Gomes, Kenji Uchida, and Don H. Baker, Jr. 1966. 9 pp. 3 figs. Two molten salt systems were evaluated as electrolytes for the repetitive recovery of tungsten from tungsten oxide (WO_3) made by calcining commercial-grade ammonium paratungstate. Using a sodium chloride-sodium fluoride-potassium aluminum tetrafluoride electrolyte at 800° C, 1 pound of 99.8 percent tungsten was recovered for each 2.7 killowatt-hours of energy consumed. The metal contained 1,100 ppm carbon, was in dendritic masses of spherical grains, and had an apparent bulk density of 5.41 g/cm^3. Tungsten of 99.9-percent purity was won from a sodium pyrophosphate-sodium tetraborate-sodium chloride electrolyte at 1,000° C; 6.0 kilowatt-hours of energy was consumed for each pound of metal recovered. The metal contained 120 ppm of carbon, was in dendritic masses of hexagonal acicular crystals, and had an apparent bulk density of 7.25 g/cm^3. Each metallic impurity—aluminum, calcium, copper, iron, nickel, and silicon—in the two tungsten products was 16 ppm or less.

RI 6743. Hydraulic Transport of Coal, by Arnold P. Pipilen, Murray Weintraub, and A. A. Orning. 1966. 31 pp. 16 figs. In a study of the principal factors affecting the transport of coal-water mixtures through a centrifugal pump and a pipeline, the interrelation between solids concentration, velocity, and pressure drop was established for a bituminous lump coal (minus 2 inch) in concentrations of up to 48 weight-percent. An optimum concentration was found to exist for maximum capacity of a given pipeline and for minimum energy requirements per ton of coal. Coal size degradation by particle fracture took place in the pump; abrasion and attrition to form fines took place in both pump and line. A novel system of studying flow of solid-liquid mixtures in pipelines by the determination of relative sound intensities was developed.

RI 6744. Extraction of Alumina by Leaching Melted and Quenched Anorthosite in Sulfuric Acid, by H. Leitch, H. G. Iverson, and J. B. Clemmer. 1966. 32 pp. 6 figs. Investigates melting, quenching, and sulfuric acid leaching on alumina from mixtures of albite and anorthite and from anorthosites containing 26 to 32 percent alumina. Variations in pouring temperature, quenching, and leaching conditions were studied with respect to the extraction of alumina and impurities. Virtually all of the alumina was dissolved by leaching melted and quenched California anorthosite in boiling 16-percent sulfuric acid solution for 15 to 30 minutes. The leach solutions were readily separable from the solid residue by conventional thickening and filtration techniques. Only 2 to 5 grams of SiO_2, Fe_2O_3, or CaO dissolved per 100 grams of alumina. The quantity of SiO_2 in solution varied inversely with the duration of the leach and with the concentration of the H_2SO_4 solution used. Melted and quenched Wyoming and Minnesota anorthosites with SiO_2:CaO weight ratios of 4.3 and 3.2, respectively, were less amenable to sulfuric acid leaching than California anorthosite with an SiO_2:CaO weight ratio of 5.3. However, excellent results were obtained on the Wyoming and Minnesota anorthosites by the addition of SiO_2 to these materials before melting, in quantities sufficient to adjust the SiO_2:CaO weight ratios of the furnace charges to between 4 and 6.

RI 6745. Experimental Longwall Mining in a Pennsylvania Anthracite Mine (in Two Parts). 2. Use of a Shearer Loader, by Wilbert T. Malenka and Robert J. Brennan. 1966. 12 pp. 6 figs. In its search for a highly productive mining system for anthracite beds pitching from 10° to 20°, where conventional mobile equipment cannot be used, the Bureau initiated a longwall project by introducing a shearer drum cutter loader of European origin. Because of the undulating nature of the roof and floor and changing bed thicknesses, the machine proved inflexible and extra work was required in lifting bottom coal and blasting top coal. Part 1, Use of Yielding Steel Props, was published in 1964 as RI 6378. Work done in cooperation with the Glen Alden Coal Co.

RI 6746. Sympathetic Detonation of Ammonium Nitrate and Ammonium Nitrate-Fuel Oil, by R. W. Van Dolah, F. C. Gibson, and J. N. Murphy. 1966. 34 pp. 19 figs. An investigation was made of the distances over which sympathetic detonation of ammonium nitrate (AN) and ammonium nitrate-fuel oil (AN-FO) might be expected. Large-scale gap tests used two types of AN-FO donor charges in three sizes with AN, both at ambient and elevated temperatures, and AN-FO acceptor charges. Donor sizes were varied to test the validity of a scaling law commonly used in quantity distance tables. The up-and-down experimental design was chosen to determine the 50-percent initiation point efficiently. The acceptor charges were instrumented to indicate initiation and to determine detonation velocity. Other electronic techniques for measuring the rate of growth, stability of detonation, and detonation pressures were employed. Air shock and fragment velocities between charges were measured by electronic and photographic methods, and determination of side-on air-blast pressures and impulse duration were made for about half the shots. Separation distances between donor and acceptor were found to be larger than anticipated both for the AN and AN-FO. With AN-FO acceptors and a 16-gage steel faced donor, one initiation occurred at a separation of 53 feet or nearly 16 charge diameters; with AN, initiation occurred at 4 to 5½ charge diameters. Work done in cooperation with the Manufacturing Chemists Association.

RI 6747. In-Situ Measurements of Rock Deformation in a Vein-Type Deep Mine (in Two Sections). 1. Instrumentation and Techniques, 2. Analysis of Measurements in the Star Mine, Burke, Idaho, by Galen G. Waddell. 1966. 47 pp. 24 figs. Dilation and contraction of the rock surrounding horizontal access openings of a deep mine were analyzed during stope advance to determine what type of measurements, made with relatively inexpensive instrumentation, would best reflect the rock behavior. A variety of instruments, mostly mechanical extensometers, were used. Detailed descriptions are given of down-the-hole extensometers, floating rockbolt clusters, transit surveys, and other instruments and measuring techniques. Although all of the radial-deformation-rate graphs illustrated useful rock behavior data, the most informative graphs were compiled from data procured with the radial extensometers that penetrated, to various depths, the rock around the access openings. An analysis is given of measurement data on the rock around lateral drifts and across and adjacent to the nearly vertical vein of the Star mine, Burke, Idaho. Several useful relationships were found between the rock deformation rate and the stoping process. Information was produced on the elastic state of rock around an underground opening, effectiveness of stope support, rheology of rock, zone of influence around stopes, effectiveness of rockbolts, axis of maximum strain in a plane perpendicular to the long axis of the lateral, and other phenomena. This information could be of particular value in determining location, design, and support of underground openings.

RI 6748. Flammability Characteristics of Selected Halogenated Hydrocarbons, by H. E. Perlee, G. H. Martindill, and M. G. Zabetakis. 1966. 12 pp. 2 figs. Autoignition temperatures and limits of flammability of nine halogenated hydrocarbons in atmospheres of air, oxygen, and nitrogen tetroxide were measured in a modified standard autoignition apparatus and limit-of-flammability apparatus previously developed at the Bureau of Mines. Of the nine halogenated hydrocarbons investigated—bromochloromethane, bromotrifluoromethane, bromochlorodifluoromethane, 1,1,2-trichlorotrifluoroethane, 1-bromo-1-chloro-2,2,2-trifluoroethane, dibromodifluoromethane, 1,2-dibromo-1,1,2,2-tetrafluoroethane, 1,1,1,3,3-pentachlorotrifluoropropane, and 1-bromo-2,4-dichloro-1,2,3,3,4-hexafluorobutane—two formed flammable mixtures with nitrogen tetroxide and six with oxygen; none formed flammable mixtures with air. Three of the halogenated hydrocarbons formed no flammable zones with any of the three oxiding atmospheres. For those halogenated hydrocarbons that supported combustion in oxygen atmospheres, explosion pressures developed during constant-volume burning of mixtures near the middle of the flammable zone were observed to range from about 6 psig for dibromodifluoromethane to 158 psig for 1-bromo-1-chloro-2,2,2-trifluoroethane. In all cases, the calculated burning velocities of these mixtures were less than 8 in/sec. Work done under Air Force Propulsion Laboratory Delivery Orders.

RI 6749. Effects of Certain Mineralogical Features on Phosphate Recovery, by J. W. Town, W. G. Gruzensky, and P. E. Sanker. 1966. 12 pp. 5 figs. The Bureau of Mines conducted phosphate beneficiation studies to determine the influence of mineralogical and textural features on the recovery of phosphate from select bed and composite samples representing different phosphate rock types of the western Phosphoria Formation. Batch heavy-liquid tests showed that ore grade, pellet size, and type of interstitial material were significant parameters affecting concentrate grade and recovery. Recoveries at acid grade (31.5 percent P_2O_5) ranged from 98 to 56 percent. Liberation was essentially complete at 28 mesh, and recoveries tended to drop when overgrinding occurred.

RI 6750. Rates of Adsorption of Methane on Pocahontas and Pittsburgh Seam Coals, by L. J. E. Hofer, James Bayer, and Robert B. Anderson. 1966. 13 pp. 3 figs. Determines rates for adsorption and desorption of methane as a function of particle size and temperature, using coals from the Pocahontas No. 3 seam (lvb) from the Bishop mine of western Virginia, and the Pittsburgh seam (hvab) from the Pursglove No. 15 mine of northern West Virginia. For a given coal sample and temperature, the rate curves for adsorption and desorption are essentially the same when expressed on a fractional approach to equilibrium basis. The rates of adsorption and desorption increased eightfold as the particle size was decreased from 6-8 to 270-325 mesh per inch. The adsorption process appears to be diffusion controlled. Rate of sorption processes increased with increasing temperature; however, the amount adsorbed at equilibrium decreased.

RI 6751. Petrographic and Flotation Studies on the Meade Peak, Idaho, Phosphate Samples, by J. W. Town. 1966. 16 pp. 2 figs. Petrographic classification and flotation studies were made to determine if acid-grade concentrates could be obtained from individual and composite samples from the Meade Peak member of the Phosphoria Formation, Idaho. The petrographic studies were made to determine the effect of compositional features on concentration of phosphates. The ore grade, ovule size, and clay content were the main features affecting grade and recovery of phosphate. Flotation results on roasted ore with a tall oil emulsion scheme showed that beds containing over 10 percent P_2O_5 could be beneficiated and composited with the two high-grade beds to produce a composite concentrate containing 31.9 percent P_2O_5 at 84.3 percent recovery. Treatment of these intermediate-grade phosphate beds by flotation increased ore reserves over 200 percent and increased the ore-to-waste ratio in the ore zone from 1:5.7 to 1:0.27.

RI 6752. Analyses of Some Crude Oils From Fields in West Texas, by C. M. McKinney and Ella Mae Shelton. 1966. 163 pp. Bureau of Mines routine crude oil analyses are reported for 286 samples from the major producing geological formations of 161 fields in west Texas. Tables are included which show the geographical and geological source of the samples, their general characteristics, and the analytical data determined and computed for each sample. A brief discussion covers use of the data to estimate the types of hydrocarbons present in distillate fractions obtained during the analysis.

RI 6753. Direct Determination of Oxygen in Coal, by R. F. Abernethy and F. H Gibson. 1966. 21 pp. 1 fig. A modified Unterzaucher method was applied to the direct determination of oxygen in coal. Coal samples were pyrolyzed in a nitrogen atmosphere, and the gaseous oxygen compounds liberated were converted to carbon monoxide by a platinized-carbon catalyst at 900° C. After passing over heated copper and through a tube containing soda-asbestos and magnesium perchlorate, the purified carbon monoxide was oxidized to carbon dioxide by iodine pentoxide—liberating an equivalent amount of iodine. The iodine was titrated with 0.02 N sodium thiosulfate; in a few tests the weight of carbon dioxide produced was determined. Direct oxygen determinations of coal included organic oxygen from the coal substance, plus a small quantity of inorganic oxygen derived principally from carbonate minerals and from combined water of silicates in the mineral matter. The influence of mineral matter on the direct oxygen determination was investigated by testing (1) untreated coal, (2) demineralized coal from which most of the mineral matter except pyrite was removed by treatment with hydrofluoric and hydrochloric acids, and (3) coal samples treated with dilute hydrochloric acid.

RI 6754. The Thermodynamic Properties of the ZnO-Fe_2O_3-Fe_3O_4 System at Elevated Temperatures (in Two Parts). 1. The Thermodynamic Properties as Related to the Spinel Structure, by R. L. Benner and H. Kenworthy. 1966. 44 pp. 16 figs. Describes an investigation of the ZnO-Fe_2O_3-Fe_3O_4 system at 1,000°, 1,300°, and 1,400° C, with oxygen pressures between 1.0 and 1×10^{-4} atmospheres. The results, divided into the thermodynamic properties as related to the spinel structure and the thermodyamic properties as related to zinc concentrate roasting, were used to calculate the activities of ZnO, Fe_2O_3, and Fe_3O_4 within the spinel solid solution region of the ternary system, and the pseudobinary activities of $ZnFe_2O_4$ and Fe_3O_4. The activities of both systems show large positive deviations from Raoult's Law, especially at high Fe_3O_4 concentrations. The free energies, the enthalpies, and the entropies of mixing for the binary system were calculated from the binary activities, and the entropies of mixing were compared with two statistical models, one representing the mixing of a normal with an inverse spinel. The binary entropy of mixing seemed to be better represented by the latter statistical model, indicating that the tetrahedral and octahedral cations of the reactants tend to remain in the product, even at the high temperatures of the study. This comparison also indicated that the cations of the components are the major contributing factors to the thermodynamic properties.

RI 6755. Carbon Reduction of Chromite, by Willard L. Hunter and Danton L. Paulson. 1966. 20 pp. 9 figs. Studies the effect of temperature upon the reduction of chromite by carbon and the relative reducibility of chromites as a function of their composition. Ferric oxide was also studied to provide comparative data. Based on the temperature at which chromite was 50 percent reduced in 15 minutes, Transvaal chromite reduced most easily, followed by Mouat, then by Kampersian, and finally by Rhodesian DFC material. Statistical analysis of test results indicated that the ferric iron content of chromites affects their reduction behavior more than any other constituent.

RI 6756. Carbon Deposition for Thermal Recovery of Petroleum. A Statistical Approach to Research, by Harry R. Johnson and Edward L. Burwell. 1966. 21 pp. 5 figs. The carbon deposition characteristics of a high-gravity, paraffin-base crude oil were studied in the laboratory. The results indicate that a fuel supply adequate to initiate a combustion wave can be deposited in high-gravity-oil reservoirs. These results are significant because there has been considerable doubt whether oils over 35° API gravity are able to deposit sufficient fuel. Considered in these studies were the effects of air flux, temperature, initial oil saturation, and time on carbon deposition. Conditions that maximized carbon deposition in the laboratory and an understanding of the nature of carbon formation are shown by graphical interpretation of the data. Statistical techniques were used to design and analyze the results of the retort tests. For the same amount of laboratory work, this approach yields more information about the systems that were studied than the classical method of research presently used in many laboratories. In addition, the accuracy of calculating the effect of each variable on carbon deposition is twice that of the classical approach. This report develops the statistical approach to research without complex mathematics, thus enabling the reader to grasp the concept of how statistics can be applied to study many complicated problems.

RI 6757. High Energy-Rate Forging and Extrusion and the Effect on Structure and Properties, by Jack G. Croeni, John S. Howe, Jr., and Haruo Kato. 1966. 31 pp. 18 figs. Studies the influence of high energy-rate deformation on the structures and properties of low-carbon steel, stainless steel, titanium, titanium-6 percent aluminum-4 percent vanadium, beryllium, molybdenum, and tungsten. The purpose of this study was to determine relative formability, the effect of energy and temperature on metalworking parameters and resulting structures, and the properties of materials formed by this technique. Forming techniques were limited to upset forging and direct extrusion on pneumatic-mechanical forming machines. Results show that considerable grain refinement can be achieved by careful control of deformation and forming temperature by high-energy techniques. Significant improvements in strength were observed as a result of this refined structure Approximate deformation resistance as a function of temperature was determined for a variety of materials.

RI 6758. Ignition and Control of Burning of Coal Mine Refuse, by James W. Myers, Joseph J. Pfeiffer, Edwin M. Murphy, and Franklin E. Griffith. 1966. 24 pp. 23 figs. Laboratory experiments showed that air permeates more readily segregated than nonsegregated refuse and that air permeability is greater in coarse than in fine particle refuse. Minus 3½-inch refuse ignites spontaneously more readily than minus ¼-inch refuse. The burning of a 1,000-pound conical coal pile was controlled by capping with an 18-inch-thick layer of minus ¼-inch refuse containing 37 percent combustible. In field trials, the burning of refuse at operating mines was controlled by capping with a layer of fine refuse. Water, applied as a spray or by injection, quenched surface flames and cooled the burning waste. Inspection of refuse piles at operating mines showed that the spontaneous ignition tendency is affected by the exposed surface relative to the total volume and the segregation of particles during dumping.

RI 6759. Use of a Continuous Borer in Mining Pitching Anthracite Beds, by W. H. Tavenner and J. T. Schimmel. 1966. 25 pp. 7 figs. Describes the use of a continuous borer to mine an anthracite bed 30 feet thick on a pitch of 15° to 45°. The continuous borer operated on a coal floor that was frequently soft because of heaving. The continuous borer could not bore openings on a grade exceeding 27 percent (15° pitch). Because 15° was also the lower limit of the pitch of the bed, the continuous borer was used only to drive gangways. This machine virtually filled the workplace, leaving insufficient space to place heavy-duty timber and cushioning material between the timber and coal back to allow for normal expansion of the uncut coal. The lightweight yieldable steel arch against the coal back gave inadequate support to control convergence, which in a disturbed area sometimes occurred with explosive violence. This exposed the machine operator to a hazardous condition and caused the company to discontinue the use of the continuous borer. Work done in cooperation with the Raven Run Coal Co.

RI 6760. Computer Techniques for Calculating Shape Factors and Channel Volumes From a Potentiometric Model for Use in Waterflood Performance Calculations, by R. V. Higgins, D. W. Boley, and A. J. Leighton. 1966. 49 pp. 9 figs. Presents a computer program for calculating the shape factors and volumes of cells from a potentiometric model, using coordinates of the intersections of the stream lines and equal potentials and a few additional coordinates. Shape factors are used in flow computations when the geometry is complicated. The program also includes computer instructions to divide the channels into cells of equal volume to obtain the shape factor for each of these equal volume cells. An illustrated example using the potentiometric model for the waterflood of a seven-spot well-spacing pattern is presented. The information contained in the report is of value not only to those allied to the subject but also to others, because many of the techniques can be conveniently used in formulating other computer programs.

RI 6761. Equivalence of Coal Dust and Methane at Lower Quenching Limits of Flames of Their Mixtures, by J. M. Singer, A. E. Bruszak, and J. Grumer. 1966. 14 pp. 6 figs. Quenching distances for flames of methane-coal dust mixtures were determined with air and oxygen-enriched air. Coals used were Pittsburgh, Sewell, and Pocahontas No. 3. Quenching distances were greater for flames of hybrid mixtures of coal dust and methane than for methane flames of corresponding stoichiometry. From the data of quenching distances and methane-coal dust concentrations were calculated the quenching equivalence, which is the increase in coal dust concentration required to maintain a given quenching distance value as the methane concentration decreases. These equivalences could be useful in identifying hazardous methane-coal dust mixtures in mines.

RI 6762. Recovery of Manganese Sulfate Crystals From Solution by Submerged Combustion Evaporation and by Thermal Crystallization, by H. C. Fuller. 1966. 30 pp. 6 figs. Submerged combustion and inverse solubility methods were investigated as promising alternative means for crystallizing manganese sulfate from solutions produced by leaching manganese ores with either sulfuric acid or sulfur dioxide. Evaporation of water from typical manganese sulfate solutions by submerged combustion techniques enabled production of a slurry containing 32 to 39 pct $MnSO_4 \cdot H_2O$ crystals suspended in a saturated solution of manganese sulfate. Such a slurry required further processing by thickening or filtration and drying to produce crystals of $MnSO_4 \cdot H_2O$. In a second approach semicontinuous processing of manganese sulfate solutions by thermal crystallization under pressure effected a recovery of 94.5 pct of the $MnSO_4 \cdot H_2O$ as dry free-flowing crystals. Treatment of a solution containing about 100 grams manganese per liter at 189° C produced a "barren" solution containing only 1.9 grams manganese per liter. Calculations made on comparable manganese sulfate solutions show that the heat requirement of the thermal crystallization method was about one-third to one-fourth that of the submerged combustion method.

RI 6763. Derivation and Application of a Material Balance Equation for Partly Depleted Oil Reservoirs Repressured With Gas, by Alton B. Cook and F. Sam Johnson. 1966. 16 pp. 6 figs. A material balance equation was derived for calculating (1) the initial oil volume and (2) the relationship of average reservoir pressure to net gas in storage in reservoirs used for natural gas storage operations. The equation is also applicable to secondary-recovery operations where reservoirs are completely repressured and gas cycled. This equation minimizes two probable sources of error in conventional material balance calculations; namely, inaccurate measuring of and accounting for produced gas, and differences between true reservoir pressure and average reservoir pressures as derived from bottom-hole pressure measurements. A new procedure is presented for calculating water encroachment. By solving the conventional material balance equation and the derived equation for gas storage simultaneously, the values for initial oil in place and net water encroachment can both be determined.

RI 6764. Magnetic Roasting of Iron Ores With Ferrous Scrap, by M. M. Fine and Charles Prasky. 1966. 23 pp. 7 figs. Describes the theory, experimental procedures, and the results obtained to date in the development of the Bureau's process for magnetically roasting iron ores using scrap iron as a means of reduction. Since magnetic separation is an operational step common to magnetic taconite plants, the preliminary research studies emphasized only the novel magnetic roasting step. The studies included the use of automobile scrap, ferrous reductants such as borings and turnings, and pereduced pellets. Technical feasibility of the process was demonstrated both on a bench and pilot scale. Quality magnetic concentrates with recoveries of over 90 percent were obtained from a direct shipping ore containing 59.5 percent Fe and from fine-grained semitaconites with about 30 percent Fe.

RI 6765. Improvement of a Commercial Hypereutectic Aluminum-Silicon Master Alloy, by R. R. Lowery, J. G. Croeni, and H. Kato. 1966. 25 pp. 16 figs. Describes development of hypereutectic aluminum-silicon alloys which had better commercial properties than the unmodified hypereutectic alloy. A commercial aluminum-20 weight-percent silicon master alloy was selected as a binary base for improvement. The primary silicon grains were reduced from ASTM 4.5 to ASTM 8.5 by the use of phosphorus and phosphorus compounds. The remaining eutectic matrix was refined by sodium metal additions of 0.2 weight-percent. Solid solution strengthening of the alpha aluminum was obtained by adding 2 percent copper and 0.5 percent magnesium; also, 1 percent nickel was added to harden the alloy. Optimum thermal treatment consisted of a solution treatment for 10 hours at 480° C with hot water quench, followed by aging for 6 hours at 175° C. The final alloy exhibited a Rockwell B hardness of 75 ± 2 in the heat-treated condition. The ultimate tensile strength was 39,500 psi with no recordable elongation. The coefficient of linear thermal expansion was 20.4×10^{-6} per ° C in the temperature range 20° to 300° C. No wear resistance data were collected.

RI 6766. Flammability Characteristics of Trichloroethylene, by H. E. Perlee, G. S. Scott, and G. H. Martindill. 1966. 8 pp. 3 figs. The concentration limits of flammability and autoignition temperatures of trichloroethylene in atmospheres of air, oxygen, and nitrogen tetroxide have been determined in a spherical vessel. The autoignition temperatures of TCE in atmospheres of air, oxygen, and nitrogen tetroxide were found to be 419°, 396°, and 221° C, respectively. The flammability zones of TCE-air, TCE-oxygen, and TCE-nitrogen tetroxide mixtures at 100° C were found to be 10.5 to 41, 7.5 to 91, and 13.5 to 69 volume-percent TCE, respectively. In addition maximum combustion pressures of 50 psig and 140 psig were recorded for constant volume combustion of the lower limit mixtures of trichloroethylene in air and oxygen, respectively.

RI 6767. Sampling and Coking Studies of Coal From the Kukpowruk River Area, Artic Northwestern Alaska, by Robert S. Warfield, W. S. Landers, and Charles C. Boley. 1966. 59 pp. 14 figs. Eight samples of high-volatile bituminous coal, each large enough for a study of its coking properties, were obtained from a location along the Kukpowruk River, Arctic Northwestern Alaska. Bench scale and pilot plant carbonization studies with several patterns of coal blending were conducted. The data from these tests were compared to data from similar tests on a coking blend used by the Kaiser Steel Corp. at Fontana, Calif. The majority of the samples representing the 20-foot seam was found to have significant coking properties and produced coke approaching metallurgical quality when blended with selected coking coals. Although oxidation effects were evident in the samples representing upper portions of the seam, it appears that the whole seam could be used.

RI 6768. Some Generalized Probability Distributions With Special Reference to the Mineral Industries (in Five Parts). 5. Theoretical Confirmation and Applications, by Robert M. Becker. 1966. 60 pp. 3 figs. Part 5, the last of this series, deals with the theoretical confirmation and application of results developed in parts 1 and 2. The bulk-sampling variances of Hassialis and Kassel and Guy are compared with those in part 2, both as to formulation and as applied to ores and coal. The results provide confirmation for much of the development in part 2. Examples are presented for determining the reliability of bulk samples with respect to various measurable characteristics. These characteristics include, for example, assays for elements or compounds and particle surface area. The bulk samples considered consist either of a given weight, a given volume, or a given number of particles. In addition to problems of sample reliability, some of these examples may also be applicable to quality control. Several possible applications of results developed in parts 1 and 2 are outlined. These include tests for random data, degree-of-mixing indices, and particle-fineness indices.

RI 6769. The Thermodynamic Properties of the ZnO-Fe_2O_3-Fe_3O_4 System at Elevated Temperatures (in Two Parts). 2. The Thermodynamic Properties as Related to Zinc Concentrate Roasting, by R. L. Benner and H. Kenworthy. 1966. 16 pp. 5 figs. A compound stability diagram was constructed for the Zn-Fe-S-O system to show the phases that should be thermodynamically stable at various temperatures, oxygen pressures, and SO_2 pressures. The diagram was demonstrated to have good qualitative value for predicting stable phases that may, in turn, be related to the recovery of zinc in the leaching phase of the electrolytic zinc process. The study showed that roasting temperature is the most significant variable in preventing roaster formation of zinc ferrite, which is directly related to subsequent extraction of zinc in the leaching step. Part 1 was published as RI 6754.

RI 6770. A Streak Camera Method for Measuring Dynamic Equation of State Properties of Rock, by Lippe D. Sadwin, Norman M. Junk, and Wilbur I. Duvall. 1966. 14 pp. 6 figs. Describes a high-speed streak camera method for making equation of state measurements (shock and particle velocities) on samples of rock under dynamic loading conditions. Experimental data are given for tests on 12 samples representing 5 rock types. Analysis of these data shows that the method is practical and that good reproducibility of results can be obtained. The pressure range covered in the tests was from 1 to 50 kilobars.

RI 6771. Consolidation and Mechanical Properties of Electrowon Molybdenum, by E. A. Loria and J. M. Kees. 1966. 18 pp. 14 figs. High-quality sheet of electrowon molybdenum was attained by a sequence of procedures on pressed and arc-melted crystalline powders. These procedures included high-temperature, high-vacuum sintering treatments and the use of metal deoxidizers instead of carbon to improve the mechanical properties of the molybdenum sheet. Rolled sheet 60 mils thick was evaluated by tensile and bend tests, hardness measurements, microstructures, and recrystallization treatments. After stress relieving, yield strength ranged from 85,000 to 110,500 psi (0.2-percent offset) and ultimate strength ranged from 87,200 to 117,250 psi with 4.5- to 25-percent elongation observed for arc-melted sheet, and 5.0- to 28-percent elongation observed for powder metallurgy sheet. In room temperature blend tests, the sheet yielded plastically, indicating that the ductile-brittle transition point was below room temperature. The diamond pyramid hardness (DPH) of the molybdenum sheet changed from 214 to 293 DPH for the stress-relieved condition to 177 to 185 DPH for the fully recrystallized condition. The brittleness of the recrystallized molybdenum, reported by other investigations as characteristic of sheet prepared from commercial-grade hydrogen-reduced powders, was not in evidence. Recrystallized tensile specimens pulled at room temperature had an average elongation of 31 percent.

RI 6772. Demonstration and Evaluation of Five Methods of Secondary Backfilling of Strip-Mine Areas, by F. E. Griffith, M. O. Magnuson, and R. L. Kimball. 1966. 7 pp. 13 figs. Cost data are given for five methods of secondary backfilling of strip mines previously partially backfilled. The operations were conducted in north-central Pennsylvania; an average of 600 linear feet of highwall was backfilled in each trial. Major obstacles and the relative merits of the methods are discussed. Work done in cooperation with the Department of Mines and Mineral Industries and the Department of Forests and Waters, Commonwealth of Pennsylvania.

RI 6773. Explosion Hazards of Ammonium Nitrate Under Fire Exposure, by R. W. Van Dolah, C. M. Mason, F. J. P. Perzak, J. E. Hay, and D. R. Forshey. 1966. 79 pp. 40 figs. An attempt has been made in this investigation to define the conditions under which ammonium nitrate (AN) might detonate as a result of involvement in fire. The initiation of detonation by shocks derived from explosives or from projectile impact was investigated as a function of temperature and charge diameter. A new technique was devised to investigate the burning of raw and contaminated AN under pressure. No transition to detonation in AN was obtained in the burning experiments. The critical diameter for detonation of fertilizer-grade AN was found to be quite small when the AN was at temperatures just below melting point; this indicates that initiation of detonation may be less difficult at elevated temperatures but such initiation by gas-phase detonation was shown to be unlikely. Transition from burning to detonation was obtained with AN intimately mixed with fuels that included polyethylene, paper, and fuel oil when these were contained in vessels with restricted vents. However, the experimental results supported by an analytical study indicate that the initiation of detonation in AN from fire exposure in normal storage and from transportation incidents is quite improbable. The detonation of AN in recent incidents more likely may have resulted from the effects of adjacent explosions. Work done in cooperation with the Manufacturing Chemists' Association, Inc.

RI 6774. Effect of Charge Weight on Vibration Levels From Quarry Blasting, by James F. Devine, Richard H. Beck, Alfred V. C. Meyer, and Wilbur I. Duvall. 1966. 37 pp. 15 figs. The radial, vertical, and transverse components of particle velocity were recorded along gage arrays extending in one or two directions for 145 to 3,170 feet at five quarries. Of the 39 quarry blasts, 12 were instantaneous blasts, 5 were of the one hole per delay type, using millisecond delayed caps, and 22 were multiple hole per delay type employing millisecond delay detonating fuse connectors. Charge weight per hole ranged from 8 to 1,500 pounds, and the charge weight per delay interval, including the instantaneous blasts, ranged from 25 to 4,620 pounds. Statistical analysis of the particle velocity-distance data shows that the square root of the charge weight per delay interval can be used as a scaling factor in a propagation equation.

RI 6775. Reduction Roasting-Acid Solution Techniques in Laboratory Processing of Minnesota Manganiferous Ores, by P. L. Weston and M. M. Fine. 1966. 22 pp. 8 figs. High-temperature reduction roasting, magnetic separation, acid-leaching, and autoclave precipitation processes were used to recover iron and manganese from brown Cuyana range ores of Minnesota. Wet magnetic separation concentrated over 90 percent of the iron in 3 of 4 ores as high-grade products analyzing 74 to 85 percent iron, 2.5 to 6 percent manganese, and 3 to 10 percent SiO_2. The nonmagnetic fractions were leached with dilute sulfuric acid extracting 83 to 93 percent of the contained manganese and small amounts of iron. The leach solutions contained Mn-to-Fe and Mi-to-SiO_2 ratios favorable enough for possible consumption in metallurgical manganese operations. Exceptionally pure Mn solutions were achieved by pressure precipitation of the remaining iron in an autoclave followed by lime precipitation of silica and alumina.

RI 6776. Drillability Studies. Impregnated Diamond Bits, by James Paone and Dick Madson. 1966. 16 pp. 8 figs. Drillability studies were made with impregnated diamond bits in the laboratory on 7 rock types and in the field on 21 different rock types. Results indicate that drill parameters of rotational speed, thrust, and torque must produce sufficient applied forces to induce stress levels that cause continuous failure in rock to achieve efficient penetration rates. Higher rotational speeds appear to be more effective in drilling relatively harder rocks, although the increased speed causes more bit wear; increases in thrust result in higher drilling rates but not linearly; and up to a critical value a linear relation exists between torque and penetration rate for a specific rock type. Penetration rates with impregnated bits show a trend similar to that obtained with surface-set bits for rock under 25,000 psi compressive strength.

RI 6777. High-Temperature Columbium and Tantalum Alloys, by H. R. Babitzke, R. E. Siemens, and H. Kato. 1966. 16 pp. 7 figs. To develop alloys suitable for use at elevated temperatures, columbium and tantalum were combined with tungsten, hafnium, vanadium, zirconium, and titanium, and the resulting alloys were evaluated with respect to fabricability, hardness, electrical resistivity, strength at elevated temperatures, oxidation resistance, and bend transition. Of the 23 compositions tested, Cb-20Hf-5W-10Ti exhibited superior high-temperature properties. A recrystallized sample of this alloy was fabricable at room temperature, had a strength of 44,000 psi at 1,200° C, and had an oxidation rate of only 7.7 $mg/cm^2/hr$ at 1,000° C.

RI 6778. Using Probability Models as a Basis for Making Decisions During Mineral Deposit Exploration, by Scott W. Hazen, Jr., and William L. Meyer. 1966.

83 pp. 35 figs. This report documents 653 sets of sample data involving 78,366 assays obtained from past exploration for various minerals and metals. Most of these data have been taken from published reports describing exploration projects, conducted jointly by the Bureau of Mines and the Geological Survey, for the Strategic Minerals Program from 1940 through 1949. Means and standard deviations have been computed for the exploration assay data and have been plotted on graphs for 22 minerals and metals. A mathematical model, based on the binomial distribution, has been developed to explain the configuration of the plots of the exploration means and standard deviations. The two statistics, mean and standard deviation, which describe assay data, have been used for simulating probability models. These probability models then have been combined with the binomial model of the exploration assays and related to the sequential decision process associated with exploration drilling for mineral deposits. These probability regions can be used to form the basis for sequentially predicting the probable range of the average grade of mineral or metal that may be expected as an exploration drilling program is continued after the initial discovery of mineralization has been made.

RI 6779. Method of Analysis of Impurities in Helium in the Parts-per-Billion Range, by G. W. Weems and David E. Emerson. 1966. 5 pp. 1 fig. The Bureau of Mines combined preconcentrating techniques and mass spectrometry to develop a parts-per-billion general analysis of impurities in helium. The impurities are preconcentrated using a Bureau trace-impurity analyzer; 35-mm Hg pressure of helium is left in the concentration trap to sweep the impurities into the mass spectrometer and provide a 10-mm Hg sample pressure.

RI 6780. Volatilization of Cesium Chloride From Pollucite Ore, by I. L. Nichols and K. C. Dean. 1966. 8 pp. 1 fig. Volatilization of cesium from pollucite ore was investigated as an initial step in the production of purified cesium metal or cesium salts. High recovery of cesium and rubidium as chloride sublimates was accomplished by 2-hour roasts in a tube furnace using charges containing 1 part ore, 2 parts limestone, and 0.23 part calcium chloride. Recoveries of cesium in the sublimate product were 89.1, 92.9, and 95.2 percent, respectively, using 1,100° C and vacuum, 1,250° C with an air sweep, and 1,250° C without an air sweep. Most of the lithium, sodium, and potassium sublimed with the cesium and rubidium, but virtually none of the calcium, aluminum, and silicon in the charges was volatilized.

RI 6781. High-Temperature Heat Contents and Entropies of Two Praseodymium Oxides and Three Terbium Oxides, by L. B. Pankratz. 1966. 8 pp. 1 fig. High-temperature heat contents were measured for two praseodymium oxides and three terbium oxides. These were Pr_2O_3 (298° to 1,600° K), $PrO_{1.833}$ (298° to 1,050° K), Tb_2O_3 (298° to 1,050° K), $TbO_{1.718}$ (298° to 880° K), and $TbO_{1.812}$ (298° to 850° K). With the exception of $PrO_{1.833}$, all results were regular. $PrO_{1.833}$ had a small thermal anomaly at 760° K with an extra absorption of 380 cal/mole. The measured heat content values, tabulated smooth heat contents, and entropy increments are reported. Heat content equations were derived.

RI 6782. Low-Temperature Heat Capacities and Entropies at 298.15° K of Ferrous Molybdate and Ferrous Tungstate, by W. W. Weller. 1966. 5 pp. Heat capacities of ferrous molybdate and ferrous tungstate were measured over the temperature range 51° to 298.15° K. Ferrous tungstate has a lambda-type heat capacity anomaly at 74° K. The 298.15° K entropies are $FeMoO_4$, 30.9 cal/deg mole and $FeWO_4$, 31.5 cal/deg mole.

RI 6783. Laboratory Investigation of the Response of Guard Electrodes in Oil-Well Logging, by C. I. Pierce and J. Pasini III. 1966. 40 pp. 31 figs. An electrolytic tank model was used to investigate the response of guard electrodes of different dimensions under different simulated reservoir conditions. Sandstone disks from the Berea and Connellsville Formations were used as resistive beds in the model, and agar gel or water was used as conductive beds. In the experiments, bed thickness, hole diameter, mud resistivity, and bed resistivity were varied. The guard electrode is an excellent tool for determining true bed resistivity in the thin-bedded oil reservoirs of the Appalachian area. Vertical resolution and resistivity values are good when there is little or no invasion. Resistivity values are near true bed resistivity in beds thicker than about six hole diameters when the electrode-to-hole-diameter ratio is close to 1. However, low-resistivity muds cause false peaks to appear on the logs near bed boundaries in thick beds, and for resistive beds having a thickness approximately three to five times the hole diameter, apparent resistivities tend to be excessively high when mud resistivity is low.

RI 6784. Glass-Crystal Transformation of Nepheline and Wollastonite and Heat of Formation of Nepheline, by R. Barany. 1966. 8 pp. The heats of the glass-crystal transformation of nepheline ($Na_{0.794}K_{0.206}AlSiO_4$) and wollastonite ($CaSiO_3$) and the heat of formation of nepheline at 298.15° K were determined by solution calorimetry. For the glass-crystal transformations, the heat values were -9 ± 9.3 kcal/mole for nepheline and -8.1 ± 0.6 kcal/mole for wollastonite. The heat of formation of nepheline was -34.8 ± 0.6 kcal/mole from the oxides and -501.0 ±0.5 kcal/mole from the elements.

RI 6785. Electrodeposition of Aluminum From Fused-Salt Electrolytes Containing Aluminum Chloride, by P. C. Good, M. O. Butler, and L. A. Yerkes. 1966. 13 pp. 3 figs. Work was done to determine conditions necessary for efficient electrodeposition of aluminum from fused chloride electrolytes. Aluminum was deposited from a molten chloride salt electrolyte over the temperature range of 150° to 750° C. At lower temperatures in a heat-resistant glass cell, aluminum was deposited on stainless steel and on aluminum cathodes. The deposit was recovered in the form of light, feathery dendrites that could not be consolidated. At 750° C, molten aluminum was deposited at cathode current efficiencies as high as 90 to 100 percent on titanium diboride cathodes and in molten aluminum cathodes. Nitride-bonded silicon carbide was the best cell material, although porcelain was also used. The electrolyte consisted of a mixture of sodium and potassium chlorides in 1-to-1 mole ratio, containing aluminum chloride in concentrations ranging from 2 to 30 weight-percent in cells holding up to 1,000 grams of electrolyte. Generally favorable results were attained in studies made at temperatures greater than the melting point of aluminum.

RI 6786. Effects of Bleeder Entries During Atmospheric Pressure Changes, by J. W. Stevenson and D. S. Kingery. 1966. 15 pp. 8 figs. Reports on the influence that atmospheric pressure changes exert in a gassy coal mine on a ventilating air current with a system of bleeder entries. During the season when abnormal barometric fluctuations usually occur, recording instruments monitored the air current ventilating an active coal-producing area. It was found that the rate of coal production caused a more significant change in methane concentration than did barometric change. The hazard that accompanies methane release due to expansion of the gob gases during atmospheric lows was minimized by the effective bleeder system.

RI 6787. Cell With Four Variable Compartments for Rapid Infrared Analysis, by Willis M. Beckering, C. M. Frost, and W. W. Fowkes. 1966. 8 pp. 4 figs. A cell was designed having four variable compartments in series to facilitate analysis of multicomponent mixtures. Use of the cell considerably decreases the time required for differential absorption analyses. A solution of a major component is placed in each compartment, and the light absorbed by each of these components is varied by increasing or decreasing the path length of the appropriate cell. Simple calculations then establish the amount of the component present. In analyzing unknown mixtures, compensation is made for compounds known to be present, and the differential spectrum representing components not accounted for is recorded and analyzed.

RI 6788. A Method for Determining the Electrical Resistivity of Solid Anthracite Specimens, by Albert F. Baker, G. A. Brady, and J. W. Eckerd. 1966. 18 pp. 8 figs. Techniques were developed and circuitry was assembled for measuring the total and volume resistances to the flow of electric current through solid specimens of anthracite. The two-, three-, and four-terminal test methods demonstrated the extreme sensitivity of resistivity to differences in anthracite characteristics and showed response to changes resulting from variations in structure, temperature, and moisture content.

RI 6789. Fused-Fluoride Electrowinning of Thorium-Base Alloys, by D. G. Kesterke, D. C. Fleck, and T. A. Henrie. 1966. 14 pp. 5 figs. Low-melting thorium-base binary alloys or metal solutions were prepared by two different techniques involving the electrolysis of ThO_2 dissolved in fluoride melts. Experiments were performed at 950° to 1,250° C using electrolytes containing ThF_4 and various alkali and alkaline earth fluorides. In the first method, electroreduction of ThO_2 and deposition of thorium on a nickel or iron cathode formed a molten alloy that dripped off and collected on the bottom of the cell, or in a tungsten cup. An electro-codeposition technique was used to prepare thorium-base alloys or solutions containing nickel, iron, chromium, or manganese. Electrolytic reduction of the component metal oxides and simultaneous deposition of the two metals on a tungsten cathode yielded a liquid alloy product. Complementary experiments were performed on the fused fluoride electrowinning of dendritic thorium from ThO_2 at 1,075° to 1,200° C in which thorium crystals were recovered and arc-melted into buttons. Major contaminants were aluminum, carbon, copper, iron, oxygen, and silicon, totaling 0.2 percent.

RI 6790. Determination of Oxides of Nitrogen in Diesel Exhaust Gas by a Modified Saltzman Method, by Rogers F. Davis and William E. O'Neill. 1966. 5 pp. A new method was developed for the determination of oxides of nitrogen in diesel exhaust gas. The procedure, a modification of the Saltzman method, uses an NO_2 absorbent for the diesel exhaust gas; the colorless absorbent becomes purple on contact with NO_2. When used properly this procedure gives satisfactory results in 2 hours, whereas the standard phenoldisulfonic acid method required approximately 8 hours. The new method is not satisfactory for determination of oxides of nitrogen in the overrich fuel-to-air ratio range.

RI 6791. Vapor Pressure of Carbon Dioxide at the Ice Point, by Paul V. Mullins and Earle S. Burnett. 1966. 10 pp. 1 fig. Review and evaluation of all available data on the vapor pressure of carbon dioxide at the ice point, including previously unpublished results obtained by the Bureau of Mines, are presented. Suggested corrections and adjustments to all the data yield an average value of 26,136.4 mm mercury. Indicated agreement is within plus 1 part in 8,000 to minus 1 part in 11,000. A novel pressure bomb in which a sample of pure carbon dioxide is placed and sealed by a diaphragm fluid separator and its use as a reference pressure standard for extended and repeated use in the calibration of deadweight gages is described.

RI 6792. Analyses of Tipple and Delivered Samples of Coal Collected During the Fiscal Year 1965, by S. J. Aresco, J. B. Janus, and F. E. Walker. 1966. 38 pp. 35 cents. The Bureau of Mines has been active in promoting the purchase of coal for Government use under specifications that define the requirements in terms of heating value of the coal, expressed in British thermal units, and the composition as shown by proximate analyses. To these, when required, are added the ash-softening temperature, the free-swelling index, and the Hardgrove grindability index. Under most of these specification contracts, the bidders guarantee the quality of the coal, and that guaranteed by the successful bidder becomes the standard of his contract. The deliveries are sampled in accordance with instructions issued by the Bureau of Mines; the samples are analyzed in the Bureau laboratory to determine whether the coal is of the quality guaranteed by the contractor; if it is not, a price adjustment is made. Analyses of the delivered coal and tipple samples (samples collected at mine tipples as coal is being loaded into railroad cars or trucks) provide valuable data for use in evaluating future bids. In addition, the continuous sampling of coal as delivered is a check on the practical results obtained in burning the coal. The Government purchased approximately 5 million tons of coal in fiscal year 1965. In connection with these purchases, the Bureau analyzed 7,448 samples. These are published for the use of Government officials and the public. A series of publications has been completed on coal analyses by states, or, where production is small in any one state, by groups of adjacent states. In addition to analytical data showing composition and quality of coals of the states, the publications contain brief descriptions of the geological structure of the coal basins, typical mining conditions in the various districts, the principal economic data of the industry, and the relationship of mine or channel samples to delivered and tipple samples. The present publication covers many states but deals only with the analytical data of the coals. *(Out of print.)*

RI 6793. Evaluation of Ethylene as a Gas Tracer in Underground Gas Storages, by C. J. Walker and Ray V. Huff. 1966. 15 pp. 9 figs. Describes a theoretical and laboratory study undertaken to determine the feasibility of using ethylene as a tracer for natural gas in underground gas-storage reservoirs. The study indicated that ethylene was a useful gas tracer in underground gas storages. Tracer losses were not excessive. Laboratory tests were conducted at pressures as high as 500 psia in both wet and dry consolidated-sandstone cores, evaluating tracer loss with gas blends containing natural gas with different concentrations of thylene tracer. Under certain conditions losses were less than 17 percent. Work done in cooperation with the Pipeline Research Committee, American Gas Association.

RI 6794. Decomposition of Manganese Sulfate by a Partial Reduction Process, by H. C. Fuller and V. E. Edlund. 1966. 18 pp. 3 figs. A method was devised and developed for decomposing manganese sulfate at a significantly lower temperature than that required by the conventional procedure of using heat alone. This technique, called the partial reduction method, effected decomposition at 700° to 800° C, as compared to 900° to 1,000° C normally required. The process consisted of heating, in the absence of oxygen, a mixture of manganese sulfate and a controlled quantity of a reducing agent. The suitability of commercial-type equipment was tested in laboratory size models of an externally heated rotary kiln, a rabbled muffle-hearth furnace, and a fluidized-bed reactor. The rabbled-hearth furnace gave the best results with the least operating difficulty. It produced a gas containing more than 80 percent SO_2 and eliminated 96 percent of the sulfur when coal was used as the reductant. Sintering of the powdery decomposition product produced an agglomerate containing, in percent, 63.6 Mn and 0.4 S.

RI 6795. Presence of Thienothiophenes in Wasson, Texas, Crude Oil, by R. L. Hopkins, C. J. Thompson, H. J. Coleman, and H. T. Rall. 1966. 9 pp. 2 figs. The work described was performed to determine whether sulfur compounds of the thienothiophene class occur in crude oil. The presence or absence of various classes of sulfur compounds in crude oils is of interest and value to petroleum science. The Bureau of Mines, for the first time, identified hydrocarbon products of desulfurization that point directly to the identity of two individual thienothiophenes, namely 3-methylthieno[2,3-*b*]thiophene and 2-methylthieno[3,2-*b*]thiophene, in Wasson, Texas, crude oil. These identifications, described in detail, were accomplished using microdesulfurization, mass spectrometry, and gas-liquid chromatography.

RI 6796. Synthesis of Alkyl Cycloalkyl and Dicycloalkyl Sulfides, by R. L. Hopkins, R. W. Higgins, H. J. Coleman, C. J. Thompson, and H. T. Rall. 1966. 12 pp. 5 figs. Fifteen alkyl cycloalkyl sulfides and three dicycloalkyl sulfides were synthesized to provide reference compounds in the search for these classes of sulfur compounds in crude oils. In synthesizing sulfides by alkaline alkylation, the order in which the reactants were added was shown to determine the yield and purity of the product.

RI 6797. Decaking of Coals in a Fluid Bed, by A. J. Forney, R. F. Kenny, S. J. Gasior, and J. H. Field. 1966. 22 pp. 17 figs. Summarizes the findings of methods of treating caking coals in a fluid bed to destroy their caking properties. In batch tests it was found that several coals, including those with a free-swelling index greater than 8, could be decaked at temperatures from 400° to 425° C with a fluidizing gas composed of inert gas or steam containing 0.2 percent oxygen and a minimum residence time of 5 minutes. When treatment decreased the free-swelling index from 8 to 1½ or lower, the resulting treated coal was noncaking. In a continuous unit with continuous feed and discharge of coal, slightly more severe conditions were required to decake the coal. For 18- to 100-mesh coal a temperature of 430° to 440° C and an oxygen-to-coal ratio of 0.4 cubic foot of oxygen per pound of coal feed was necessary. Finer mesh sizes required lower oxygen-to-coal ratios. In tests using air only as the fluidizing medium and treatment temperatures well below the softening range, the caking properties of 150- to 200-mesh coal were destroyed in 30 to 40 minutes of residence time at 200° C. Coarser sizes of 18 to 48, 48 to 100, and 100 to 150 mesh required longer residence time. The composition of the volatile matter in the coal was changed during treatment by the formation of oxygenated compounds. Carbonizing the treated coal at 538° C showed the oxygenated compounds that had been formed during treatment increased the yield of carbon oxides and decreased the yield of gaseous hydrocarbons, thus decreasing the heating value of the product gas.

RI 6798. Oil Recovery by Low-Pressure Gas Drive in the Keener Sand, Bonds Creek Oilfield, Lafayette District, Pleasants County, W. Va., by Leo A. Schrider and James A. Wasson. 1966. 46 pp. 21 figs. This report analyzes the successful low-pressure gas drive in the Keener sand of the Bonds Creek oilfield, Pleasants and Ritchie Counties, W. Va., and predicts its future performance. Core analysis from two wells and electrical and radioactivity logs were used to evaluate the reservoir characteristics. Production records of a 37-year period indicate that over 240,000 barrels of oil have been produced from the Keener sand by low-pressure gas injection. Decline-curve analysis shows that 165,000 additional barrels should be recovered from 108 acres of productive sand by continuing this secondary-recovery method.

RI 6799. Drop-Weight Testing of Explosive Liquids, by Charles M. Mason, Robert W. Van Dolah, and Milton L. Weiss. 1966. 15 pp. 8 figs. The Bureau of Mines evaluated equipment and procedures for drop-weight testing of explosive liquids as prescribed by Test 4, a widely used method. It was demonstrated that partial ignitions, originally designated as negative results, should be designated positives. It was also shown that wear or erosion of the sample cups and the type of mount used for the apparatus had important effects on the results. Relative sensitivity as measured by Test 4 was found to vary slightly with temperature. The Bureau also designed a fixed 2-kg weight and associated electromagnetic release, which subsequently were incorporated as standard in a revision of Test 4. The original concept that the test involves only adiabatic compression was found to be an oversimplification; an alternate mechanism for the initiation process is proposed in which due consideration is given to the effects of cavitation and microjets.

RI 6800. High-Temperature Corrosion Studies. Influence of Yttrium on Oxidation of Nickel at 1,200° C, by Robert M. Doerr, J. W. Jensen, and Charles C. Myers. 1966. 21 pp. 8 figs. The oxidation kinetics of Ni-Y alloys in the range 0.04 to 8 weight-percent Y and high-purity Ni were compared by the use of a sensitive volumetric apparatus. The reactions followed approximately the parabolic rate law; for oxidations in O_2 at 0.5 atm and 1,200° C, the parabolic rate constant was about $0.37+(0.064)(Y-2.11)$ mg cm^{-2} min$^{-1/2}$, where Y represents the weight-percent Y in the alloy. Internal oxidation of Y occurred in the alloy specimens and the resultant Y_2O_3 particles, which were in patterns related to the eutectic structure of the alloys, served as markers showing that the subsequent oxidation of the surrounding Ni was by inward diffusion of O. The scale consisted in each case of NiO, but the inner parts of the scale on the alloy specimens included the patterned Y_2O_3 particles. The thickness of the inner parts of the scale depended directly on the Y concentration, and the thickness of the Y_2O_3-free outer parts of the scale were inversely related to the Y content of the alloys. There is thus a relationship between the thickness of the outer part of the scale and the protectivity of the scale. Outward diffusion of Ni and inward movement of O, from the inner boundary of the Y_2O_3-free part of the scale, is proposed as a mechanism for these results.

RI 6801. An Evaluation of the Western Phosphate Industry and its Resources (in Five Parts). 3. Idaho, by A. L. Service. 1966. 201 pp. 66 figs. Idaho has nearly 6 billion tons of potential sources of phosphorite, 10 to 31 percent P_2O_5 above and within 100 feet below entry level, the largest potential of any State in the United States. In 1963 Idaho ranked third after Florida and Tennessee in total mine and marketable production of phosphate rock; Montana ranked fourth. This report describes phosphate deposits, mines, and prospects in 10 districts covering most of the Idaho phosphate field. All mine production of phosphate rock in Idaho comes from surface mines and is processed to phosphate fertilizers, phosphoric acid, and elemental phosphorus. Producing districts are Fort Hall (Gay Mine), Trail Creek (Conda and Ballard mines), and Crow Creek (Georgetown Canyon mine). FMC Corp. and J. R. Simplot Co. at Pocatello have the largest elemental phosphorus and fertilizer production facilities, respectively, in the State, followed by Monsanto Co. and El Paso Natural Gas Products Co. (formerly Central Farmers Fertilizer Co.). The only other major phosphate processing plant in the State is the phosphoric acid and phosphate fertilizer complex at Kellogg operated by the Bunker Hill Co. In 1963 a plant was constructed and put on line at Monsanto, Idaho, to recover vanadium from ferrophosphorus produced by electric furnace operations in the area. El Paso Natural Gas Products Co. completed construction of a fertilizer and phosphoric acid plant near Conda in 1965. There is a small fertilizer plant producing phosphate fertilizers for local consumption in Soda Springs.

RI 6802. Producing Hafnium-Enriched Feed Solutions From Zircon, by Gerald W. Elger, Lloyd H. Banning, and Kenneth W. Moser. 1966. 22 pp. 12 figs. This report describes development of the fusion-leach crystallization-precipitation process for producing a high-hafnium-content feed material for hafnium-zirconium separation plants. Mixtures of zircon, potassium silicofluoride, and potassium carbonate (or potassium chloride) were fused to prepare soluble potassium zirconium hexafluoride-potassium hafnium hexafluoride salts. High extraction of these salts was obtained by countercurrent leaching the fused material in dilute hydrofluoric acid. About one-half of the hafnium was recovered in hafnium-enriched mother liquor by cooling clarified leach liquor to crystallize most of the zirconium salt. Additional hafnium was recovered from the primary crystals in a multiple dissolution-recrystallization step. Hafnium-enriched oxides having a hafnium-zirconium ratio of more than three times that of zircon were precipitated from the combined mother liquors. The hafnium and zirconium recoveries in the precipitate were 83 and 24 percent, respectively. About 71 percent of the zirconium and the remainder of the hafnium were recovered in potassium zirconium hexafluoride crystals of low hafnium content.

RI 6803. Identification of Sulfur Compounds in Petroleum. Analysis of a Wasson, Texas, Crude Oil Distillate Boiling From 111° to 150° C, by H. J. Coleman, C. J. Thompson, R. L. Hopkins, and H. T. Rall. 1966. 20 pp. 18 figs. Knowledge of the types of naturally occurring sulfur compounds in petroleum is of both theoretical and practical interest to petroleum chemists and geologists. This knowledge has been extended by the identification of 77 sulfur compounds, including 36 thiols, 23 chain sulfides, and 18 cyclic sulfides in a 111° to 150° C boiling range distillate of Wasson, Texas, crude oil. The characterization procedure used in separating and identifying these compounds included isothermal distillation, vacuum fractionation, liquid-solid chromatography (alumina adsorption), chemical treatment, gas-liquid chromatography, microdesulfurization, and infrared analysis. The procedural steps described represent a systematic method of sulfur compound analysis considered applicable for determining the nature and concentration of the sulfur constituents present in any straight-run petroleum distillate of the above boiling range. Work done in cooperation with the American Petroleum Institute (Research Project 48).

RI 6804. Laboratory Evaluation of Flow Characteristics of Oil-Producing Sandstones in Illinois, Indiana, and Kentucky, by Eliot J. White and Oren C. Baptist. 1966. 20 pp. 11 figs. The Bureau of Mines tested cores from 35 wells from 14 oil-producing zones in southern Illinois, southern Indiana, and western Kentucky to determine why rates of water injection were apparently low in some zones. Since these zones contain only minor amounts of clay minerals, it is concluded that permeability reduction results from movement of dislodged silica particles and other material, including the clays, that line the pores. Both single-phase and two-phase permeability measurements, however, indicated that most samples had only low to moderate water sensitivity, so that permeability reduction due to such particle movement should usually not be of practical significance. The effective permeability to water was considerably lower than the effective permeability to oil during two-phase flow measurements, as is typical of most reservoir rocks. It can be concluded, therefore, that relatively high injection pressures will be required in waterflooding thin zones or zones having low permeabilities.

RI 6805. Electrolyte Life in Winning Tungsten From Scheelite, by John M. Gomes, Kenji Uchida, and Don H. Baker, Jr. 1966. 9 pp. 4 figs. In the repetitive electrowinning of tungsten from scheelite, the calcium impurity buildup in the molten electrolyte results in decreased metal purity, metal recovery, and current efficiency. Periodic addition of B_2O_3, which reacts with the lime liberated from the scheelite, more than tripled the life of the electrolyte in winning 99.9-percent-pure tungsten and also reduced the number of units of electrolyte required per unit of tungsten recovered from six to four.

RI 6806. Effect of Charge Diameter on Explosive Performance, by Harry R. Nicholls and Wilbur I. Duvall. 1966. 22 pp. 10 figs. The effect of varying the diameter of explosive charges on the generation and propagation of strain waves was studied. The parameters compared were strain amplitude, impulse, energy, and pulse shape. Three different explosives were detonated in three different charge diameters. Charges of cast 50/50 pentolite detonated at the same velocity in 5-, 2.5-, and 1.5-inch diameters. Charges of ammonium nitrate-fuel oil prills and 45-percent semigelatin dynamite showed a strong detonation rate-diameter dependency. Detonation of these two explosives was considered nonideal. Differences in the diameter of the charge caused less difference in the strain-generating abilities of pentolite than in those of the other two explosives. This was also true for impulse and energy. Rise and fall times of the strain pulses for all three explosives were proportional to detonation time and cavity volume, respectively.

RI 6807. Activity of Manganese in Liquid Iron-Manganese Alloys, by C. W. Schultz, N. Riazance, and S. L. Payne. 1966. 10 pp. 4 figs. The vapor pressure of manganese in equilibrium with a series of liquid iron-manganese alloys was determined by the carrier gas method over a broad range of alloy composition. From these data, the activities of manganese in the iron-manganese system were calculated. The system appears to be ideal.

RI 6808. Oxidation Leaching of Copper Sulfides in Ammoniacal Pulps at Elevated Temperatures and Pressures, by Martin H. Stanczyk and Carl Rampacek. 1966. 13 pp. 1 fig. The Bureau of Mines investigated leaching of selected copper sulfide minerals and a composite of impure flotation concentrates at elevated temperatures and pressures with ammoniacal solutions. Copper extractions of 96 percent were obtaned by leaching chalcopyrite at 75° C under oxidizing conditions for 60 minutes. An extraction of 99 percent of the copper contained in the composite concentrate was obtained by leaching the product for 90 minutes at 75° C. In tests of bornite, chalcocite, and covellite, 90 to 97 percent of the copper was extracted at 20° C provided an 8-hour reaction period was used. At 75° C essentially complete dissolution of the copper from these three minerals was accomplished in 60 minutes. Additions of ammonium sulfate to the leach solutions were required to obtain high-percentage extractions of the copper from bornite, chalcocite, and covellite. Although ammonium sulfate was not required when digesting chalcopyrite, copper extraction was enchanced and less free ammonia was required when ammonium sulfate was added to the leach pulps. The chemistry of leaching copper minerals was studied. It was determined that chalcocite altered to covellite as one step in the dissolution reaction. When leaching iron-bearing copper sulfides, hydrated iron oxide formed on the mineral surfaces, indicating that a diffusion process prevailed. No evidence of covellite was detected. Work done in cooperation with the University of Arizona.

RI 6809. Extraction and Separation of Selected Lanthanides With a Tertiary Amine, by D. J. Bauer. 1966. 13 pp. 9 figs. Demonstrates the feasibility of fractionating lanthanide nitrates with a tertiary amine on lanthanum-cerium and thulium-ytterbium pairs. Optimum values were determined for pH, phase concentration, and percent chelation of metal ions in the aqueous phase. Percent extraction is markedly dependent on the concentration of lithium nitrate in the aqueous phase. Selective masking of the heavier element in each extraction system with DTPA or EDTA aqueous-phase chelating agents resulted in lanthanum-cerium separation factors of 8.5 and thulium-ytterbium separation factors of 3.4.

RI 6810. Piezoelectric Pulsing Equipment for Sonic Velocity Measurements in Rock Samples From Laboratory Size to Mine Pillars, by Francis X. Cannaday and Gary M. Leo. 1966. 23 pp. 18 figs. The Bureau of Mines developed equipment to measure the sonic velocity of pulses transmitted through rock samples varying in size from laboratory specimens to mine pillars in place. Pulses are produced by electronically excited piezoelectric ceramic transducers. Special equipment components were developed by Bureau facilities; other components are commercially available. The technique permits a nondestructive, repetitive, stable, shaped pulse to be used in place of explosive caps or hammer blows. Longitudinal wave travel time measurements were taken on an oscilloscope screen; transverse wave measurements were taken under special field conditions. Results were consistently repeatable within the accuracy of the oscilloscopes utilized.

RI 6811. Thermal Phenomena During Ignition of a Heated Dust Dispersion, by John Nagy and Donald J. Surincik. 1966. 25 pp. 9 figs. The Bureau of Mines adapted thermal theories explaining combustion of gases to correlate parameters affecting ignition of dust dispersions. The dust dispersions were ignited in a Godbert-Greenwald furnace at atmospheric pressure. Ignition temperature and the concentrations of fuel, admixed inert powder, and atmospheric oxygen were related mathematically. Values for these parameters obtained in laboratory experiments for cornstarch agreed with theory. The developed equation permits extrapolation; the predicted upper ignition limits correspond with limited experimental data from laboratory- and large-scale tests. Explanation of the effect of fineness of dust on ignition parameters is attempted by introducing a surface-area constant to modify the activation energy. Arguments are presented to show that the ignition process is a solid-gas phase reaction rather than an ignition of prevolatilized gases.

RI 6812. Photoelastic Study of an Internally Stressed Circular Opening in a Biaxial Stress Field, by M. S. Oudenhoven and G. T. Krempasky. 1966. 25 pp. 15 figs. This Bureau of Mines investigation was conducted to obtain an experimental solution of stress changes in the vicinity of a circular opening in an infinite plate. Plates were stressed biaxially in compression and subjected, by four different-length shoes, to a uniform pressure at opposing points on the opening periphery. The principal stresses along the vertical and horizontal axes, which result from peripheral pressure, were obtained from the photoelastic analysis of four frozen-stress epoxy models. These principal stresses were then superimposed on the mathematically determined principal stresses (along the same axes) obtained from a theoretical biaxial stress field in which the magnitude of the lateral pressure was one-third that of the vertical pressure. The results indicate that an increase in shoe length increases the radial compressive stress and the tangential tensile stress (except tangential compression at $r/a=1$, which exists for all shoe lengths). Also, a partial control of the stresses within one-half radius of the opening surface is accomplished by a change in the magnitude and placement of peripheral pressure.

RI 6813. Crystalline Titanium by Sodium Reduction of Titanium Lower Chlorides Dissolved in Sodium Chloride, by V. E. Homme and M. M. Wong. 1966. 27 pp. 11 figs. Low- and high-temperature reduction techniques were employed by the Bureau of Mines in study of conditions favorable to the formation of massive titanium crystals. The low-temperature method, feeding molten sodium to solidified titanium lower chloride-sodium chloride, produced higher quality and high quantity crystalline metal. The percentage of crystalline titanium was increased with increasing reactor diameter, melt depth, and titanium dichloride concentration. The high-temperature technique, feeding molten sodium to melts above 800° C, produced needle-type crystals of lower quality and with less consistent results than the low-temperature method. Layers of titanium foil, sponge, fine needles, wool, and crusts of sintered granules were formed during the early part of the low-temperature reduction, and massive crystals were produced beneath this barrier in the latter part of the reduction. Crystalline titanium having an average hardness of Bhn 76 and representing 58 percent of the total titanium was obtained. Lamellar crystals up to 1½ inches long with a hardness as low as Bhn 54 were also produced. A second-stage reduction for reclaiming titanium from offgrade sponge is described. Titanium produced by this method was comparable in quality to that from sodium reduction of titanium tetrachloride.

RI 6814. Mechanical Strength of Coke and Iron Pellets at Elevated Temperatures, by G. W. Birge, J. H. Lynch, Jr., and D. E. Wolfson. 1966. 16 pp. 4 figs. The Bureau of Mines investigated the effect of temperature on the mechanical strength of cokes of the type normally used in blast furnace operations. Eight samples of industrially produced cokes were subjected to ASTM tumbler tests at temperatures as high as 1,100° C (2,012° F); these temperatures had no significant effect on tumbler results for cokes with stability indexes of 40.6 to 59.9. Two foundry cokes which were tested at only one elevated temperature (900° C) decreased slightly in tumbler stability. Iron ore pellets made from a variety of ores and by various industrial methods were not significantly affected by temperature when tested in an oxidizing atmosphere at 1,000° C (1,832° F) by the tentative standard ASTM method.

RI 6815. An Improved Method for Evaluating the Incendivity of Explosives to Coal Dust. A Progress Report, by N. E. Hanna, P. A. Richardson, and R. W. Van Dolah. 1966. 13 pp. 5 figs. Experience with the current version of Gallery Test 4, in use since 1913 to evaluate the incendivity of permissible explosives in the presence of coal dust, has shown the procedure to have inadequate discrimination. Consequently the Bureau of Mines used the up-and-down method of statistical design to investigate the incendivity of permissible explosives in the presence of coal dust and gas. A suitable device was developed to measure coal-dust concentrations in the air-gas mixtures and to disperse the dust in the gallery atmosphere. A proposed testing method which uses suspended shots in a predispersed coal dust-gas-air mixture was evaluated. The new method can discriminate between different explosives with respect to their incendivity. Maximum ignitibility of the coal dust cloud by permissible explosives occurred in the vicinity of 0.3 oz/cu ft. About 10 percent sodium chloride in permissible explosive formulations had a very significant effect in reducing the probability of igniting coal dust. Bundled charges were more incendive than column charges.

RI 6816. Infrared Spectroscopy Studies of a Xanthate-Galena System, by R. E. Coleman and H. E. Powell. 1966. 24 pp. 10 figs. The molecular species occurring at the mineral-reagent interface of the galena-aqueous potassium ethyl xanthate system was studied by developing a technique for using an attenuated reflection method in conjunction with standard infrared spectroscopy procedures. Lead ethyl xanthate was detected from the infrared spectra of all galena surfaces treated in the pH range of 7 to 11. At pH 8.5, lead ethyl xanthate formed as a film chemically bonded to the galena surface. A solvent extraction sampling method was employed with infrared spectroscopy to obtain quantitative data on the lead ethyl xanthate removed from the galena surface. The data showed that between pH 7 and 11 the quantity of lead ethyl xanthate physically adsorbed decreased as the pH was decreased; in the same pH range, the quantity of the free lead ethyl xanthate in the aqueous medium remained constant, and the amount of unreacted xanthate varied.

RI 6817. High-Energy-Rate Extrusion of Low-Density Tungsten Powder Billets, by Jack G. Croeni, John S. Howe, Jr., and H. Kato. 1966. 12 pp. 9 figs. The Bureau of Mines developed a method to extrude low-density tungsten powder billets into rods and sheet bar with high-energy-rate forming equipment. Billets were compacted and sintered in an atmosphere of hydrogen to obtain a density of approximately 60 percent. Extrusion was conducted at reduction ratios of 6.25 to 1 and 9 to 1 at 1,800° C to produce high-density, sound material. Yield strengths obtained were higher than those of material produced by conventional powder-metallurgy techniques, but ductility was lower at high temperatures.

RI 6818. Electrolytes for Electrorefining Hafnium, by M. M. Wong, J. M. Hiegel, and G. M. Martinez. 1966. 9 pp. 3 figs. Salt mixtures consisting of KCl, $BaCl_2$, and $HfCl_4$ with RbCl or CsCl were investigated as electrolytes for refining hafnium. The presence of RbCl or CsCl in the electrolyte appeared to suppress the volatility of $HfCl_4$. Best electrorefining was obtained with an electrolyte containing 50.7 percent KCl, 27.1 percent $BaCl_2$, 15.7 percent CsCl, and 6.5 percent $HfCl_4$. In this electrolyte, hafnium metal with an average oxygen content of 470 ppm was produced from an anode feed containing 1,600 ppm oxygen. All metallic impurities were lowered, except titanium, manganese, and tin.

RI 6819. Analyses of Crude Oils From 546 Important Oilfields in the United States, by C. M. McKinney, E. P. Ferrero, and W. J. Wenger. 1966. 345 pp. The Bureau of Mines analyzed 626 crude oils from 546 oilfields in the United States that produced 2,500 BOPD or more during at least 1 of the last 3 years. Included also are crude oil analyses from eight fields that produced less but which were located in areas having few or no fields that produced 2,500 BOPD. The tables show the geographical and geological source, general characteristics, and determined and computed analytical data for each sample. The analyses were made according to the Bureau of Mines routine method and are directly comparable to other previously published analyses. $1.75.

RI 6820. Determination of Cesium and Rubidium by Flame Photometry, by Kenneth R. Farley and H. E. Peterson. 1966. 19 pp. 9 figs. The Bureau of Mines developed a rapid and accurate flame photometric procedure for determining cesium and rubidium in ores and in products associated with the extractive metallurgy of these elements. The effect of associated ions is neutralized by addition of buffer solution; alkali metal effects are neutralized by parallel analyses made on standard solutions similar in composition to the sample being studied. The overall accuracy of the method is within 2.5 percent of the amount of cesium or rubidium present; the range from 1 to 25 percent is the most accurate.

RI 6821. Reclaiming Magnetite in Dense-Medium Circuits by Froth Flotation, by J. A. Cavallaro and A. W. Deurbrouck. 1966. 11 pp. To determine whether magnetite consumption could be reduced and salable coal production increased by using froth flotation units in series with magnetic separators, the Bureau of Mines conducted laboratory froth flotation tests on primary magnetic separator effluents obtained from three coal preparation plants. Tests were performed in a standard 500-gram-capacity laboratory batch flotation cell. Oleic acid and methylisobutyl carbinol were used as the collector and frother, respectively. Magnetic recovery was comparable to that expected from secondary magnetic separation, and salable float coal recoveries of 0.8 to 7.6 tons per hour were obtainable. The economics of the proposed technique appear to be sound.

RI 6822. Heats and Free Energies of Formation of Anhydrous Carbonates of Barium, Strontium, and Lead, by L. H. Adami and K. C. Conway. 1966. 71 pp. The heats of formation of anhydrous barium carbonate (witherite), strontium carbonate (strontianite), and lead carbonate (cerussite) were determined by solution calorimetry. The solution mediums were hydrochloric acid for barium and strontium carbonates and perchloric acid for lead carbonate. The heats of formation at 298.15° K are as follows: $BaCO_3$, -297.5 ± 0.8 kcal/mole; $SrCO_3$, -294.6 ± 0.5 kcal/mole; and $PbCO_3$, -168.0 ± 0.3 kcal/mole.

RI 6823. Analysis of Stresses in a Rock Disk Subjected to Peripheral Thermal Shock, by T. S. Chen and R. L. Marovelli. 1966. 50 pp. 28 figs. A study was made by the Bureau of Mines of the temperature and thermal stress distributions in thin circular disks subjected to peripheral thermal shock at various rates of heat transfer. The theoretical analysis is based on one-dimensional radial heat flow by conduction in the disk, and on heat exchange by convection between the disk and its surroundings. Preliminary experimental data obtained from shock tests on thin circular disks of basalt, quartzite, and taconite show reasonably good agreement with theory. The case of constant properties and plane stress is treated. Solutions of the stress distribution are presented for both cooling and heating shocks. The elastic energy stored at fracture is examined, and on this basis an average stress theory is formulated. Physical properties vital to the studies include thermal conductivity, thermal diffusivity, tensile strength, Young's modulus, and linear coefficient of thermal expansion. This work is of importance in predicting the thermal shock responses of a rock body of finite size.

RI 6824. Calibration of a Rotating Piston Deadweight Gage by Means of a Mercury Column Less Than 1 Meter High. Significance of Piston Constants and Their Applications, by E. S. Burnett and P. V. Mullins. 1966. 22 pp. 2 figs. Rotating piston deadweight gages have been used for many years for measurement of pressure to several hundred atmospheres. They have been calibrated by comparison of fluid pressures produced by various loads bearing on the piston bases, as measured by corresponding heights of balancing columns of mercury. When expressed in appropriate units, these ratios of column heights to piston loads are called piston constants. Experimental arrangements and procedures for their determination are presented in this paper, followed by a discussion of their significance and of their subsequent applications.

RI 6825. Preparation Characteristics of Coal From Webster County, W. Va., by A. W. Deurbrouck. 1966. 30 pp. 3 figs. This report describes the preparation characteristics of the significant coalbeds from which samples could be obtained in Webster County, W. Va. In 1964 approximately 825,000 tons of coal was produced in the county, of which 732,000 tons was mechanically cleaned in three preparation plants. The Sewell coalbed accounted for 94 percent of the coal produced. Twelve samples were collected from five coalbeds—Lower Kitanning, Peerless, Iager, Sewell, and Fire Creek. Four of the samples would require upgrading to meet metallurgical requirements; two others of just over 8.0 percent ash would require some upgrading. In general the coalbed samples collected in the country were of medium-sulfur and medium- to low-ash content as received or after removal of the sink 1.58-specific-gravity material.

RI 6826. Two- and Three-Phase Relative Permeability Studies, by Erle C. Donaldson and Gordon W. Dean. 1966. 23 pp. 14 figs. Gas-displacement tests were made in Berea Sandstone and Arbuckle Limestone cores to determine the relative permeabilities to gas, oil, and water for two- and three-phase dynamic systems. Three-phase relative permeabilities were obtained by displacing oil and water from the core with gas and measuring the flow rates of the three fluids simultaneously. It was found that relative permeabilities to fluids in a porous medium are affected by the saturation distributions of other fluids in the medium as well as by their own saturation distributions.

RI 6827. Reaction Interface Speed as a Reducibility Index for Iron Ore, by J. P. Hansen, T. N. Rushton, and C. W. Schultz. 1966. 33 pp. 16 figs. Reducibility tests were run by the Bureau of Mines on an open hearth lump ore and four groups of pellets whose smelting characteristics had been determined previously in the Bureau's experimental blast furnace. When reduction data from various tests were plotted on specially prepared paper 1-(1-percent reduction/100)$^{1/3}$ against time, the plots were linear. The iron-wustite interface therefore advances at a constant rate. The rate of the interface advance in mm/min was used as a reducibility index. The reducibility index measured at 900° C, using 0.45 cu ft hydrogen per minute varied inversely with the surface area of the sample. Even with carefully controlled surface areas, however, duplicate reducibility indices varied considerably. When enough tests were run to give a stable mean, the mean reducibility index did correlate with blast furnace production for the four pellet groups. Results indicated that if the interface speed itself were to be used for correlation with blast furnace production, a sample size of about 180 grams of minus 0.742- plus 0.525-inch particles should be used with a test temperature of 900° C and a flow of 0.45 cu ft hydrogen per minute.

RI 6828. Nonpegmatitic Beryllium Occurrences in Arizona, Colorado, New Mexico, Utah, and Four Adjacent States, by H. C. Meeves. 1966. 68 pp. 25 figs. The nonpegmatitic sources of beryllium in Arizona, Colorado, New Mexico, Utah, and four adjacent States investigated by the Bureau of Mines are described. The investigations included 155 properties from which over 6,200 rock samples were collected; more than 5,500 samples were analyzed by the nuclear beryllium-detection technique. Twenty-four of the properties examined had rock containing more than 0.10 percent BeO. Many of the beryllium determinations were made in the field with portable detection instruments by direct scanning of outcrops and by testing samples of rock brought to the instrument. The large domestic resources of low-grade nonpegmatitic beryllium ore in Utah, which were discovered by private enterprise and which respond favorably to small-scale treatment processes, may come into commercial use and thus reduce the dependence of the United States on imported beryl.

RI 6829. Reaction of Coal in Argon and Argon-Hydrogen Plasmas, by Walter Kawa, Richard D. Graves, and Raymond W. Hiteshue. 1966. 19 pp. 3 figs. Coals of various rank were reacted by the Bureau of Mines in plasma jets generated from argon and argon-hydrogen mixtures containing up to 33 volume-percent hydrogen. Average plasma temperatures ranged from about 3,400° to 12,000° C. Products were a solid residue and a gas containing hydrogen, methane, acetylene, diacetylene, and oxides of carbon. The highest yield of acetylene obtained with argon plasmas was 15 percent by weight of moisture- and ash-free coal. The data indicated that acetylene yields of 40 percent or higher can be obtained from the reaction of coal in argon-hydrogen plasmas, although results from these experiments could not be correlated with operating variables because of low recoveries. The plasmas contained sufficient energy to heat the coal to temperatures as high as 9,000° or 10,000° C, but complete devolatilization did not occur in any experiment.

RI 6830. Selective Flotation of Mica From Georgia Pegmatites, by James S. Browning and Ralph B. Adair. 1966. 9 pp. 1 fig. The Bureau of Mines conducted laboratory and small-scale continuous tests of weathered mica pegmatite ores from Hart County, Ga., to determine the technical feasibility of recovering commercial-grade mica concentrates by flotation. Two modifications of the Bureau-developed anionic-cationic method were used. In one method, sodium carbonate and calcium lignin sulfonate were used for pH control and quartz depression; this method yielded mica concentrates containing 98.5 percent mica with a recovery of 91.4 percent. In the other modification, lime and sodium silicate were used with the calcium lignin sulfonate; concentrates containing 98.9 percent mica with a recovery of 86 percent were obtained. Work done in cooperation with the University of Alabama.

RI 6831. Laboratory Study of Effect of Cement and Dispersant Additives on a Hydraulic Backfill, by D. R. Corson. 1966. 15 pp. 7 figs. The Bureau of Mines is conducting research on the effects of various established and potential soil-stabilization additives to hydraulic backfill. This initial phase is an evaluation of the effect of inclusion of varying amounts of portland cement and combinations of cement and a dispersant on the bearing strength of backfill. Results of unconfined compression tests are given for over 200 sample cylinders incorporating a fill material with cement or cement and dispersant. Inclusion of a minor amount of dispersant (0.2 percent by weight) is found to yield a significant increase in strength for 20-to-1 and leaner sand-cement mixes. An apparent optimum concentration of dispersant exists beyond which no further increase in strength is achieved. A dispersant-cement ratio of 1.8-to-1 yielded a strength increase of 515 percent over the strength of untreated 40-to-1 sand-cement mixes. The significance of the investigation with respect to the mining industry is discussed.

RI 6832. Adsorption Phenomena and the Reduction of Iron Oxides. Mechanism of Reduction of Iron Oxides With Carbon Monoxide, by S. E. Khalafalla, C. W. Schultz, and T. N. Rushton. 1966. 22 pp. 5 figs. The Bureau of Mines investigated the kinetics of reduction of wustite and magnetite with carbon monoxide. A mechanism was postulated wherein the interaction between gaseous and adsorbed carbon monoxide appears to be the rate-determining process. This mechanism fully accounts for the experimental rate equation which relates the velocity of reduction to the pressure of the reducing gas at constant temperature. It also explains the variability of the heat of activation of the reduction process with the state of aggregation of the oxide material. The integrated rate equation is in perfect agreement with the experimental reduction-time curves.

RI 6833. Delination of Texas Lignite Beds by Statistical Techniques, by G. S. Koch, Jr., and Manuel Gomez. 1966. 38 pp. 9 figs. Statistical methods applied at the Bureau of Mines Denver Mining Research Center to data from metallic ore bodies were used to evalaute lignite reserves from core data and to predict the extent of lignite horizons in some Texas lignite beds. Six lignite seam units were studied using data from 361 drill holes. The data indicate a total of 214.2 million tons of lignite in the area examined and probable reserves of 113 million tons in an area 2,000 feet beyond the limits established by the drill holes. It was demonstrated that lignite reserves present in lenticular beds could be reliably determined by statistical techniques and that core drilling could be optimized to yield maximum information with minimum drill holes. The technique described is applicable to other coalbeds. Work done in cooperation with the Texas Power & Light Co.

RI 6834. Influence of Repetitive Electrolysis on Winning Molybdenum, by H. J. Heinen and D. H. Baker, Jr. 1966. 11 pp. The Bureau of Mines studied repetitive batch electrowinning of molybdenum from molybdic oxide (MoO_3) to determine the effects on electrolyte life, purity of metal product, and overall cell performance. The electrolyte contained 54.0 weight-percent sodium tetraborate ($Na_2B_4O_7$), 23.6 weight-perecent sodium chloride ($NaCl$), 14.9 weight-percent sodium fluoride (NaF), and 7.5 weight-percent MoO_3. The feed materials were pure and technical-grade MoO_3. Electrolysis was conducted at 1,000° C in a graphite cell in an atmosphere of air and carbon oxides. Electrolyte degradation did not occur during repetitive winning of molybdenum from pure MoO_3 in an 8-day (5,400-ampere-hour) period of operation. Electrowon metal contained <0.1 percent total impurities. The electrode configuration is a key factor in the direct conversion of technical-grade MoO_3 to metal by repetitive cyclic electrolysis. The best configuration found was a cathode crucible and a central anode. Metal purity of 99.8 percent and a current efficiency of 91 percent were maintained until the combined impurity buildup in the electrolyte reached 4.7 percent silicon, 1.0 percent aluminum, and 0.6 percent iron. One pound of molybdenum was produced per 1.5 pounds of solvent salts employed. About 25 percent of the initial NaCl and NaF contents of the electrolyte were lost owing to volatilization and crucible penetration.

RI 6835. Preparation of Submicron Tungsten Powder by Hydrogen Reduction of Tungsten Hexachloride, by J. E. Tress, T. T. Campbell, and F. E. Block. 1966. 14 pp. 4 figs. The Bureau of Mines prepared submicron tungsten powder by reducing tungsten hexachloride with hydrogen. The particle diameters of the resulting tungsten powders ranged from 0.015 to 0.046 micron. Within the limits of the variables investigated, no clear-cut correlation was found between process conditions and final size of the powder. Oxygen was the major contaminant in the product, being present both as an adsorbed gas and as suboxides of tungsten. Studies showed that the powder yielded compacts of approximately 45 percent of theoretical density when compacted mechanically. Low-temperature sintering produced more rapid densification in these compacts than in compacts prepared from conventional powders. Adding up to 20 percent ultrafine powder to conventional tungsten powder caused an increase in density upon compaction with maximum densification occurring at approximately 12 percent ultrafine powder.

RI 6836. Density and Molar Volumes of Binary Fluoride Mixtures, by B. Porter and R. E. Meaker. 1966. 13 pp. 8 figs. The densities of LiF, NaF, and KF, of binary mixtures of these alkali fluorides, and of binary mixtures of UF_4, ThF_4, YF_3, LaF_3, and CeF_3 with each of the alkali fluorides were measured as functions of the melt composition and temperature. Molar volumes at 1,000° C were calculated for all the mixtures. Binary systems containing LiF exhibited molar volume ideality. Binary fluoride systems containing either NaF or KF as the alkali fluoride exhibit positive deviations from molar volume additivity. However, molar volumes in the NaF-KF system are ideal.

RI 6837. Fire Hazard of Urethane Foam in Mines, by Donald W. Mitchell, Edwin M. Murphy, and John Nagy. 1966. 29 pp. 15 figs. Certification tests for urethane-foam systems and techniques for applying foam safety in mines are described. Fire hazard from foam exists if flame propagates beyond the ignition source or penetrates the foam. Foam that passes the certification tests can be applied on stoppings, continuous sections of ribs of relatively wide passageways (with no foam on the roof), short sections of roof such as overcasts, roof cavities, and intersections (with no foam on the ribs), and between buntons on one wall of a shaft. Foam on the ribs and adjoining roof presents a fire hazard. Stoppings covered with foam passing the certification tests are more resistant to penetration of heat, flame, and smoke than similar stoppings without foam. Flame propagation can be arrested by water sprays. Spontaneous ignition of foam can be prevented.

RI 6838. Inelastic Deformation of Rock Under a Hemispherical Drill Bit, by James Paone and Sathit Tandanand. 1966. 26 pp. 16 figs. The Bureau of Mines studied the behavior of rocks at the initial state of crater formation that results from the stresses created under a drill bit to determine which mechanical properties of rock are important in rock fragmentation by drilling. Although a definite relation between the drilling strength and relevant mechanical properties has not been established, maximum yield strength of rock is aparently a parameter of drillability of rock. The strengths of rock were considered from the Mohr-Coulomb criterion from which the surface of failure was constructed. The results from previous triaxial tests on Solenhofen limestone were adopted to verify the criterion of failure. Inelastic behavior of some rock types was observed under a low-velocity impact of a hemispherical bit and under static indentation with a similar bit. Permanent set at low applied loads in the indented area was measured with an interferometric technique. Quantitative determinations of strengths of Solenhofen limestone, Indiana limestone, and Tennessee marble were made under static indentation. The maximum yield strength estimated from the average stress over the indented area was used as the crushing strength of rock under a drill bit.

RI 6839. Influence of Continuous Carbonization Method, Temperature, and Carrier Gas on the Amounts of Individual Pyrolysis Products From a Subbituminous Coal, by C. Karr, Jr., J. R. Comberiati, K. B. McCaskill, and P. A. Estep. 1966. 9 pp. 1 fig. The Bureau of Mines studied the influence of carbonization method, temperature, and carrier gas on the composition of eight different low-temperature tars produced from a Colorado subbituminous coal. A fluidized bed was compared with an entrained bed, temperature was varied from 500° C to 650° C, and external heating using recycle gas as the carier gas was compared with internal heating using oxygen-containing gas. The entrained bed yielded significantly more *m*-cresol and *m*-ethylphenol, indicating that thermodynamic equilibrium was more nearly approached in the system. Increasing the temperature greatly increased the yield of benzenes and naphthalenes, while paraffins, olefins, and total tar acids were reduced. Using oxygen in the carrier gas decreased the yield of low-boiling phenols and increased that of paraffins and olefins at 650° C.

RI 6840. Detonation Initiation in Alkane-Oxygen Mixtures, by E. L. Litchfield and M. H. Hay. 1966. 6 pp. 3 figs. The techniques for direct initiation of detonation, developed by the Bureau of Mines, have been applied to gaseous mixtures of oxygen with methane, ethane, propane, butane, or hexane. An exploding wire was used as the initiation source to determine minimum stored electrical energies required to effect detonation of mixtures between one-half and two times the stoichiometric fuel ratios. Detonations were obtained in the most easily initiated mixtures of ethane, propane, butane, and hexane for initiation energies between 24 and 33 joules at 1 atm and 28 to 43 joules at 0.5 atm initial pressure. Methane mixtures, at 1 atm, were not observed to detonate when initiated with up to 484 joules.

RI 6841. Recovery of Additional Beryllium From Fluoferrate Leach Residue, by R. O. Dannenberg and J. M. Maurice. 1966. 12 pp. 3 figs. This Bureau of Mines report describes the results of research to develop a process for recovering additional beryllium from a commercial mill waste product, fluoferrate leach residue. Forty-five percent of the total beryllium in the leach residue was recovered in a beryllia product assaying over 98 percent BeO by a process comprising (1) leaching with 1 *N* sulfuric acid, (2) adjusting the acidity of the leach liquor to pH 2, (3) extracting the beryllium with di-2-ethylhexyl phosphoric acid (EHPA), (4) stripping the loaded extract with sodium hydroxide solution, (5) boiling the sodium beryllate strip solution to precipitate beryllium hydroxide, and (6) calcining the beryllium hydroxide. Calculated reagent requirement per pound of BeO recovered by a proposed flowsheet were 28.1 lb sulfuric acid, 0.04 lb flocculant, 0.15 lb EHPA, 0.06 lb isodecanol (IDA), 0.22 gal kerosine, and 6.3 lb sodium hydroxide.

RI 6842. Yield and Ultimate Strengths of Rock Bolts Under Combined Loading, by Lars Osen and Edward W. Parsons. 1966. 22 pp. 15 figs. The Bureau of Mines investigated (1) the effect of torsion on yield and ultimate strengths of bolts when the torsion is applied first and tensile load is applied independently of torsion and (2) various methods of increasing the tension-torque ratio and/or narrowing the data spread of the tension-torque relationship. A special torsional attachment was fabricated to attach to a universal testing machine to independently subject rock bolts to combined tensile and torsional loads. It was found that initially installed torsion is nullified during tensile loading and the tensile yield and ultimate strengths are not significantly reduced. Lubricating various components of a bolt assembly or using hardened washers will improve the tension-torque relationship during conventional installation; however, the torsional load is not nullified during this type of loading. Hence, a bolt is subjected to a combined stress throughout the loading cycle; the yield point will thus be lowered compared with the pure tensile yield if care is not taken during installation to stay below the torsional yield.

RI 6843. Presplitting Rock in the Presence of a Static Stress Field, by Harry R. Nicholls and Wilbur I. Duvall. 1966. 19 pp. 17 figs. Preliminary tests on presplitting rock in the presence of an in situ static stress field were undertaken to study the influence of a horizontal static stress field on the creation of a vertical presplit fracture plane. These tests indicated that it is easier to fracture the rock parallel to the in situ maximum compressive stress than in other directions. Instrumented shots indicate that the interaction of stress waves generated by the detonating charges is probably responsible for starting tensile fractures between shotholes and that expanding gases may propagate these initial cracks by a wedging action. The hole spacing for good presplitting appears to be equal to the half wavelength of the stress wave. However, wider hole spacing appears feasible if the initial fracture is started by closer hole spacing.

RI 6844. Chemical Processing of Florida Phosphate Rock Slime, by M. H. Stanczyk and I. L. Feld. 1966. 11 pp. The Bureau of Mines made bench-scale laboratory tests on a sample of typical Florida phosphate slime to determine alumina and phosphate extractions obtainable by agitation leaching, by baking and curing, and by a leach-electrolysis scheme. Recovery of mineral values from leached slime pulps by resin-in-pulp ion exchange contact and the reaction of the leached pulps to filtration, flocculation, and settling were also investigated. The best extractions of alumina and phosphate were obtained by (1) agitation leaching with sulfuric, hydrochloric, or nitric acid at an elevated temperature or (2) curing or baking the slime with sulfuric acid. Alumina extractions ranged from 80.8 to 90.0 percent and phosphate extractions ranged from 93.3 to 98.4 percent when the slime was leached at 90° C with sulfuric, hydrochloric, or nitric acids. Baking the slime with sulfuric acid at 200° C for 4 hours yielded an alumina extraction of 92.3 percent and a phosphate extraction of 97.0 percent, whereas curing with sulfuric acid at 100° C for 24 hours gave slightly higher alumina and phosphate extractions. Flocculation and settling properties of the slime were virtually unaffected in all cases. Filter area requirements, although somewhat improved as compared to untreated slime, remained relatively high. The lowest filter area requirement obtained was 44 square feet per ton of dry solids treated per day. Contacting leached slime pulps with ion exchange resins depleted the leach pulps of solubilized values; however, the filtration and settling properties of the barren pulps were unaffected. A leach-electrolysis scheme resulted in some concentration of solubilized phosphorus, but the method showed little promise of being commercially feasible. Work done in cooperation with the University of Alabama.

RI 6845. Tungsten Recovery From Low-Grade Concentrates by Amine Solvent Extraction, by P. E. Churchward and D. W. Bridges. 1966. 17 pp. 4 figs. The Bureau of Mines developed a process using amines for recovering tungsten as ammonium paratungstate from alkaline leach liquors without producing synthetic scheelite as an intermediate product. Over 90 percent of the tungsten in low-grade scheelite or ferberite concentrate was recovered as ammonium paratungstate by (1) autoclave leaching the concentrate with Na_2CO_3, (2) solvent extraction of the acidified leach liquor with kerosine solutions of either a quaternary amine (Aliquat 336) or a primary amine (Primene JM-T), (3) stripping the tungsten values from the quaternary amine with ammoniacal NH_4Cl, or from the primary amine with NH_4OH, and (4) crystallization of ammonium paratungstate from the strip liquor. Reagent consumption in pounds per pound of WO_3 recovered was, for the quaternary amine, 3 Na_2CO_3, 3.5 H_2SO_4, 2.2 NH_4Cl, 1 NH_3, and 0.4 glacial acetic acid; for the primary amine, it was 3 Na_2CO_3, 3.5 H_2SO_4, 0.06 NH_4Cl, and 0.9 NH_3. Both reagents extract molybdenum along with tungsten. Silicate and phosphate are partly extracted and contaminate the product; leach liquors containing these impurities require preliminary purification.

RI 6846. Crude Oil Characterizations Based on Bureau of Mines Routine Analyses, by H. M. Smith and J. H. Hale. 1966. 28 pp. 12 figs. Data from the Bureau of Mines routine method for the analysis of crude petroleum are used to characterize crude oils. Some data are used directly while other data are used to calculate aromatic, naphthalene, and paraffin contents of the distillation fractions and the correlation index of the paraffin-naphthene portion of the fractions. The calculated properties show significant differences in composition between crude oils. The methods of calculation and interpretation of data are explained and illustrated.

RI 6847. A Laboratory Comparison of the Adsorptivity of Eight Commercially Available Charcoals, by C. L. Klingman, A. A. Sonnek, and J. D. Marshall. 1966. 17 pp. 10 figs. The Bureau of Mines tested eight commercially available, activated charcoals experimentally to compare the following characteristics: Capacity for adsorption of nitrogen at 77° K and 170 atmospheres' pressure, surface area, carbon tetrachloride adsorption capacity, hardness, and density. The nitrogen adsorption test was devised to simulate plant conditions occurring in the final step of purification in Bureau helium facilities. The remaining tests were patterned after empirical acceptance tests that are widely used throughout the adsorbent industry. Surface area and carbon tetrachloride adsorption correlated well with nitrogen adsorption. The samples with low density generally had better adsorption qualities than those of higher density. The carbon tetrachloride test appeared to be the most practical for selecting a charcoal to be purchased, but an attrition, or hardness, test should also be run to be sure the charcoal will not crumble in use.

RI 6848. Nitrogen Gas in Five Oilfields on the Nesson Anticline in North Dakota, by L. C. Marchant. 1966. 24 pp. 16 figs. This Bureau of Mines report tabulates data on nitrogen-gas reservoirs and isolated occurrences of inert gases in several Williston basin oilfields. Recoverable reserves of nitrogen gas in the Minelusa nitrogen interval within the areas of five oilfields on the Nesson anticline in North Dakota are estimated at about 1.27 trillion standard cubic feet, based on computer analyses of logs from over 300 wells. This volume of nitrogen represents a large source of high-pressure inert gas and warrants consideration of possible application in oil-production operations. Drill-stem tests made in two of the fields indicated that nitrogen can be produced at rates up to 28 million cubic feet per day. Work done in cooperation with the University of Wyoming.

RI 6849. A Knudsen Effusion Apparatus for Vapor Pressure Measurements, by Stephen D. Hill, Arnold Adams, and F. E. Block. 1966. 18 pp. 6 figs. The Bureau of Mines devised and constructed a modified Knudsen effusion apparatus, permitting a constant measure of the weight of effusing vapor, to determine the equilibrium vapor pressure of metal halides at temperatures up to 1,200° K and over the pressure range 10^{-5} to 10^{-2} torr. The reliability of the apparatus was established by determining the vapor pressure of potassium chloride. After correcting for partial dimerization of the vapor, data obtained on solid KCl between 750° and 950° K can be expressed by the following equation:

$$\log P_{atm} = 7.369 \pm 0.008 - \frac{11{,}207 \pm 75}{T}.$$

A third-law treatment of the data yields an average heat of sublimation for the reaction $KCl_s = KCl_g$ at 298.15° K of 53.394±0.015 kcal/mole. The corresponding second-law value is 52.633±0.331 kcal/mole.

RI 6850. Preparation of High-Purity Molybdenum by Molten Salt Electrorefining, by R. E. Cumings, F. R. Cattoir, and T. A. Sullivan. 1966. 24 pp. 10 figs. The Bureau of Mines made electrorefining tests in inert-atmosphere, molten salt cells to develop methods for the preparation of high-purity molybdenum. Seven of the electrolytes investigated were suitable for the preparation of refined metal. The electrolytes were composed of molybdenum chloride in alkali chlorides or mixtures of alkali and alkaline-earth chlorides. An electrolyte composed of potassium chloride and potassium hexachloromolybdate was selected for a larger scale, more detailed study on the basis of its ease of preparation, its ability to retain the molybdenum salt, and the type of deposits obtained. High-purity molybdenum in the 99.99-percent-purity range was successfully prepared as dense plate up to 80 mils thick and as dendritic crystals. The temperature of electrolysis and the current density were major factors in determining whether plate or dendritic crystals of molybdenum were obtained.

RI 6851. Thermoelectric Properties of Yttrium Selenides and Tellurides, by L. D. Norman, Jr. 1966. 19 pp. 7 figs. The Bureau of Mines investigated the thermoelectric properties of yttrium selenides and tellurides from room temperature to 900° C. X-ray crystallographic data were determined for the yttrium-selenium and yttrium-tellurium compounds that were orthorhombic with a cubic substructure. The yttrium selenides and tellurides exhibited semimetallic to insulator conduction properties with figures of merit of 10^{-9} to 10^{-4} °C^{-1}. The monoselenide and monotelluride behavior was partially degenerate; unsatisfied bonds were the source of the large number of charge carriers. The higher stoichiometry selenide compounds were intrinsic semiconductors, but with high electrical resistivities. A critical defect or impurity ionization energy for carrier activation appeared to exist in the majority of telluride compounds. Mobility and energy band determinations are required to interpret completely the observed effects in most of the compounds studied.

RI 6852. Determination of Copper With Disodium Ethylenedinitrilo Tetraacetate (EDTA), by R. E. Stiles and D. L. Munneke. 1966. 12 pp. The modified perchloric-EDTA method devised by the Bureau of Mines for the determination of copper in high-grade samples gives results that are more precise and more accurate than those from the classical sulfuric-iodometric method. Although the perchloric-EDTA method is more costly than the conventional method, the saving in time alone largely offsets this difference. Specifically, the modifications made in the conventional procedure comprise (1) use of perchloric acid instead of sulfuric acid for dissolution of copper minerals, (2) precipitation of copper as copper sulfide from dilute perchloric acid solution, (3) wet oxidation and dissolution of the precipitated copper sulfide, (4) use of larger amounts of indicator than those employed in the Schwarzenbach method of titrating low-tenor copper solutions with disodium ethylenedinitrilo tetraacetate and murexide indicator, and (5) use of refrigeration to partially stabilize aqueous solutions of the indicator.

RI 6853. Vapor Deposition of Molybdenum-Tungsten Alloys, by J. G. Donaldson and H. Kenworthy. 1966. 12 pp. 5 figs. Binary alloys of molybdenum and tungsten were prepared by the Bureau of Mines in laboratory-scale experiments by hydrogen reduction of their vaporized hexafluorides. Near-optimum deposition parameters were determined, and the nature of the deposited alloys was investigated. Dense, homogeneous alloys were codeposited between 650° and 750° C with a reduction efficiency of more than 75 percent. The alloy composition was uniform when the hydrogen ratio in the gas feed mixture did not exceed three times the stoichiometric requirement. Regulating the proportions of the metal hexafluorides in the gas feed provided a large degree of control over the composition of the deposit. Hardness of the deposits varied directly with the proportion of excess hydrogen in the gas feed and with the weight-percent of tungsten in the alloy. Hardness was not affected by deposition temperature over the range 650° to 750° C for specimens of similar composition. Extreme brittleness and unsuitable physical shapes of the alloys prevented tensile strength measurements.

RI 6854. Mass and Infrared Spectra of Selected Unsaturated Hydrocarbons and Oxygenates, by R. F. Kendall and B. H. Eccleston. 1966. 107 pp. Only a limited number of mass and infrared reference spectra of high-purity unsaturated hydrocarbons and oxygenates are presently available in the literature. To aid Bureau of Mines research programs requiring such references, 64 mass spectra and 70 infrared spectra were obtained and are reported. The individual compounds, acquired from commercial sources, were purified by preparatory gas chromatography. Purity determinations were made using a combination of analytical gas chromatography, microhydrogenation, and catalytic deoxygenation. These spectra will aid spectroscopists in the identification of compounds of the types reported.

RI 6855. Radioactive Techniques for Continuously Measuring Flotation Froth Density and Pulp Flow Rates, by J. V. Batty, H. L. Gibbs, and A. M. Poston, Jr. 1966. 18 pp. 9 figs. The Bureau of Mines devised techniques involving the use of beta- and gamma-ray-emitting radioisotopes and successfully adapted these techniques to the density of mineralized flotation froths, the rate of flow of finely ground ore pulps, and the residence time of pulps in processing circuits. Specifically, the water and mineral loads of flotation froths were continuously measured by determining the proportion of a constant-strength beam of beta rays that was absorbed by the froth column. Continuous measurement of the rate of flow of an ore pulp was accomplished by measuring the changing width of a free-falling stream of the pulp with a collimated beam of beta rays. The residence time of solids in conditioning and resin-in-pulp circuits was accurately measured by following the progress through these circuits of a portion of the pulp that had been tagged with the gamma-emitting Ag^{110} radioisotope.

RI 6856. Film Coefficients of Heat Transfer for Helium at 2,000° to 2,500° F in Turbulent Flow, by N. H. Coates and A. F. Galli. 1966. 22 pp. 10 figs. The Bureau of Mines determined average film coefficients of heat transfer for helium flowing through smooth, water-cooled tubes at Reynolds numbers of 5,000 to 25,000, helium inlet temperatures of 1,600° to 2,600° F, average temperature difference across the helium film of 800° to 1,300° F, and the heat flux to 215,000 Btu/(hr)(sq ft). Since helium was the only gas used, the ranges of values for physical properties of the fluid are limited—thermal conductivity from 0.15 to 0.20 Btu/(hr)(sq ft)(° F/ft), viscosity from 0.082 to 0.104 lb/(ft)(hr), and Prandtl number from 0.63 to 0.68. Four equations, three of them dimensionless, correlate these coefficients with other properties of the helium—bulk temperature, film temperature, dimensionless parameters based on temperature, and the ratio of wall temperature to bulk temperature,

$$\frac{H_iD_i}{k_b}=0.020\left(\frac{D_iG}{\mu}\right)_b^{0.8}\left(\frac{C_p\mu}{k}\right)_b^{0.4},$$

$$\frac{h_iD_i}{k_f}=0.0197\left(\frac{D_iG}{\mu}\right)_f^{0.8}\left(\frac{C_p\mu}{k}\right)_f^{0.4},$$

$$\frac{h_iD_i}{k_b}=0.0215\left(\frac{D_iG}{\mu}\right)_b^{0.8}\left(\frac{C_p\mu}{k}\right)_b^{0.4}\left(\frac{\mu_w}{\mu_b}\right)^{0.14},$$

$$h_i=0.0198\,\frac{G^{0.8}}{D_i^{0.2}}.$$

Values of the average inside film coefficient of heat transfer determined from these equations agree within 10 percent. Work done under an agreement with the U.S. Atomic Energy Commission.

RI 6857. Hot Gas Ignition Temperatures of Hydrocarbon Fuel Vapor-Air Mixtures, by J. M. Kuchta and R. J. Cato. 1966. 14 pp. 9 figs. The Bureau of Mines used laminar hot air jets of ⅛- to ¾-inch diameter to determine the hot gas ignition temperatures of various combustible vapor-air mixtures. The combustibles were *n*-hexane, *n*-octane, *n*-decane, a hydrocarbon jet fuel (JP-6), and an adipate ester aircraft engine oil (MIL-L-7808). Minimum ignition temperatures occurred at a fuel-to-air weight ratio of about 0.5 and were not greatly sensitive to variations of fuel concentration. Moderate variations of jet velocity also had little influence on these ignition temperatures. However, these temperatures decreased with increase in heat source dimensions (jet diameter). The hot gas ignition temperatures of the combustibles weer not necessarily much greater than corresponding autoignition and wire ignition temperatures when the size of the heat source and the ignition criterion were the same. Work done under a U.S. Airforce Aero Propulsion Laboratory Delivery Order.

RI 6858. A Coal-Fired Water Pump, by J. E. Zeilinger, Walter Kawa, P. S. Lewis, and R. W. Hiteshue. 1966. 12 pp. 3 figs. The technical feasibility of using energy from explosive ignitions of coal dust to pump water was demonstrated in an exploratory investigation. Ignition of small amounts of pulverized coal that were dispersed in air over columns of water pumped 5.3 gallons of water per cycle when operated against a head of 30.75 feet. Water displacement was accomplished by either manual or automatic operation through a single cycle and by automatic operation through a continuous series of cycles of 1-minute duration. Operating through single cycles, slurries containing up to 3 pounds of coal and 4.6 gallons of water were also pumped. Possible uses of an efficient coal-fired pump would include pumping water for irrigation purposes, removing water from mines, transporting coal from mines in the form of a slurry, and pumping water to elevated reservoirs at electric powerplants so that it could be used to generate electricity during peak periods of demand.

RI 6859. A One-Step Operation for Recovery of Manganese as Chloride From Ores and Slags, by A. A. Cochran and W. L. Falke. June 1967. 22 pp. 12 figs. The Bureau of Mines studied the development of practical methods for recovering manganese from the extensive, domestic resources of low-grade ores and open hearth slags. A one-step operation was developed on a laboratory scale in which manganese and iron compounds are treated with chlorine, volatilized, and separated by selective condensation. Manganese recoveries of 90 to nearly 100 percent were obtained from nine of the most important domestic ores. Analyses of the manganese chloride product indicated that it was suitable for aqueous electrolysis with little additional purification. A complete, integrated process that provides for the recovery and recycling of chlorine is proposed. This process appears to have distinct advantages over previously proposed manganese recovery processes, and, in sharp contrast to leaching procedures, it is applicable to practically any manganese-bearing material.

RI 6860. Stresses in Rock Outcrops Near Atlanta, Ga., by Verne E. Hooker and Wilbur I. Duvall. 1966. 18 pp. 7 figs. The Bureau of Mines conducted an investigation to determine the state of stress in crystalline rock outcrops near Atlanta, Ga. The secondary principal stresses in a horizontal plane near the surface are compressive and are 500 to 3,000 psi. The maximum compressive stress is northeast-southwest in the Stone Mountain-Lithonia district but changes to northwest-southwest near Douglasville. The elastic constants were determined from data obtained by static and dynamic laboratory methods and in situ velocity measurements. Results show Young's modulus to be dependent upon both stress level and anisotropy in the rock. Average secant moduli obtained from triaxial tests were used to compute the applied stress from borehole deformation measurements.

RI 6861. Thermodynamic Data for Molybdenum Carbide and Tantalum Carbide, by L. B. Pankratz, W. W. Weller, and E. G. King. 1966. 10 pp. 2 figs. The heat capacity of dimolybdenum carbide (Mo_2C) was measured from 51° to 298° K, and the entropy at 298.15° K was evaluated. Heat content measurements above 298.15° K were conducted for dimolybdenum carbide and monotantalum carbide (TaC). The results were combined with known heats of formation and the 298.15° K entropy for TaC to obtain values of the heat and free energy of formation from 298.15° K to 1,400° K for Mo_2C and from 298.15° K to 1,800° K for TaC.

RI 6862. High-Temperature Heat Content of Lithium Columbate, by L. B. Pankratz and E. G. King. 1966. 9 pp. 3 figs. The heat content above 298.15° K of ferroelectric lithium columbate ($LiCbO_3$) was measured to 1,770° K. The Curie temperature was determined to be 1,450° K, the melting point 1,540° K, and the heat of fusion 16.94 kcal/mole. Heat content and entropy increments have been tabulated for the temperature range from 298.15° to 1,800° K. Heat contents are also given in equation form.

RI 6863. Test Operation of a Pneumatic Vibrating-Blade Planer. A Progress Report on Phosphate Mining Research, by Webster S. Anderson. 1966. 16 pp. 11 figs. Bureau of Mines planer mining tests on the phosphate bed of the Douglas mine, near Drummond, Mont., indicated that a competent bed with a Mohs' scale hardness of 3 to 4 cannot be mined economically with the planer. Although planer mining was feasible where the bed was fractured enough for a 4-inch depth of cut to be consistently maintained, the depth of cut in the competent beds at the Douglas mine did not exceed 0.5 inch. Average production rates were 0.15 ton per minute and 9 tons per man-shift.

RI 6864. Surface Area Studies of Anthracite by Carbon Dioxide Adsorption, by Jerry W. Ramsey, J. O. Mapstone, G. A. Brady, and J. W. Eckerd. 1966. 10 pp. 1 fig. The Bureau of Mines studied two Pennsylvania anthracites using low-temperature carbon dioxide adsorption. A modified form of the Brunauer-Emmett-Teller equation was used to calculate specific surface areas. Two mesh sizes of each anthracite were used to determine how gamma irradiation at 10^6 and 10^8 rads, both in vacuum and in the presence of air, affected the carbon dioxide surface areas. Results show that anthracites have a system of pores that are all interconnected rather than isolated; that anthracites differ from one another in specific surface, which may correlate with density; and that irradiation in vacuum has no discernible effect on specific surface of anthracite, but irradiation in air does produce changes in specific surface.

RI 6865. A Machine-Test Method for Measuring Carbon Dioxide in the Inspired Air of Self-Contained Breathing Apparatus, by E. J. Kloos and J. A. Lamonica. 1966. 11 pp. 6 figs. The Bureau of Mines devised a new machine-test method for measuring carbon dioxide inspired by a wearer of self-contained breathing apparatus. The new method compares favorably in speed and precision with standard man-tests, in which the apparatus is tested while actually worn, and is scheduled for use in future approval tests for facepiece carbon dioxide measurements. Man-tests will still be used to measure the efficiency of the carbon dioxide sorbent materials in closed-circuit breathing apparatus.

RI 6866. Intermediate Phases in the Magnesium-Cerium System Between Magnesium and Mg_9Ce, by R. L. Crosby and J. L. Holman. 1966. 18 pp. 4 figs. Microscopical and X-ray diffraction techniques were used to identify two intermediate phases in that part of the solid region of the magnesium-cerium system between magnesium and Mg_9Ce. Previous literature had reported only one intermediate phase for this region, but chemical analysis determined the approximate composition of the two compounds to be $Mg_{23}Ce_2$ and $Mg_{17}Ce_2$. The range in composition of the two intermediate phases was found to be limited to less than 0.3 atomic percent cerium. The study did not determine the crystal structure of $Mg_{17}Ce_2$, but that of $Mg_{23}Ce_2$ is tetragonal with $a = 10.33$ A and $c = 19.51$ A.

RI 6867. Investigation of Correlation Between Assay Values and Unequal Sample Interval Lengths, by Scott W. Hazen, Jr., and William L. Meyer. 1966. 46 pp. 23 figs. Relationships that may exist between assays and sample-interval lengths when using unequal sample intervals in mine sampling have been investigated as part of the problem of adapting statistical methods to the analysis of weighted average grades. The theoretical relationship between the amount of difference in the weighted and unweighted average grade of ore and the size of the correlation coefficient between assay value and sample-interval length was found to be linear. Differences between actual field data and the expected theoretical linear relationship are examined. It is hypothesized that the use of unequal sample intervals in mine sampling is, in fact, stratified sampling in a statistical context. Statistically, methods currently used in mine sampling, involving unequal sample intervals, fail to consider differences in the inherent variances in grade of ore within the various strata established by using unequal sample intervals. Consequently, the strata are sampled with different precision. This difference in precision of sampling between strata may account for much of the deviation between the plotted points representing actual field sampling data and the theoretical linear relationship between the amount of the difference between weighted and unweighted average grade of ore and the size of correlation coefficient between assays and sample-interval lengths.

RI 6868. Comparison of Products From High-Temperature Irradiation and Carbonization of Coal, by A. G. Sharkey, Jr., J. L. Shultz, and R. A. Friedel. 1966. 9 pp. 9 figs. The Bureau of Mines investigated gases from flash and laser irradiation of Pittsburgh seam (hvab) coal to determine the action of high temperatures on irradiation. Temperatures in excess of 1,000° C were reached with both types of irradiation. Craters about 300 microns in diameter were produced in the coal with millisecond pulses from the laser unit rated at 1.7 joules' output. Gaseous products from laser and flash irradiations in vacuum contained 21 and 8 percent acetylene, respectively. Diacetylene, vinylacetylene, and other products to molecular weight 130 were indicated in the mass spectrum of the gas from the laser study. Single experiments were also conducted in which the laser energy, particle size of the coal, and atmosphere were varied. The results indicated that the distributions of products obtained from the flash and laser irradiations of coal were different from that produced in high-temperature carbonization.

RI 6869. Fly Ash as a Coagulant Aid in Water Treatment, by Richard C. Ballance, John P. Capp, and Jerry C. Burchinal. 1966. 13 pp. 9 figs. Fly ash from four sources and in certain proportions was shown to assist chemical coagulation of turbid water and settling of chemically induced floc. Fly ash reduced the time required to form the first visible floc, promoted more uniform flocs about 2 mm in diameter, and increased the mean settling rate of floc particles. Also, the additon of fly ash produced denser sludges than those obtained with alum alone. Final turbidities were independent of fly ash particle size and carbon content. Optimum proportions of fly ash additive are given.

RI 6870. Recovery of Additional Oil From Water-Drive Reservoirs, by Larman J. Heath and C. H. Riggs. 1966. 11 pp. 1 fig. The Bureau of Mines explored the use of air or natural gas for recovering additional oil from natural water-drive reservoirs with little or no original gas saturation. Engineering and production data for a field in the Mid-Continent area, results of limited laboratory experiments, and data shown in the literature were considered. Injecting air into a water-coned well could seriously damage the well. Injecting natural gas into the watered-out zone could improve the producing water-oil ratios. In the reservoir studied, oil recovery can be increased by injecting natural gas to decrease water-oil ratios. Laboratory tests on a core from the field show an increase in oil recovery of 7.6 percent of the original oil in place as a result of increasing the free gas saturation. This recovery could amount to as much as an additional 6 million barrels of oil from this field.

RI 6871. Correlation of BM-AGA Carbonization Yields From 13- and 18-Inch-Diameter Retorts, by C. Ortuglio and J. G. Walters. 1966. 19 pp. Equations were developed to determine the relationship of yields and products obtained from Bureau of Mines-American Gas Association method carbonization in 13- and 18-inch-diameter retorts. The developed equations indicate that results of carbonization in 18-inch-diameter retorts can be predicted from results obtained with 13-inch-diameter retorts.

RI 6872. Carbonizing Properties of Coals From Fayette and Greenbrier Counties, W. Va., by D. E. Wolfson and J. H. Lynch, Jr. 1966. 18 pp. 1 fig. Twenty-two samples of West Virginia coals were carbonized at 900° C by the Bureau of Mines-American Gas Association (BM-AGA) method, and yields of products and physical properties of cokes were determined. Eighteen samples represented the Coalburg, No. 2 Gas, No. 2 Gas and Peerless, Powellton, Eagle, Big Eagle, Lower Eagle, Sewell, Fire Creek, and Pocahontas No. 6 beds in Fayette County, and four samples represented the Sewell and Fire Creek beds in Greenbrier County. Expansion characteristics of the majority of samples were determined in the Bureau of Mines sole-heated oven. Chemical analyses were determined for all coals. The coals in Fayette County are high volatile A, medium volatile, and low volatile in rank, and the Greenbrier coals are medium volatile in rank. Most of the coals are chemically suitable for metallurgical coking. All coke strength indices are within acceptable limits for metallurgical coking coal. All the high-voltage A coals contracted and the medium- and low-volatile coals expanded in the sole-heated oven expansion test.

RI 6873. Heats of Formation of Lithium Sulfate and Five Potassium- and Lithium-Aluminum Silicates, by R. Barany and L. H. Adami. 1966. 18 pp. The heats of formation of seven substances were determined by solution calorimetry. At 298.15° K, the heat of formation of lithium sulfate from lithium, rhombic sulfur, and oxygen was -343.1 ± 0.7 kcal/mole, and the heat of formation of lithium sulfate monohydrate from lithium, rhombic sulfur, oxygen, and hydrogen was -414.3 ± 0.7 kcal/mole. For the silicates, the heats of formation at 298.15° K from the elements were kaliophilite, -503.8 ± 0.5 kcal/mole; leucite, -721.6 ± 0.8 kcal/mole; eucryptite, -505.2 ± 0.6 kcal/mole; alpha spodumene, -727.9 ± 0.9 kcal/mole; and beta spodumene, -721.1 ± 0.9 kcal/mole. The corresponding heats of formation at 298.15° K from the constituent oxides were kaliophilite, -42.7 ± 1.1 kcal/mole; leucite, -42.8 ± 1.1 kcal/mole; eucryptite, -16.1 ± 0.7 kcal/mole; alpha spodumene, -21.0 ± 0.7 kcal/mole; and beta spodumene, -14.3 ± 0.7 kcal/mole.

RI 6874. Preparation Characteristics of Coal From Randolph County, W. Va., by A. W. Deurbrouck. 1966. 30 pp. 3 figs. The Bureau of Mines analyzed 13 samples collected from three Randolph County coalbeds. The Peerless and Sewell bed samples were generally of metallurgical quality as received from the mines or could be easily upgraded. However, the Lower Kittanning coalbed samples proved to be quite inimical to upgrading to metallurgical quality.

RI 6875. Electrolytic Methods for Producing Titanium and Titanium Alloys, by E. K. Kleespies and T. A. Henrie. 1966. 10 pp. 5 figs. A technique was demonstrated for electrowinning titanium from titanium nitride and titanium dioxide. Titantium-nickel-copper metal solutions containing 26 to 61 weight-percent titanium were prepared by electrolyzing titanium nitride in molten mixtures of potassium fluotitanate and sodium chloride or barium chloride and depositing titanium on nickel-copper cathodes. A titanium-nickel alloy was prepared by electrolyzing titanium dioxide in an electrolyte of potassium fluotitanate, sodium fluoride, and calcium fluoride and depositing titanium on solid nickel cathodes. This alloy contained 21 weight-percent titanium and had a combined oxygen-carbon content of less than 0.1 weight-percent. A compartmented cell confined the oxide feed near the anode and inhibited oxygen contamination of the metal.

RI 6876. A Computer Method of Fitting Surfaces to Assay and Other Data in Three Dimensions by Quadratic-Regression Analysis, by Richard F. Link, Norman N. Yabe, and George S. Koch, Jr. 1966. 42 pp. 22 figs. A statistical technique, useful for analysis of assay and other data characterized by location in three dimensions, is described. If present, trends in the data are defined for the purposes of improving ore estimation, predicting ore beyond existing workings, and aiding geological interpretation. The technique is to fit linear and quadratic polynomial equations to the data through the statistical method of regression analysis. The fitted linear equations have the geometric form of hyperplanes; the fitted quadratic equations have the geometric form of ellipsoids or elliptic hyperboloids of one or two sheets. To visualize these three-dimensional froms, contour maps of a series of plane sections through the fitted surfaces are plotted. Both the fitting of the polynomial equations and the plotting of the contour maps are done by electronic computer to facilitate calculations and to obtain accurate results. Computer programs are described in appendixes. Methods employed are illustrated by an example analysis, based on data from a part of the Fresnillo mine, Zacatecas, Mexico.

RI 6877. Separation of HF From $HF\text{-}SiF_4\text{-}H_2O$ Mixtures, by Robert K. Koch, Arden D. Fugate, and Henry E. Blake, Jr. 1966. 15 pp. 5 figs. Separating HF from $HF\text{-}SiF_4\text{-}H_2O$ mixtures by passing the mixed gases through a sodium fluoride slurry in an airlift scrubber and forming a mixed precipitate of $NaHF_2$ and Na_2SiF was investigated. The oven-dried precipitate was thermally dissociated in two stages. The first stage was carried out at 400° C and dissociated $NaHF_2$ to NaF and HF. Condensation and analysis of the evolved HF proved it to be 97 to 99 weight-percent HF containing 0.79 to 0.99 weight-percent H_2O and 10 to 93 ppm silicon. The second stage was carried out at 700° C and dissociated Na_2SiF_6 to NaF (for recycle) and SiF_4. The quantity of HF recovered from gaseous $HF\text{-}H_2O$-air mixtures decreased with increasing relative H_2O concentrations. Air was beneficial when scrubbing extremely dilute wet HF gases. At HF partial pressures of 0.24 and 0.013 mm Hg in the scrubber entrance gases, HF partial pressures of 6.2×10^{-4} and 9×10^{-5} mm Hg were obtained, respectively, in the scrubber exit gases. Scrubber efficiencies were 99.7 and 99.3 percent.

RI 6878. Electrorefining of Titanium-Nitrogen Alloys, by Oliver Q. Leone and D. E. Couch. 1966. 11 pp. 4 figs. Electrorefining tests using titanium-nitrogen alloys as anode material showed that no significant quantity of nitrogen was transferred to the cathode deposit. The nitrogen of the anode remained in the scale, and the titanium-nitrogen alloy was anodically insoluble in the electrolyte when the nitrogen content was 11 weight-percent.

RI 6879. Sulfur Compound Characterization Studies on High-Boiling Petroleum Fractions, by C. J. Thompson, N. G. Foster, H. J. Coleman, and H. T. Rall. 1966. 17 pp. 8 figs. This study describes the preparation of sulfur compound concentrates boiling from 225° to 400° C and reports the sulfur types detected in these concentrates by low-voltage mass spectrometry (LVMS). Existing LVMS methods were extended; the procedures described should be generally applicable to high-boiling petroleum distillates and concentrates as a preliminary means of narrowing the number of fractions to be considered for more detailed separation and identification studies. The following major sulfur compound constituents of petroleum are indicated by the data: benzothiophenes, dibenzothiophenes, naphthanothiophenes, naphthenobenzothiophenes, and homologs and isomers of these. Cyclic and chain sulfides comprise a significant portion of the gas-oil range sulfur compound types. The presence of some classes of sulfur compounds containing two sulfur atoms per molecule was indicated. Work done in cooperation with the American Petroleum Institute.

RI 6880. Drillability Studies, Statistical Regression Analysis of Diamond Drilling, by James Paone, William E. Bruce, and Pauline R. Virciglio. 1966. 26 pp. 6 figs. This report shows the feasibility of predicting drillability, analytically, by using regression analysis techniques. The approach is new in diamond-drilling research. Further, the study shows that this technique may be of value to drill manufacturers and others in mathematically delineating performance characteristics of new drills in specific rock types. Another application might be the prediction of penetration speeds in extraterrestrial material based on the physical properties of the materials as samples become available. Prediction equations for penetration rates are presented for 9 rocks drilled in the laboratory and for 20 rocks drilled under field conditions. The prediction equations are based on drill operating parameters and on characteristics of the rock penetrated. No single physical property appeared consistently in the best predictor equations, and all the physical properties were found to be highly correlated with each other.

RI 6881. Effect of Gamma Radiation on the Reaction of Anthracite With Fluorine and Chlorine, by Ralph Husack, G. A. Brady, and J. W. Eckerd. 1966. 17 pp. 7 figs. The Bureau of Mines investigated the effect of gamma radiation on reactions between Pennsylvania anthracite and fluorine and chlorine. In the tests with fluorine about 90 percent of the coal reacted at 350° C to form volatile products whether or not irradiation was employed. Up to 0.8 ml of liquid products per gram of anthracite was collected. Among the 25 compounds indicated by gas chromatography, fluoroform and 1,1-difluoroethylene were tentatively identified from their relative retention times and perfluorocyclopentane from its infrared spectrum. In addition, a clear, hard wax, probably a fluorocarbon, was formed at 45° C in both the presence and absence of radiation. With chlorine there was no significant difference due to radiation, and preliminary tests indicated that the chlorine reacted more with the organic matter of anthracite at 200° C than with inorganic matter. At 400° C the results were inconclusive because of excessive corrosion in the reaction vessel.

RI 6882. Electrowinning and Tapping of Lanthanum Metal, by E. S. Shedd, J. D. Marchant, and T. A. Henrie. 1966. 10 pp. 3 figs. The Bureau of Mines investigated electrowinning and tapping lanthanum metal from lanthanum oxide in a fluoride bath. The electrolyte was composed of LaF_3, BaF_2, and LiF. Metal containing 0.2 percent impurities was produced at a rate of over 2 pounds per hour. Principal impurities were carbon, aluminum, and silicon. Low-carbon metal was produced by continually discharging the carbon oxide gases and maintaining 0.1-atmosphere pressure. Anode reactions and cell design were found to be important factors in cell operation. Both frozen electrolyte skulls and tungsten metal crucibles proved satisfactory for collecting the metal and did not react with the molten lanthanum.

RI 6883. Stratigraphic and Geographic Variation of Shale-Oil Specific Gravity From Colorado's Green River Formation, by John Ward Smith and John W. Harbaugh. 1966. 11 pp. 3 figs. Variations in specific gravity of oil retorted from oil shales of the Eocene Green River Formation in northwestern Colorado were evaluated statistically, demonstrating that these variations are very strongly associated with stratigraphic position and less strongly but still significantly associated with geographic location. Specific gravity of oil retorted from these oil shales apparently varies with the carboxyl group content of the oil shale's organic matter. Higher temperatures accompanying increasing depth of burial probably progressively decarboxylated oil shale's organic matter, producing the decrease of oil specific gravity associated with deeper stratigraphic position. The geographically associated oil-gravity variations were probably produced by regional variation in the original thickness of late Cenozoic extrusive rocks once overlying the Green River Formation.

RI 6884. The Use of Coal and Modified Coals as Adsorbents for Removing Organic Contaminants From Waste Waters, by G. E. Johnson, L. M. Kunka, A. J. Forney, and J. H. Field. 1966. 56 pp. 11 figs. Batch tests of coals and coal-derived materials were made by the Bureau of Mines to determine their effectiveness in removing organic contaminants (COD or chemical oxygen demand, comprising those organic compounds that can be chemically oxidized, and ABS or alkylbenzene sulfonate, common household detergents) from the final effluent of secondary-treated waste waters. The adsorptive capacities of fly ashes, coals, including at least one sample of each rank found in this country, pretreated coals, and miscellaneous materials, including commercial chars and coke, were determined and compared with that of granular activated carbon. The coals, though not as effective as activated carbon, possess an economic advantage—they are relatively inexpensive, and they can still be burned as fuel without any loss of fuel value after use in waste-water treatment. A hvcb coal was found to be one of the best, having about one-fourth the capacity of activated carbon for COD, adsorbing about 4 percent of its weight before it became saturated. Several coals contained constituents that added to the COD content of the treated water. Thus, knowledge of the performance of the coal is necessary to insure selection of a proper coal as adsorbent. Some of the fly ashes tested were quite effective, removing as much as 66 percent of the COD and 76 percent of the ABS present. The effectiveness of the fly ashes improves with increasing carbon content. Coals pretreated by mild oxidation were ineffective as adsorbents. Work done under an agreement with the Public Health Service, U.S. Department of Health, Education, and Welfare.

RI 6885. Reconnaissance of Yttrium and Rare-Earth Resources in Northern New Jersey, by Roger L. Williams. 1967. 34 pp. 7 figs. Northern New Jersey was investigated as a potential future source of yttrium and the rare-earth elements. The studies consisted of geophysical surveying, sampling, and exploratory drilling. Thirty-three deposits were investigated, of which five demonstrated some potential resources of yttrium and rare-earth minerals. Results indicate that the deposits examined do not contain quantities of yttrium and the rare-earth elements recoverable under present economic conditions. Detailed studies conducted at the Scrub Oaks mine, near Dover, N.J., delineated an yttrium and rare-earth-bearing zone within the magnetite-hematite ore body that represents a potential low-grade deposit. Two hundred and eighty-five feet of diamond drill core was obtained from exploration studies conducted at the Bemco prospect in Sussex County. Low-grade deposits were identified at the Canfield phosphate mine and the Tanners Brook monazite placers in Morris County, and the Marble Mountain prospect in Warren County.

RI 6886. Heat Content of Some Blast-Furnace and Synthetic Slags, by E. F. Foerster and P. L. Weston, Jr. 1967. 21 pp. 6 figs. The Bureau of Mines used a diphenyl ether calorimeter to determine the heat contents of natural and synthetic blast-furnace slags. For solid slags, enthalpy ($H_T - H_{300}$) at 1,448° to 1,680° K ranged from 282.1 to 348.5 cal/g (±3 percent); liquid slag values were 400.1 to 514 cal/g (±3 percent) in the temperature range between 1,626° and 1,890° K. Experimental results for liquid slags were 14.3 to 16.2 percent higher than the enthalpies calculated from thermodynamic tables; values for solid slags ranged from 5.3 percent lower to 3.9 percent higher than calculated values. Experimental results for liquid synthetic slags ranged from 14.9 to 24.3 percent higher than the calculated enthalpies; values for solid synthetic slags were from 1.0 to 3.4 percent higher.

RI 6887. Deep Mine Stress Determinations Using Flatjack and Borehole Deformation Methods, by Robert W. Ageton. 1967. 25 pp. 14 figs. The Bureau of Mines investigated the in situ vertical component of the rock stress in the rib of the haulage drift on the 6100-level of the Star mine, Burke, Idaho, using the flatjack and borehole deformation methods. The estimate of the vertical component of stress about 2 feet into the rib at a station along the haulage drift on the 6100-level of the Star mine by the flatjack method is approximately 5,875 psi, whereas the borehole deformation procedure at this station yielded a value of 5,500 psi for the same depth into the rib. The test zone is approximately 5,625 feet below the surface. No attempt was made to extrapolate stress estimates beyond the depth of the flatjack installation.

RI 6888. Comparison of Two Methods for Studying Relative Performance of Explosives in Rock, by Thomas R. Bur, Lyle W. Colburn, Harry R. Nicholls, and Thomas E. Slykhouse. 1967. 40 pp. 20 figs. The strain and pressure gage methods for evaluating the relative performance of explosives in rock were compared. This comparison was based on a study of the responses of strain and pressure gages to explosion-generated seismic waves. Several explosives, representing a wide range of detonation pressures, were used. In general the relative performance of these explosives, as determined from amplitude, impulse parameter, and energy parameter measurements, is the same if the compressive portion of the strain pulse and the comparable portion of the pressure pulse are considered. Other similarities and differences of the two methods are also discussed. Work done in cooperation with the Dow Chemical Co.

RI 6889. Refining Iron-Contaminated Zinc by Filtration and Centrifugation, by J. A. Ruppert and P. M. Sullivan. 1967. 15 pp. 6 figs. The Bureau of Mines investigated methods of refining iron-contaminated zinc to marketable quality and developed a laboratory-scale process in which aluminum, added as a refining agent, reacted with the iron, forming solid Fe_2Al_5 which floated to the surface of the melt. Solids were separated by both filtration and centrifugation, using a unique type of "dipping" centrifuge devised during the work. Typical zinc recovery was 95 percent, and iron content of the metal was lowered from 0.37 to 0.02 percent.

RI 6890. Theoretical Stress Distribution Near Explosively Expanded Rock Bolt Anchors, by M. S. Oudenhoven and Lars Osen. 1967. 10 pp. 5 figs. The Bureau of Mines conducted an investigation to determine the theoretical stress distribution in the vicinity of explosively expanded rock bolt anchors independent of their bolts. Plane-strain solutions applicable to this problem were obtained by combining the field pressure with the uniform pressure that would be produced by vertically placed anchors having 2-, 3-, and 4-foot spacings. High rock stress which would be produced by an anchor was localized, as would be expected from St. Venant's effect, and increased as the field pressure decreased.

RI 6891. Bench-Scale Production of Carbon Disulfide From Lignite Char and Sulfur, by E. A. Sondreal, A. M. Cooley, and R. C. Ellman. 1967. 20 pp. 11 figs. The Bureau of Mines investigated the use of lignite char for producing carbon disulfide; CS_2 production rates were as high as when wood charcoal was used as raw material. The maximum space velocity for CS_2 produced in the bench-scale study was 9,280 hour^{-1}, reacting sulfur and lignite char at 792° C. The reaction temperature and the temperature at which the char was carbonized were the two most important factors in determining CS_2 production rates. Increasing the carbonization temperature in nitrogen from 400° to 900° C advanced the temperature at which carbon disulfide was first produced from 550° to 850° C. The average activation energy for reacting chars with sulfur was 44,000 cal/g mole. The reaction was first order with respect to the partial pressure of sulfur. Increasing the rate of sulfur admision caused a decrease in rate of production at otherwise similar conditions. Rates were not affected by either char size or sodium carbonate catalysis. High space velocities at moderate temperatures using inexpensive lignite chars could offer an economic advantage in the manufacture of carbon disulfide provided that yields were attractive.

RI 6892. Investigations of the White Mountain Mercury Deposit, Kuskokwim River Basin, Alaska, by Raymond P. Maloney. 1967. 94 pp. 15 figs. The Bureau of Mines investigated the White Mountain mercury deposit, in the Kuskokwim River basin, to better determine the extent of mercury mineralization and to encourage its development by private industry. A program of diamond drilling, augering, buldozer trenching, and sampling was carried on during four field seasons, from 1960 to 1963, inclusive. Significant amounts of cinnabar, with only trace amounts of arsenic and antimony, occur in dolomite over an area about 4,000 feet long and 1,500 feet wide. The deposit differs from other mercury deposits in the Kuskokwim River basin by the absence of silica-carbonate and rhyolite intrusives. Small-scale mining was started in 1963 as the result of Bureau investigation and continued during the summers of 1964 and 1965. The investigations indicate that open-pit mining might be the most feasible method of working this deposit.

RI 6893. Flexible Liners for Underground Support. Applicability Considerations and Experimental Procedures, by Ernest L. Corp and Robert C. Bates. 1967. 90 pp. 42 figs. First in a projected series on the use of flexible liners for support of underground mine openings, this report presents information obtained from an extensive review of the literature on this subject. It also includes results of some preliminary test work by the Bureau of Mines. Investigations thus far indicate that flexible liners offer numerous advantages over rigid-type supports. By deforming in the direction of the applied stress, the stresses are redistributed from the liner to the surrounding material. The corresponding buildup of passive resistance in the direction of diametric extension causes an equalization of stresses around the liner, thereby enabling the liner to carry loads in a more efficient manner. However, additional experimental data are needed to establish design criteria that will permit maximum utilization of the flexible liner concept in mining. Testing of small-scale models, accompanied by measurement of free-field stresses in material surrounding the model, is recommended as the most suitable approach to the problem. The experimental procedures necessary to such an approach are outlined in detail, and a statistical design for the experiments is proposed. The report also describes a device developed by the Bureau for measuring free-field soil pressures to 1,000 psi and a technique for evaluating the response of the device.

RI 6894. Solid-State Electromigration of Impurities In Cerium Metal, by J. D. Marchant, E. S. Shedd, and T. A. Henrie. 1967. 13 pp. 11 figs. The Bureau of Mines studied solid-state electromigration to determine the value of the technique as a method of purifying cerium metal. Cermium metal in bars 6 inches long and ½ inch in diameter was refined at 600° by solid-state electrolysis to remove iron, copper, and manganese. Iron and manganese were electrotransported to the anode, and copper was electrotransported to the cathode. The concentration of iron at the anode of a cerium bar was 800 times greater than the concentration at the cathode. The concentration of manganese at the anode was twice the value at the cathode. The concentration of copper was 170 times greater at the cathode than at the anode. A radiotracer technique was used to follow the iron migration in the cerium metal. Molybdenum, silicon, and aluminum impurities were not electrotransported.

RI 6895. Lake Superior Iron Resources. Preliminary Samples and Metallurgical Evaluation of Selected Michigan-Wisconsin Iron Formations, by L. F. Heising and D. W. Frommer. 1967. 31 pp. 8 figs. The Bureau of Mines evaluated 42 composite samples from selected Michigan-Wisconsin iron formations by reductive roasting-magnetic separation and flotation at minus 325 mesh. Samples having poor to marginal response on initial examination by conventional methods were reevaluated by finer grinding, by reagent suite modifications, and by selective flocculation-desliming techniques. Results ranged from excellent on Menominee range samples to relatively negative on Gogebic range ores. Marquette range samples ranged from responsive to nonresponsive, depending upon grain size and mineral association.

RI 6896. Equation of State for Helium-Nitrogen Mixtures From 133.15° to 748.15° K With Pressures to 300 Atmospheres, by Robert E. Wood, W. J. Boone, Jr., J. D. Marshall, and F. W. Baer. 1967. 178 pp. 15 figs. The compressibility factors, Z, of helium, nitrogen, and helium-nitrogen mixtures in the three-dimensional space of temperature, pressure, and gas composition have been related to the Leiden form of the virial equation of state. The dependency of virial coefficients through the fifth on temperature and gas composition has been established for the temperature range 133.15° to 748.15° K. Compressibility factors, Z, have been computed from the equation of state and tabulated as functions of gas composition, pressure, and temperature. Tabular values of Z are presented for 30.00 through 100.00 percent helium for temperatures from 240° through 700° R for pressures from 14.696 through 3,050 psia and for temperatures from 720° through 1,300° R for pressures from 14.696 through 1,500 psia. Tabular values of Z are presented at increments of 5.00 percent helium and 20° R, for pressures greater than 50 psia, at increments of 50 psi. A comparison of the equation of state with 2,508 experimental compressibility factors within the pressure, gas composition, and temperature range of the compressibility factor tables presented herein gives the following results:

Root mean squared error in $Z = 0.0007$;

Mean of the absolute deviations in $Z = 0.0004$.

The accuracy of the tabulated compressibility factors varies; however, it is estimated that no compressibility factor presented will differ from any reliable experimental compressibility factor by more than 3 parts in 1,000. The equation of state has also been compared with experimental compressibility factors for gas compositions, temperatures, and pressures outside the range of those presented in the tables. The equation of state can be used to compute the compressibility factors of helium, nitrogen, and any given helium-nitrogen mixture over the entire temperature range 133.15° to 748.15° K (239.67° to 1,346.67° R). However, to obtain compresibility factors which do not differ from those derived from experimental data by more than 3 parts in 1,000, the pressure range must be restricted in some regions.

RI 6897. Gold Distribution in Diamond-Drill Core From the Homestake Mine, Lead, S. Dak., by George S. Koch, Jr., and Richard F. Link. 1967. 27 pp. 7 figs. As a means of investigating the distribution and variability of gold in ore from the Homestake mine, Lead, S. Dak., the Bureau of Mines performed a designed sampling experiment, and assay results were statistically interpreted. Fifty-six feet of diamond-drill core from five boreholes was sawed into 1-inch-long cylinders, which were sampled randomly and were assayed. Analyses of variance of the assay results were used to compare and assess the different types of variation: within drill holes, among paired drill holes, among unpaired drill holes, and among furnace runs. The extreme variability in gold mineralization found is the natural variability on the smallest scale that can be detected by fire assay; most of the variability is associated with among-feet rather than within-feet sample intervals. Because of the extreme variability, one-half of the gold is in 3 percent of the samples.

RI 6898. Linear Discriminant Analysis of Multivariate Assay and Other Mineral Data, by Richard F. Link and George S. Koch, Jr. 1967. 25 pp. 7 figs. The objective of this report is to explain a statistical method for the summarization, organization, and classification of multivariate assay and other data from the mineral industry. Multivariate data are those characterized by several measurements at each data point, such as assay data from a mixed metal mine or blast furnace data. A specific method of linear discriminant analysis, the Mahalanobis d^2 procedure, is explained, starting from elementary principles; the d^2 procedure enables many measurements at many data points to be studied by investigating the interrelationships among the data. The relation of linear discriminant analysis to other statistical methods for treating multivariate data, in particular the eigenvalue technique of factor analysis, is also explained. Example analyses are made on data from the Frisco mine, San Francisco del Oro, Chihuahua, Mexico. The data comprise assay values for silver, lead, copper, and zinc taken at some 19,000 sample points distributed into 91 groups. (*Out of print.*)

RI 6899. Carbonizing Properties of Coals From Logan and Mingo Counties, W. Va., by D. E. Wolfson, C. Ortuglio, and J. H. Lynch. 1967. 16 pp. 1 fig. The Bureau of Mines carbonized 35 coal samples from Logan and Mingo Counties, W. Va., at 900° C, using the Bureau of Mines-American Gas Association method, and determined yields of products and physical properties of cokes. Twenty samples represented the No. 5 Block, Stockton, Chilton, Cedar Grove, Lower Cedar Grove, Alma, No. 2 Gas, and Eagle beds in Logan County, and 15 samples represented the Coalburg, Buffalo Creek, Winifrede, Cedar Grove, Lower Cedar Grove, Alma, and No. 2 Gas beds in Mingo County, W. Va. Chemical analyses were determined for all coals. All coals in both counties rank as high-volatile A bituminous. Most of the coals are chemically suitable for metallurgical coals. Coals with acceptable ash and sulfur contents can be used as major constituents in coking blends with higher rank coal to yield coke with satisfactory properties for blast furnace use.

RI 6900. Nonlinear Regression and the Principle of Least Squares. A Method of Evaluating the Constants and a New Method for Calculating Variances and Covariances, by Robert E. Barieau and B. J. Dalton. 1967. 21 pp. This report gives the principles of the method used by the Helium Research Center of the Bureau of Mines when solving nonlinear-regression problems and contains the mathematical equations necessary to accomplish the following objectives: The evaluation of the parameters in such a way that the sum of the weighted squares of the residuals of an experimental observable is a true minimum, regardless of the functional relationship between the variables and these parameters; and the evaluation of all variances and covariances of the parameters by means of the usual approximation of the law for the propagation of errors.

RI 6901. Effect of Lime Structure in Oxygen Steelmaking, by F. X. Tartaron and J. D. Ruschak. 1967. 41 pp. 39 figs. Behavior of hard-burned quicklime was compared with that of soft-burned quicklime in an oxygen converter utilizing oxygen blowing in a rotating cylindrical vessel, set at a 30° to 60° angle to the horizontal and operated at a predetermined speed of rotation. Four pairs of tests were made, each comparing hard lime with soft lime. Three of the pairs differed from one another in the quantity of lime employed, and the fourth differed in blowing time. All four pairs showed an increase in yield when soft lime was used. Three of the pairs revealed that the ratio of the oxygen consumed with soft lime to the oxygen consumed with hard lime was the same as the ratio of metal yield with soft lime to the metal yield with hard lime. The fourth pair contained an error and could not be included. Finally, a close inverse relation was found between the combined iron in the slag and the combined lime in the slag, which can be expresed by the equation percent Fe = 52.67 − 0.906 (percent CaO).

RI 6902. Heats of Formation of Ytterbium and Thulium Trichlorides, by J. M. Stuve. 1967. 7 pp. Standard heats of formation ($\triangle H_f^\circ$) of $YbCl_3$ (c) and $TmCl_3$ (c) were measured by solution calorimetry. Heat of solution data are given for ytterbium and thulium metals and corresponding anhydrous trichlorides in 4.360 molal hydrochloric acid. The derived standard heats of formation of $Ybcl_3$ (c) and $TmCl_3$ (c) were −229,370 ±720 and −235,820 ±400 cal/mole, respectively, at 298.15° K. The resulting heats of formation for $YbCl_3$ and $TmCl_3$ are about 1 kcal and 6.3 kcal more negative than previously published values.

RI 6903. Further Studies on Sympathetic Detonation, by R. W. Van Dolah, F. C. Gibson, and J. N. Murphy. 1966. 35 pp. 22 figs. The Bureau of Mines extended its investigations into sympathetic detonation of ammonium nitrate (AN) and ammonium nitrate-fuel oil (AN-FO) to define the scaling law for safe separation from detonating AN-FO Both missile- and non-missile-producing AN-FO donors, weighing up to 5,400 pounds, were employed with acceptors of the same size. The usual cube-root scaling law was not confirmed; exponents for the relationship $S=f\ (W^x)$ for AN were 0.51 with non-missile-producing donors and 0.61 for missile-producing donors. For AN-FO an exponent of 0.80 was indicated in the missile-producing case. AN-FO in polyethylene bags appeared somewhat more easily initiated than bulk AN-FO. The efficacy of barricades in protecting AN charges was investigated. Sympathetic detonation distances were reduced from one-third to one-seventh when sand-filled barricades were employed. The investigation was extended to boxed dynamite with both types of donors. With 1,600-pound missile-producing donors and an equivalent weight of dynamite, initiation would be expected in 50 percent of the trials at 167 feet. The corresponding value in the non-missile case was 67 feet. The data developed in this program of sympathetic detonation will allow the development of a rational set of safe separation distances for AN, AN-FO, and explosives. Work done in cooperation with the Manufacturing Chemists' Association.

RI 6904. Analyses of Tipple and Delivered Samples of Coal. Collected During Fiscal Year 1966, by S. J. Aresco and J. B. Janus. 1967. 43 pp. The Bureau of Mines has been active in promoting the purchase of coal for Government use under specifications that define the requirements in terms of the heating value of the coal, expressed in British thermal units, and the composition as shown by proximate analyses. To these, when required, are added the ash-softening temperature, the free-swelling index, and the Hardgrove grindability index. Under most of these specification contracts the bidders guarantee the quality of the coal, and that guaranteed by the successful bidder becomes the standard of his contract. The deliveries are sampled in accordance with instructions issued by the Bureau of Mines; the samples are analyzed in the Bureau laboratory to determine whether the coal is of the quality guaranteed by the contractor; if it is not, a price adjustment is made. Analyses of the delivered coal and tipple samples (samples collected at mine tipples as coal is being loaded into railroad cars or trucks) provide valuable data for use in evaluating future bids. In addition, the continuous sampling of coal as delivered is a check on the practical results obtained in burning the coal. The Government purchased approximately 5.5 million tons of coal in fiscal year 1966. In connection with these purchases, the Bureau analyzed 7,211 samples. These are published for the use of Government officials and the public. *(Out of print.)*

RI 6905. Reactions of Manganese With Silica, by H. G. Iverson and E. L. Singleton. 1967. 16 pp. 4 figs. Solid state reactions of manganese with silica were investigated in high-temperature tests. Reactions of 0.5 to 4.0 moles manganese (Mn) with 1 mole silica (SiO_2) at 1,100° C and of 2.0 Mn:SiO_2 mole-ratio mixtures at 1,000° to 1,150° C yielded products consisting of a slag phase and a metallic phase. At 1,100° C, the slag phase from reactions of the low Mn:SiO_2 mole-ratio mixtures was composed of SiO_2 and rhodonite ($MnSiO_3$), and the slag phase from the high Mn:SiO_2 mixtures was composed of $MnSiO_3$ and tephroite (Mn_2SiO_4). The metallic phase from the corresponding low Mn:SiO_2 mole-ratio reactants consisted of two manganese silicides, Mn_5Si_3 and Mn_3Si; from the high Mn:SiO_2 mixtures, it was Mn and the manganese silicide (Mn_3Si). For the higher mole ratios of Mn:SiO_2 the manganese content in the metallic phase increased, while the manganese and silica contents of the slag phase remained nearly constant. The slags did not contain free or uncombined manganese oxide (MnO). For the 2.5 to 4.0 Mn:SiO_2 mole-ratio mixtures reacted at 1,100° C, the maximum quantities of silica reduced and of the manganese in the slag appeared to become asymptotical at about 41 and 48 percent, respectively. A brominating procedure was developed that was highly selective in removing the metallic constituents from the reaction product, leaving the slag phase as residue. X-ray diffraction patterns were obtained on prepared silicides Mn_5Si_3, Mn_3Si, and MnSi.

RI 6906. Extraction of Euxenite Metal Values by Fusion With Ammonium Sulfate or Ammonium Bisulfate, by Van E. Shaw and R. E. Lindstrom. 1967. 11 pp. 6 figs. Fusion of an 86-percent euxenite concentrate with ammonium sulfate was investigated by the Bureau of Mines. Reaction for 4 hours at 400° C results in conversion of both the rare-earth elements and the titanium-columbium components to water-soluble compounds. Similar results are obtained with ammonium bisulfate. Stirring the fusion mass decreases the reaction time substantially. Alternatively, treating the fusion product with a 3-hour, 650° C calcining step renders the non-rare-earth constituents insoluble, thereby allowing selective leaching of a pure rare-earth fraction with an overall yield of 97 percent.

RI 6907. Effects of Rare-Earth Additions on Plain-Carbon Steel, by P. G. Barnard. 1967. 25 pp. 4 figs. The Bureau of Mines investigated the effects of various additions of rare-earth metals or rare-earth oxides on the mechanical properties of cast and wrought plain-carbon steels. Rare-earth metals, as misch metal, were added to medium-carbon steel in amounts to 0.70 weight-percent; rare-earth oxides, as a commercial mixture, were added in amounts to 1.50 weight-percent. The melting and casting of conditoned steels were done in a vacuum-induction furnace, to avoid formation of oxides from the melting atmosphere and to provide better control over chemical composition. At room temperature, data for tensile strength, yield strength, elongation, and hardness of cast and wrought steels were obtained by standard testing equipment and procedures. Impact tests were conducted on as-cast steel specimens. The greatest amount of tensile ductility and impact strength was obtained in as-cast steel with 0.50 to 0.70 weight-percent misch metal additions. No significant improvement on mechanical properties was indicated in wrought steels containing rare-earth metal additions in the range from 0.10 to 0.70 weight-percent. In general, the rare-earth oxide additions up to 1.50 weight-percent had little effect on the tensile properties of steel in the cast, wrought and annealed, or wrought and normalized condition.

RI 6908. Experimental Studies of Incineration in a Cylindrical Combustion Chamber, by Murray Weintraub, A. A. Orning, and C. H. Schwartz. 1967. 39 pp. 28 figs. In an investigation of the incineration of combustible wastes, the Bureau of Mines studied the effect of dimensional parameters, process variables, and fuel properties on the operation of an incinerator that consisted of a single cylindrical combustion chamber in which all combustion air was supplied tangentially above the fuel. Construction and operation of three designs of such a device proved that the tangential overfire air design is effective in providing efficient combustion and low concentration of particulate matter in the effluent gas. A correlation was found that related burning rate with air rate, chamber diameter, and inlet port diameter. In one of the incinerator models, ignition was by radiation from a preheated surface. The temperature of this surface was required to be 1,400° to 1,600° F to insure ignition of moist refuse; however, this had little effect on combustion rates. In the combustion of moist refuse, evaporation of the water proceeded through the fuel bed as a wave, with an ignition wave following the evaporation. (*Out of print.*)

RI 6909. Reservoir Oil Characteristics, Cut Bank Field, Montana, by C. Q. Cupps and J. Fry. 1967. 36 pp. 8 figs. In view of increased interest in secondary recovery of oil in the Cut Bank field, Montana, a review has been made of unpublished data obtained during a 1943-44 study of reservoir oil characteristics in this field. Considerable uncertainty was attached to interpretations of subsurface oil sample analyses from six Cut Bank zone wells, one Lander sand well, and one Moulton sand well, because of adverse sampling conditions and wide range in the data. Much of this uncertainty has been removed by this review which has shown two of the Cut Bank zone samples and the Moulton sand sample to be representative of the reservoir oils. Estimates of original reservoir oil characteristics derived from differential-liberation analyses of these samples show that the oil in the Cut Bank zone was initially saturated at the gas-oil contact pressure, 750 psia, and the oil in the Moulton sand was undersaturated with a saturation pressure of only 380 psia.

RI 6910. Design of Gas-Motivated Solids Dispersion Devices, by Murray Weintraub. 1967. 6 pp. 3 figs. The Bureau of Mines investigated the aerodynamic factors that control the functioning of the blowcase devices used in pneumatic processes for dispersing solids. Alumina powder of 8-micron mass-mean diameter was placed in 0.75-inch-diameter by 10-inch-long cylinders, and a blowcase technique was employed. It was determined that dimensions and gas rates for discharging the powder from the cylinder by a stream of gas may be calculated by assuming a fluidization mechanism and extrapolating residues to a desired finite quantity or to zero at the terminal velocity. The state of agglomeration of a powder at discharge may be determined from measurements of the velocity required for zero residue.

RI 6911. Infrared Vibrations of Benzene Rings in Condensed Thiophenes, by F. R. McDonald and G. L. Cook. 1967. 25 pp. 6 figs. This report presents a discussion of the spectra of 39 condensed thiophenes in which the structure includes at least 1 benzene ring. The vibrational bands present in three regions of the infrared spectra of these thiophenes were interpreted by comparing the similarities of the spectra of condensed thiophenes with the spectra of substituted benzenes. In the overtone-combination region 23 of the 39 condensed thiophenes had spectra which contained sufficient detail to be usable for correlating this region of the spectrum with the appropriate benzene spectrum. In the in-plane deformation region it was possible to make correlations for the vibrations of 18 of the 39 condensed thiophenes whose infrared spectra were studied. In the out-of-plane deformation region the C-H out-of-plane vibrations for hydrogen on benzene rings in the condensed thiophenes can be correlated using known data from substituted benzenes.

RI 6912. The Application of an Improved Continuous Electrophoresis Apparatus to the Study of Petroleum, by R. J. Heemstra and R. T. Johansen. 1967. 24 pp. 13 figs. A continuous flowing paper electrophoresis cell was used to separate petroleum and petroleum extracts into characteristic patterns. The electrophoresis of Bachaquero, Lagunillas, Boscan, and Gibson petroleum in nitrobenzene and acetic acid-based electrolytes was investigated. The extent of separation in the patterns was studied by measuring the metal and porphyrin contents of the effluents. Qualitative separations were achieved in some systems, whereas either system demonstrated only a high degree of electrophoretic migration.

RI 6913. Dielectric Constants and Dissipation Factors for Six Rock Types Between 20 and 100 Megahertz, by Russell E. Griffin and Robert L. Marovelli. 1967. 21 pp. 14 figs. Dielectric constants and dissipation factors were measured for six rocks over the 20- to 100-megahertz frequency range by means of the susceptance-variation method. Results for both dry and moist specimens are presented and compared with data reported by others. Loss factors calculated from the data presented are important to the Bureau's study of rock fragmentation by means of dielectric heating.

RI 6914. Processing of High-Iron Arkansas Bauxite Ores, by T. E. Hill, Jr. and W. A. Calhoun. 1967. 18 pp. 3 figs. Laboratory metallurgical treatments of three high-iron bauxite ores from Arkansas were conducted to determine the relative effectiveness of experimental methods for recovering alumina and a commercially acceptable iron concentrate. The standard for evaluating recoveries from experimental processes was the Al_2O_3 recovery from Bayer digests of the crude ores; recoveries from digestion of the three ores were 74.1, 87.4, and 88.7 percent. Flotation, magnetic separation, or various combinations of digestion, calcination, and reduction-sintering, leaching, and magnetic separation of leach residues failed to produce Al_2O_3 recoveries as high as the standard. A high-iron-bearing fraction, containing between 68 and 78 percent of the total iron, was produced in a three-phase treatment involving a caustic lime reduction-sinter of the crude ore, water extraction of Al_2O_3 from the sinter, and magnetic separation of the leach residue.

RI 6915. Rhenium and Rhenium-Tungsten Deposition by Thermochemical Reduction of the Hexafluorides—A Preliminary Study, by F. W. Hoertel and J. G. Donaldson. 1967. 14 pp. 7 figs. Near-optimum parameters were determined by the Bureau of Mines for vapor deposition of rhenium on heated copper substrates by hydrogen reduction of rhenium hexafluoride (ReF_6). High-purity deposits of nearly 90-percent theoretical density were obtained with the reaction chamber at 250° C, with an H_2 to ReF_6 volume ratio of 25 to 1, and with an ReF_6 flow rate of 5 grams per hour. Some rhenium deposited as a loose, black powder. When the established near-optimum parameters were carefully followed, this could be minimized but never completely avoided. Varying the reaction chamber pressure, both above and below atmospheric, yielded excessive quantities of rhenium powder. Deposition efficiencies, based on only the coherent metal, ranged between 70 and 75 percent. Massive deposits contained only spectrographic traces of impurities. The average microhardness (Knoop, 100-gram load) of vapor-deposited rhenium was 907. Limited research on the deposition of rhenium-tungsten alloys by reduction of the mixed hexafluorides produced deposits in which linear composition gradients were pronounced; this nonhomogeneity was attributed to the wide variation in optimum hydrogen-reduction temperatures of the two hexafluorides (250° C for ReF_6 and 550° C for WF_6). Using deposition temperatures between 250° and 550° C did not eliminate the composition variations.

RI 6916. Phthalic and Maleic Anhydrides From Low-Temperature Lignite Tar, by John S. Berber, Richard L. Rice, Arthur L. Hiser, and Howard W. Wainwright. 1967. 17 pp. 10 figs. To improve the economics of low-temperature carbonization of coal, the Bureau of Mines is conducting research on the upgrading of the product tar to marketable chemicals. This report describes experiments on the catalytic hydrodealkylation, followed by catalytic vapor-phase oxidation of the dealkylate to phthalic and maleic anhydrides, of mixed residues from the urea adduction of lignite-neutral oil fraction and on the catalytic thermal dealkylation of high-boiling tar acids. The hydrodealkylation experiments were conducted at pressures from 1,000 to 1,750 psig and at temperatures from 600° to 1,000° F. The oxidation was, in all cases, at atmospheric pressure and 950° F. Maximum yield of maleic anhydride, based on the liquid feed to the hydrodealkylation unit, was 12.2 percent at 750° F and 1,500 psig; that of phthalic anhydride was 6.9 percent at 650° F and 1,500 psig. Maximum yield of combined anhydrides was 18.8 percent at 650° F and 1,500 psig. The nondealkylated feed material, upon oxidation, yielded 8.9 percent and 3.8 percent maleic anhydride and phthalic anhydride, respectively.

RI 6917. Theoretical and Field Waterflood Performance, Kane Sand, Kane Oilfield, Elk County, Pa., by Leo A. Schrider, John R. Duda, and Harry R. Johnson. 1967. 26 pp. 12 figs. A prediction for oil recovery from a pilot waterflood in the Kane oilfield, located in Elk, Forest, and McKean Counties, Pa., was made and compared to actual field performance. Water-injection and production histories, well logs, other field data, and results from laboratory tests of core material were used in this analysis. Performance of the pilot waterflood, initiated in January 1963, was predicted using a modified Craig, Geffen, and More calculation technique. Maximum recovery from this low permeable, preferentially oil-wet formation was predicted to be about 22,500 barrels of oil after 300,000 barrels of water had been injected into the pilot waterflood area. After additional field data were collected it became necessary to reevaluate the pilot waterflood area. The gas saturation prior to the waterflood was estimated to have been 20 percent, based on an assumption regarding the required volume of water injected to initiate oil production. In view of the actual field performance, a gas saturation of 13 percent is indicated. When this gas saturation and the method originally proposed by Craig and others are used, the predicted results are more representative. In December 1965, field performance was further analyzed using a hyperbolic-decline curve as presented by Arps. Based upon this evaluation method, the pilot waterflood in the Kane sand should produce 37,000 to 42,000 barrels of oil with the injection of 300,000 barrels of water into the pattern. By continuing this secondary-recovery project to a reasonable economic limit, ultimate oil recovery may be as much as 50,000 to 55,000 barrels, or 129 to 142 barrels per acre-foot from 36.5 acres.

RI 6918. Evaluation of a Battery-Powered Vehicle, by W. P. Haynes and H. B. Neilson. 1967. 47 pp. 20 figs. To evaluate the potential use of battery-powered vehicles, the Bureau of Mines studied the performance of a battery-powered truck propelled by a 9.6-kw dc motor in considerable detail under various driving conditions. Some of the factors investigated were gear ratios, payload (1,468-lb maximum), road grade, stops made per mile, and charging time. With the exception of some difficulty with brush wear, operation and maintenance of the truck was generally trouble-free. On range tests carrying an 868-lb payload a distance of about 50 miles at an average speed of about 19 mph in normal driving, the Bureau's battery-powered truck averaged 1.6 to 1.9 miles per ac kwhr input. Stop-and-go tests indicated that prospects for the use of battery-powered trucks in house delivery service within city limits are good; performance of the Bureau truck was sufficiently high for that type of service. The estimated power cost of 2.65 cents per mile while making 10 stops per mile was attractively low from the standpoint of fuel costs.

RI 6919. Geometry of Metal Distributions in Five Veins of the Fresnillo Mine, Zacatecas, Mexico, by George S. Koch, Jr., and Richard F. Link. 1967. 64 pp. 75 figs. As a part of a larger study of the distribution of metals within ore deposits, the geometry of distribution of gold, silver, lead, copper, and zinc in five veins of the Fresnillo mine, Zacatecas, Mexico, was established. The purpose was to obtain basic data necessary for evaluation of geological theories about processes of vein formation and useful for practical mining applications in ore estimation and prediction of ore beyond present workings. The Bureau of Mines investigation comprised statistical analysis of 64,000 assay values from some 16,000 mine samples. The samples were taken at 2-meter intervals in drifts exposing the veins through a vertical range of some 750 meters. Within individual veins, the metals are distributed in domelike patterns with highest metal contents tending to occur in ore-shoots at the center of the developed parts of the veins. However, in the block of ground containing all five veins, base metals define mathematical domes with highest contents near the center; precious metals define mathematical basins or troughs with low contents near the center. The ratio of silver assay values to lead assay values corresponds to two geographically distinct types of mineralization: one in which silver is closely related to lead, and another in which silver is independent of lead. Other metal ratios also vary regularly from one place to another. The statistical methods employed in this study would be useful for other geologists or engineers who need to analyze large amounts of assay or similar numerical data.

RI 6920. Bureau of Mines Coal-Fired Gas Turbine Research Project. Test of New Turbine Blade Design, by Jack Smith, Robert W. Cargill, Donald C. Strimbeck, William M. Nabors, and J. P. McGee. 1967. 77 pp. 69 figs. New turbine blades designed to resist ash erosion were tested by the Bureau of Mines in a pilot-scale coal-fired gas turbine. After a total of 1,963 hours, the rotor blades were only slightly eroded, and they had an estimated useful life of 20,000 to 30,000 hours. Changes in aerodynamic design of the blades succesfully concentrated the ash at the outer casing, but stepped sidewalls for the rotor drum and wear strips at the bases of the rotor blades are still needed to minimize wear at these points. Stepped sidewalls and wear strips did not adequately protect the stator blades. Ash slightly eroded their leading edges, above the inserts, and cut notches into their trailing edges near the bases. Stator blade life was estimated at 5,000 to 7,500 hours. Blade erosion in these tests was less severe than with previous designs, but more efficient combustors and ash separators are required to reduce the amount and size of ash entering the turbine to achieve acceptable blade life for commercial operation. Work done in cooperation with Bituminous Coal Research, Inc.

RI 6921. Effect of Weather on Sound Transmission From Explosive Shots, by R. L. Grant, J. N. Murphy, and M. L. Bowser. 1967. 13 pp. 12 figs. The Bureau of Mines applied automatic computational methods to analyze the degree of correlation between sound transmission and atmospheric conditions. Statistical analysis of data collected over a 5-month period indicated that the following weather variables, listed in order of decreasing importance, have a significant effect on the transmission of sound in the atmosphere: (1) Winds in the direction of travel of the sound wave increase the sound intensity and duration; (2) barometric pressures are related to low sound intensities and durations; (3) high temperatures are related to low sound intensities and durations. Inversion of the atmospheric temperature did not appear to affect sound transmission under the conditions of this study.

RI 6922. Vibratory Compaction of Mine Hydraulic Backfill, by David E. Nicholson and William R. Wayment. 1967. 52 pp. 35 figs. In a Bureau of Mines investigation of the dynamic compaction of mine hydraulic backfills, two basic forms of mechanical vibration inducers were used and compared for effectiveness of compaction. Internal compaction, using concrete probe vibrators of various sizes, and external compaction, using plate vibrators, were studied and evaluated for use in underground stopes. An aluminum plate, which was light and displaced sufficient volume to remain afloat in fluid fill, and a steel plate were both used in the external compaction tests. Efficiency of compaction was better in studies conducted with internal probe vibrators. Tests were conducted in an underground backfilled stope with three different-sized probe vibrators (2-, 4-, and 6-inch-diameter) to determine an approximate area of influence. Results showed the areas of influence to be approximately 3, 4, and 5 feet in diameter, respectively, for the three different probes. Physical properties of hydraulic slurries were determined; preferred grain-size distributions, water exudation properties, and water contents of hydraulic slurries are reported. The best compaction results were obtained with moderately well-graded, fully saturated backfills, with slow rates of water exudation, which were capable of remaining in a semifluid state during the compaction process.

RI 6923. Recrystallization of Chrome Spinel, by J. W. Town, W. A. Stickney, G. T. Engel, and P. E. Sanker. 1967. 30 pp. 8 figs. Recrystallization studies on chrome-bearing spinel materials were made by the Bureau of Mines to determine the effects of certain fluxing agents and cooling rates on the chromium-to-iron ratio of recrystalized spinel. Statistically designed and evaluated tests showed that the ratio of chromium to iron in naturally occurring chrome spinel could be increased from 1.5 to 1 to over 7 to 1 and that the ratio of chromium to iron in the chrome spinel in a stainless steel slag could be raised to over 18 to 1. Silica, magnesia, and lime had significant positive effects, while alumina had a significant negative effect. Cooling rates of 20° C per hour in a programed spiral globar electric furnace were satisfactory for growing crystals of recoverable size.

RI 6924. Equations for Calculating the Thermodynamic Properties of Fluids, Including Those in the Two-Phase Region, From an Empirical Equation of State, by Robert E. Barieau. 1967. 42 pp. General expressions for evaluating practically all the thermodynamic properties of a fluid from a single equation of state are derived. Most of the formulas are expressed in terms of the compressibility factor, with this factor being an explicit function of the temperature and the molal density. Similar expressions are given using reduced variables.

RI 6925. Low-Temperature Thermodynamic Properties of the Hydrates of Beryllium Sulfate, by T. Estelle Gardner and A. R. Taylor, Jr. 1967. 9 pp. 1 fig. Heat-capacity measurements were made over the range 8° to 350° K on beryllium sulfate dihydrate and beryllium sulfate tetrahydrate using an adiabatic calorimeter. No anomalies were noted in the curve for either compound. Smooth values of heat capacity, entropy, enthalpy function, and free-energy function were calculated from the heat-capacity data at 10° K intervals and at 273.15° and 298.15° K. The entropy values calculated at 298.15° K were 39.01 $\pm$0.12 entropy units (eu) for the dihydrate and 55.68 $\pm$0.17 eu for the tetrahydrate.

RI 6926. Laboratory Testing and Evaluation of Porous Permeable Rock for Nuclear Waste Disposal, by J. B. F. Champlin, R. D. Thomas, and A. D. Brownlow. 1967. 32 pp. 11 figs. The continuing development of the nuclear industry in the United States requires a program of waste disposal that insures against the release of large amounts of radioactivity to the environment. This paper describes research on one proposed means of disposal of this waste, that of injection into geologic formations at depth. Nuclear production plant wastes were simulated and injected into samples of sedimentary rock obtained from outcrops, quarries, and deep wells. Changes in the chemical and physical characteristics of the rocks caused by the interaction of ions and suspended particles in the waste solutions with the cementing material and claylike particles in the rock are discussed. Laboratory tests show that nuclear wastes can be injected into many natural porous, permeable geologic formations. Injectivity can be maintained over a longer period of monitoring the ionic balance and particle-size distribution of waste streams. The combination of permeability and porosity with low cation-retention capacity, as exhibited by most sandstones, would satisfy the engineering requirements for the subsurface disposal of nuclear waste. Shales and clays with their low permeability and high cation-retention capacity would make excellent confining formations. The amount of cation retained by sedimentary rocks increases with increasing valence or concentration of the cation or decreasing brine concentration. The use of rock cores as model reservoirs has proved successful in determining some of the parameters that need to be considered in full-scale field disposal of wastes. Work done in cooperation with the U.S. Atomic Energy Commission and the State of Oklahoma.

RI 6927. Methods for Producing Alumina From Clay. An Evaluation of a Lime-Soda Sinter Process, by Frank A. Peters, Paul W. Johnson, John J. Henn, and Ralph C. Kirby. 1967. 38 pp. 16 figs. An evaluation is made of a lime-soda sinter process for extracting alumina from clay. In this process, alumina is extracted by sintering clay with soda ash and limestone and then leaching the sinter with a dilute sodium carbonate solution. The sodium aluminate solution formed during leaching is separated from the residue and treated with lime in autoclaves to remove dissolved silica before alumina trihydrate is precipitated with carbon dioxide. The trihydrate is then calcined to α-alumina. Two options, dry grinding and wet grinding, are used in the sintering step. The fixed capital costs for plants producing 1,000 tons of alumina per day are $72 million for the dry grinding option and $66 million for the wet grinding option on a Marshall and Stevens chemical equipment index basis of 240.0. Specific geographic locations of plant and raw material sources are not assigned, but since this process requires large quantities of both limestone and clay, the plant site is considered as variable with relation to the clay mine and limestone quarry. A nomograph is given to find operating costs at various delivered costs of clay and limestone. If the plant is located nearer the limestone quarry so that the delivered cost of clay is $2 per ton and the delivered cost of limestone is $1 per ton, the operating costs are $76.47 and $71.61 per ton of alumina for the dry grinding and wet grinding options, respectively. On the other hand, if the plant is located nearer the clay mine so that the delivered cost of clay is $1 per ton and the delivered cost of limestone is $2 per ton, the operating costs are $80.15 for dry grinding and $75.34 for wet grinding. This process when treating clay, using either option, is not competitive under current economic conditions with the Bayer process for treating bauxite to produce alumina.

RI 6928. Preliminary Process Development Studies for Desulfating Great Salt Lake Brines and Sea Water, by D'Arcy R. George, J. M. Riley, and Laird Crocker. 1967. 34 pp. 11 figs. A process for removing sulfate from Great Salt Lake brines and other natural brines, including sea water, has been developed. Sulfate is quantitatively removed by precipitation as barium sulfate in a cyclic process employing ion-exchange techniques. Barium is continuously recovered and recycled, and sodium carbonate and sulfur or sulfuric acid are produced as byproducts in quantities sufficient to more than defray the cost of desulfation.

RI 6929. Properties of Vanadium-Base Tungsten and Chromium Alloys, by D. R. Mathews and H. G. Iverson. 1967. 22 pp. 25 figs. The Bureau of Mines investigated the effects of tungsten and chromium, separately and combined, on improving the mechanical properties and oxidation resistance of vanadium. Binary and ternary vanadium-base alloys were prepared and tested for oxidation resistance and tensile strength. Softening occurred with less than 1 weight-percent of either tungsten or chromium, followed by strengthening with higher alloying contents. Vanadium alloys containing up to 9.8 weight-percent chromium or 14.1 weight-percent tungsten were more resistant to oxidation in air at 600° C than unalloyed vanadium. For the alloys with 12.20 weight-percent chromium or 14.56 weight-percent tungsten, the maximum concentrations used, the lower yield strengths were about twice that of 38,600 psi for the unalloyed vanadium. Recrystallization temperatures for these alloys were 100° and 150° C higher, respectively. Alloys containing both chromium and tungsten had properties similar to those of the vanadium-tungsten alloys.

RI 6930. Batch and Continuous-Circuit Beneficiation of Western Phosphate Ores, by J. W. Town, C. W. Clark, C. W. Sanders, and E. E. Sullivan. 1967. 42 pp. 6 figs. The Bureau of Mines made continuous-circuit beneficiation studies to determine the optimum conditions for concentrating phosphate minerals from the intermediate- and marginal-grade ores of the Phosphoria Formation in southeast Idaho. Intermediate-grade ore was represented by a sample from Georgetown Canyon and marginal-grade ore from the Gay mine near Fort Hall. Two flowsheets were developed: The first involved roasting, attrition scrubbing, sizing to remove a concentrate, grinding of the oversize, desliming, and flotation; in the other flowsheet roasting was eliminated. Controlled attrition scrubbing was used to remove clay and silt-size quartz particles imbedded in the phosphate pellets without breaking the pellets. The minus 35- plus 200-mesh fraction was removed by sizing as a finished-acid-grade concentrate. The plus 35-mesh material was ground in a rodmill to minus 35 mesh and recycled to the attrition scrubber. The minus 200-mesh fraction was deslimed at about 800 mesh to remove clay slimes and floated with 3 to 4 pounds of emulsion per ton of feed. The aqueous fatty-acid oil emulsion consisted, by weight, of 3 parts No. 2 diesel oil, 3 parts crude tall oil, and 0.5 part water-soluble petroleum sulfonate. Results on the intermediate-grade Georgetown Canyon sample (head assay of 24.6 percent P_2O_5) showed a coarse, minus 35- plus 200-mesh concentrate containing 32.1 percent P_2O_5, at 71.6-percent recovery. Flotation of the minus 200- plus 800-mesh material recovered 16.9 percent of the phosphate at 29.0 percent P_2O_5. Combined concentrates contained 31.4 percent P_2O_5 at a recovery of 88.5 percent. The minus 35- plus 200-mesh concentrate obtained on the marginal-grade Fort Hall shale sample (head assay of 19.4 percent P_2O_5) contained 31.6 percent P_2O_5 at a recovery of 51.2 percent. Flotation of the minus 200- plus 800-mesh material recovered an additional 26.0 percent of the phosphate at 24.5 percent P_2O_5. The combined concentrates contained 28.0 percent P_2O_5 at a recovery of 77.5 percent.

RI 6931. Equivalences and Lower Ignition Limits of Coal Dust and Methane Mixtures, by J. M. Singer, E. B. Cook, and J. Grumer. 1967. 35 pp. 9 figs. This study was undertaken to obtain some fundamental information about hazardous mixtures of coal dust and methane (firedamp) likely to occur in mines. Fuel concentration liimts for ignition of mixtures of coal dust, methane, and air have been determined by a hot-gas ignition method. The limiting concentration of each of the two fuels was usually less than that corresponding to its lean flammability limit in air. The lean limits of flammability of coal dust vary with the type and size of the dust; in this study coal dust concentrations were less than 80 mg/liter. Ignition jets were turbulent pulses (emerging from a channel of 0.5-cm diam) resulting from explosions of stoichiometric mixtures of methane, oxygen, and nitrogen. Temperatures of the ignition jets were varied by changing the oxygen index (OI) $= O_2/(O_2 + N_2)$ of the primary methane-oxygen-nitrogen mixture (adiabatic flame temperatures from 2,000° to 3,000° K). The objectives of the study were to establish quantitative relations between concentrations of each fuel at ignition limits of hybrid mixtures and to study the mechanism of ignition of these hybrid mixtures by hot turbulent gases. Empirical equaitons were fitted to concentrations for four coals, namely, Pittsburgh seam (sizes A, B, and C), Sewell No. 2 seam, Pocahontas No. 3 seam, and anthracite. Equivalences of coal dust to methane were computed from these equations; equivalence being defined as $-\Delta c/\Delta m$ where c is the coal dust concentrated and m is the methane concentration, each in milligrams per liter of air. It was found that the equivalence increases as the temperature of the hot-gas jet decreases. In general, the equivalence is also an inverse function of volatile content of the coal and a direct function of the particle size. However, volatile content in itself is not a sufficient correlating variable, nor is the specific surface area of the coal dust. Some evidence of a synergistic combination of coal dust and methane was obtained in certain concentration ranges. Observations also indicate that the relatively larger particles in the coal dust do not participate totally, on a weight basis, in the ignition process, perhaps being only partly burned in the primary combustion zone of the limit flame.

RI 6932. Chattanooga Shale Investigations, by R. C. Hickman and V. J. Lynch. 1967. 55 pp. 13 figs. Preliminary evidence indicated that the Chattanooga Shale might constitute a potential vast low-grade source of uranium. Investigation by core drilling indicated that while the Chattanooga Shale may constitute a resource for the future, the very low (0.006 percent) average uranium content is not economic when compared with the relatively higher grade western ores. A total of approximately 12,000 feet of test drilling was done in 72 drillholes, and large samples were mined for extractive and metallurgical testing. An experimental mine site was selected on the basis of the drilling project.

RI 6933. Lime-Soda Sinter Process. Correlation of Reaction Products With Extractability of Alumina From Anorthosite, by Sarkis G. Ampian. 1967. 44 pp. 15 figs. Extraction of alumina was correlated with the sinter and leach products from the lime-soda sinter process for anorthosite. The effect of composition and grain size of reactants, time and temperature of sintering, and techniques of sample preparation were investigated. Greater than 90 percent Al_2O_3 extractions were obtained from dry-mixed minus 200-mesh anorthosite sinter mixes having mole ratios of $CaO/SiO_2 = 1.8$ and $Na_2O/Al_2O_3 = 0.8$. These sinter mixes were briquetted at 15,000 psi and fired between 1,200° C and 1,320° C for 20 to 60 minutes. The sinter phases that contribute to low alumina recovery were determined by X-ray diffractometry, optical microscopy, and electron probe X-ray spectrography. The mechanism of the sintering reaction was investigated by high-temperature X-ray diffractometry. The contrasts in the lime-soda sinter process for clays and for anorthosites are discussed. Explanations and suggested solutions are presented for problems such as gelation and variable alumina recovery encountered by previous investigations.

RI 6934. An Evaluation of the Western Phosphate Industry and Its Resources (in Five Parts). 4. Wyoming and Utah, by J. S. Coffman and A. L. Service. April 1967. 158 pp. 79 figs. Wyoming is estimated to have more than 700 million tons and Utah more than 2.5 billion tons of +10 percent P_2O_5 phosphate rock considered to have some future economic potential. In Wyoming, the +24 and +18 percent P_2O_5 rock potential resources total nearly 250 and 450 million tons, respectively. In Utah, the +31, +24, and +18 percent rock total approximately 33 million, 222 million, and 2.2 billion tons, respectively. These resources are all located above the local drainage levels and do not include latent resources. All of the mining and beneficiation of phosphate rock in the two States is done by San Francisco Chemical Co. The facilities include open-pit mines at Vernal, Utah, and Leefe, Wyo., an underground mine in the Crawford Mountains, Utah, and beneficiation plants at Leefe and Vernal. One of the principal markets for the phosphate rock is Western Phosphates, Inc., fertilizer plant at Garfield, Utah. Recent exploration and development have been undertaken by different companies in the Southeastern Wind River Range, Sublette Range, and Crawford Mountains. The facilities at Leefe and Vernal are in the process of expansion. Some of the areas of western Wyoming contain vast quantities of phosphate rock in minable units, but, because of their remote location, are classed as latent areas. In these areas, there are estimated to be about 700 million, 2 billion, and 3 billion tons of phosphate rock in the +24, +18 and +10 percent P_2O_5 grade classes, respectively. The Snake River Range of Idaho and Wyoming is also estimated to contain roughly 21, 106, 177, and 214 million tons of potential resources in the +31, +24, +18, and +10 grade categories, respectively. This area also contains a large amount of latent rock in the more remote areas. The possibility of exploitation of the undeveloped deposits of Wyoming and Utah depends on market conditions. In view of the vast, untapped open-pit resources available, particularly in Idaho and Utah, and the rapid expansion of all facilities in the Western phosphate field, it appears that it will be some time before market conditions warrant opening any but the best of the Wyoming or Utah deposits.

RI 6935. An Evaluation of the Western Phosphate Industry and Its Resources (in Five Parts). 5. Trends and Outlook, by A. L. Service and N. S. Petersen. May 1967. 131 pp. 30 figs. In 1965 the Western phosphate industry ranked third after Florida and Tennessee in total mine and marketable production of phosphate rock and phosphate rock products. It has become an important regional industry and, since the close of World War II, it has become important in the national phosphate economy. This report includes an evaluation of the trends and outlook for the Western phosphate industry through 1975 as part of the Bureau's program to determine the rate at which the Nation's mineral resources are being utilized. The first part of this report is concerned with the relationship between the Western phosphate industry and that of the United States and the world. It describes the principal phosphate deposits and discusses production, export, and import of phosphate rock and marketable products. The second part of the report is concerned with the Western phosphate industry and discusses trends and outlook through 1975. Projections for the utilization of phosphate rock, phosphate fertilizers, and elemental phosphorus have been developed and extended through 1975 in an effort to provide data and information pertaining to the rate of depletion of the Nation's phosphate resources.

RI 6936. Isotopic Abundance of Neon, Argon, and Nitrogen in Natural Gases. Relationship to Helium Genesis, by Lowell Stroud, Thomas O. Meyer, and David E. Emerson. 1967. 27 pp. 2 figs. Ten natural gases containing from 0.023 to 8.4 percent helium were investigated. In seven high-helium samples, the isotopic abundance of Ne^{21} was greater than in the atmosphere, being supplemented by 33 to 85 percent of "excess" or "radiogenic" Ne^{21}. The ratio of $He^4/Ne^{21}_{(rad)}$ in these gases was evaluated and found to vary between 2.9×10^7 and 5.9×10^7, a factor of approximately 2. Argon concentrations were determined by the isotope dilution method. The isotopic ratios of Ar^{40}/Ar^{36} in the high-helium gases were from 5 to 75 times the atmospheric value, with the Ar^{40} being about 80 to 99 percent radiogenic in nature. The ratios of $He^4/Ar^{40}_{(rad)}$ in all 10 gases were evaluated and found to range from 4 to 18. The isotopic ratio of N^{14}/N^{15} in four of the high-helium gases was essentially the same as in the atmosphere; in three cases it was approximately 5 percent higher than the atmosphere value of 272.0. The genesis of nitrogen and the relationship of nitrogen to helium in natural gases were reviewed and are discussed in terms of a theory for the concurrent generation of nitrogen, helium, radiogenic neon 21, and petroleum (hydrocarbon gases and liquids).

RI 6937. A Mine Production-Scheduling Model and Critical Path Analysis of Mine Development Work for Long-Range Mine Planning, by Adrian J. Mathias. 1967. 48 pp. 13 figs. This report presents the results of an investigation of a mine production-scheduling model and a critical path analysis for long-range mine planning. An example is given to illustrate how these techniques might be used to plan long-range development and production scheduling for a large underground mine. The model, based on estimated ore block grades and tonnages, and on designed mine development layout, simulates mining of ore blocks in a sequence necessary to fulfill mill requirements for ore tonnage and grade evaluation within pre-established system restrictions. Simulated production schedules are obtained as output from the model. These production schedules are then incorporated into a critical path analysis to determine the sequence for the long-range development work so as to fulfill the production schedules and thereby meet the ore grade and tonnage requirements of the mill. (*Out of print.*)

RI 6938. Effects of Ultrasonics on Electrodeposition of Copper Alloys From Cyanide Electrolytes, by Charles B. Kenahan, David Schlain, and Edmond Chin. April 1967. 32 pp. 16 figs. The effects of ultrasonic radiation on the electrodeposition of copper-zinc, copper-cadmium, and copper-tin alloys from cyanide baths were investigated by the Bureau of Mines at frequencies of 18.5 and 38 kilocycles per second and at acoustic intensities up to 0.5 watt per cm^2. Significant changes occurred in the composition of the deposited alloys; some of these deposits were brighter, harder, more adherent, or of finer grain size than nonirradiated deposits. The irradiated deposits were also smoother and less porous, and they afforded better corrosion protection for the substrate metal in sodium chloride solution. The limiting current densities of the cyanide baths were increased by the application of ultrasonics. Anode and cathode current efficiencies also were increased, and cell voltages lowered; the relationship of these effects to current density is discussed. Electrode potential measurements showed significant depolarization effects at both electrodes during ultrasonic irradiation. The resulting decrease in cell voltage was due chiefly to depolarization at the anode, and the anode became less passive. (*Out of print.*)

RI 6939. Adaptation of the Pedersen Process to the Ferruginous Bauxites of the Pacific Northwest, by Henry E. Blake, Jr., Oliver C. Fursman, Arden D. Fugate, and Lloyd H. Banning. April 1967. 21 pp. 4 figs. This work was done to determine the technical feasibility of using the Pedersen process to produce cell-grade alumina and an iron byproduct from the high-silica and titania bauxites of the Pacific Northwest. Smelting of these bauxites with lime and coke at about 1,750° C in an electric arc furnace produced calcium aluminate slags in which at least 80 percent of the alumina was leachable by sodium carbonate solution. After a lime-desilication of the sodium aluminate, leach liquors, neutralization of these solutions with carbon dioxide resulted in precipitation of an alumina hydrate of sufficient purity for calcination to cell-grade alumina. Recoveries of byproduct iron averaged over 90 percent; however, the iron contained about 1 percent phosphorus and would require additional refining. Additional small-scale tests on these slags showed the following: (1) Titania had little effect on leachability if sufficient additional lime was added to form calcium titanate ($CaO \cdot TiO_2$); (2) a slag containing about 14 percent silica required a slower cooling rate than one containing 7 percent silica for formation of high percentages of soluble aluminates; and (3) high-silica slags leached better at room temperature for long periods than at 65° C for shorter periods, but low-silica slags leached well by either method.

RI 6940. Extraction of Germanium and Gallium From Coal Fly Ash and Phosphorus Furnace Flue Dust, by R. F. Waters and H. Kenworthy. April 1967. 33 pp. 5 figs. Laboratory-scale selective volatilization methods developed by the Bureau of Mines to recover germanium and gallium concentrates from coal fly ash and phosphorus furnace flue dust are summarized. In the better experiments between 85 and 98 percent of the germanium was recovered as the lower oxide and as sulfides, and between 75 and 97 percent of the gallium was recovered as the lower oxide and as the trichloride. Grades of the condensates were inconsistent and varied between a few tenths of a percent and 8 percent, depending on the method used. In the primary extractions of germanium alone, the degree of enrichment surpassed 100 to 1, and for gallium the best ratio was 30 to 1. Upgrading of condensates by vaporization retreatment and by leaching and precipitation is discussed. An appreciable degree of mechanical preconcentration by attrition scrubbing and elutriation was possible on two fly ash samples.

RI 6941. Kinetics of Gas Synthesis Using Recycle Systems, by J. F. Schultz, F. S. Karn, and R. B. Anderson. April 1967. 23 pp. 19 figs. The Bureau of Mines investigated the hydrogenation of carbon monoxide and carbon dioxide over Raney nickel catalyst and nitrided fused-iron catalyst using both a single-pass and a recycle system. Activation energy over Raney nickel catalyst is 29 to 32 kcal/mole for synthesis from either CO or CO_2. Pressure dependence of the gas conversion is to the 0.3 power for synthesis from CO and to the 0.5 power for synthesis from CO_2. Nitrided fused-iron catalysts were tested using high recycle rates and $3H_2+1CO$, $2H_2+1CO$, and $1H_2+1CO$ feed gas at 21.4 atmospheres absolute pressure. The relative usage of hydrogen (moles H_2 consumed per moles H_2+CO consumed) was larger than in corresponding single-pass tests, and the relative usage of hydrogen approached the feed gas ratio monotonically as conversion increased. Activation energy was found to be 12 or 13 kcal/mole fresh feed gases of $3H_2+1CO$ or $2H_2+1CO$. For single-pass operation the activation energy under the same conditions was 19 to 21 kcal/mole.

RI 6942. Underground Combustion Oil-Recovery Experiments in the Venango Second Sand, Reno Pool, Venango County, Pa., by G. G. Campbell, E. L. Burwell, T. E. Sterner, and L. L. Core. April 1967. 45 pp. 28 figs. The Bureau of Mines conducted two underground-combustion oil-recovery experiments in the Venango Second sandstone in the Reno pool, Foster-Reno-Oil City field, Sugar Creek Township, Venango County, Pa., to determine the applicability of the process for reservoirs producing Pennsylvania-grade paraffin-base crude oil. Tests were terminated when analyses of produced gas showed that a self-sustaining combustion front did not exist. It was thought that insufficient fuel had been deposited in the formation. Laboratory retort tests made after the second field test was concluded showed that crude oil from the Reno area would deposit enough fuel to support combustion if air flux, temperature, and time were maintained within defined limits. Work done in cooperation with the Quaker State Oil Refining Corp.

RI 6943. Predicted Oil Recovery by Waterflood and Gas Drive, Bradford Third and Sartwell Sands, Sartwell Oilfield, McKean County, Pa., by John R. Duda, William K. Overbey, Jr., and Harry R. Johnson. April 1967. 56 pp. 22 figs. The Bureau of Mines Morgantown Petroleum Research Laboratory, with the cooperation of the Penn York Oil Co., cored the Dewdrop, Bradford Third, Lewis Run, and Sartwell sands in the Sartwell oilfield, McKean County, Pa. This report contains a review of the geology and depositional history of the field and an evaluation of the feasibility of secondary recovery of oil from the Bradford Third and Sartwell sands by waterflood or gas drive. Core analysis, geologic data, and electrical and radioactivity logs were used to evaluate the reservoir characteristics. Reservoir geometry, rock properties, fluid characteristics and saturations, and relative permeability-saturation relationships were used to assess the floodability of these two sands. The results of this study indicate that between 53,000 and 61,000 barrels of oil can be recovered by water or gas injection. The success of a waterflood or gas drive will depend on the field injection rates of the reservoirs comprising this oilfield. Following an economic evaluation, additional field work is recommended to further test the floodability of the reservoir.

RI 6944. Metallurgical Testing of Hawaiian Ferruginous Bauxites—Concluding Report, by W. A. Calhoun and T. E. Hill, Jr. May 1967. 37 pp. 10 figs. Progress made in a second and final metallurgical investigation by the Bureau of Mines of near-surface Hawaiian bauxite deposits from Kauai, Maui, and Hawaii Islands, and on a deeper deposit from Kauai, is reported. Previously reported Al_2O_3 extractions were increased by modifying conventional processes to fit the ore being tested. Increases in Al_2O_3 extraction were: Kauai, from 82.8 to 95.4 percent; Maui, 85.5 to 94.1 percent; and Hawaii, from 79.5 to 86.4 percent. Use of a caustic-reduction sinter, leaching, and magnetic separation process for Al_2O_3 extraction also produced an iron concentrate of commercial grade, except for titanium content. No successful method was developed for the recovery of a satisfactory titanium concentrate.

RI 6945. Experimental Study of Pressure Drop Across Fixed Beds of Anthracite Briquets and Blast Furnace Materials, by A. F. Baker, W. S. Sanner, R. F. Tenney, and J. W. Eckerd. May 1967. 28 pp. 16 figs. The Bureau of Mines conducted pressure-drop studies in a 4-foot-diameter simulated blast furnace shaft to compare anthracite metallurgical briquets with coke and formcoke. The test materials were used alone, layered, and in mixed burdens of commercial fuel-to-ore ratios. Anthracite briquets had a higher pressure drop per foot than furnace coke, but they had a lower pressure drop per foot than formcoke. This appears to be due to packing and shape, as well as to particle size. The superficial air velocities at which beds of briquets and furnace coke disrupted were about the same. However, if briquets of the shapes and sizes tested are substituted for furnace coke in commercial metallurgical furnaces, higher blowing pressures will be required to deliver comparable amounts of air. Test burdens with more than 5 percent material smaller than ¼-inch diameter showed significant increases in resistance to airflow. Work done in cooperation with Bethlehem Steel Corp.

RI 6946. An Economic and Technical Evaluation of Magnesium Production Methods (in Three Parts). 2. Carbothermic, by D. A. Elkins, P. L. Placek, and K. C. Dean. May 1967. 74 pp. 5 figs. This report is the second of a series of three that will evaluate, in order, the metallothermic, carbothermic, and electrolytic methods of magnesium production. The historical development of the carbothermic process is outlined. Production costs varying from 38.9 to 21.8 cents per pound of magnesium are estimated for different versions of the process. Additional suggested process modifications are listed. The technical and economic potentials of the different versions are compared. Areas deemed most promising for future research on the process are delineated.

RI 6947. New Gap-Sensitivity Methods for Explosives, by R. L. Grant, N. E. Hanna, and R. W. Van Dolah. May 1967. 17 pp. 9 figs. The Bureau of Mines developed two new gap-sensitivity methods for explosives, and especially permissible explosives, to overcome certain disadvantages of the present routine half-cartridge method. The revised methods are based on the statistical up-and-down method and give more useful requirements of the 50-percent gap values than the nonstatistical routine method. The new methods use full cartridges and incorporate certain physical improvements such as the use of cardboard tubes for containing the explosives and coal dust gaps to simulate actual mining conditions. A total of 60 samples of permissible explosives was evaluated simultaneously with the 2 improved methods and with the half-cartridge method.

RI 6948. Coking Properties of Selected Utah Coals and Blends, by W. S. Landers, Manuel Gomez, and Charles C. Boley. May 1967. 55 pp. 12 figs. Nine high-volatile bituminous Utah coals were carbonized singly and in blends with low- and medium-volatile bituminous coals. Of the nine coals, two are in commercial use as the base coals in blends that produce industrially acceptable metallurgical coke, while seven are regarded as weakly coking and are not used commercially in coking blends. The carbonization tests were made in a 10-inch-diameter, cylindrical retort, using 50-pound charges. Sunnyside coal blended with autogenous char generally produced larger and stronger coke than was yielded by straight Sunnyside coal. The volatile matter of the char and the concentration of the char in the blend appear to be important parameters influencing coke size and strength. A blend of 10 percent autogenous char of 7.2 percent volatile matter with Sunnyside coal yielded coke that was larger, stronger, and of higher apparent specific gravity than coke produced from an industrial coke oven blend consisting of 15 percent medium-volatile coal and 85 percent Sunnyside coal. Work done in cooperation with the Kaiser Steel Corporation, the Columbia-Geneva Division of the United States Steel Corporation, the Pacific Coast Company, The Colorado Fuel and Iron Corporation, and the Colorado School of Mines Research Foundation, Inc.

RI 6949. Concerning Physical Parameters for Use in an Absolute Gas Viscosimeter, by R. A. Guereca, H. P. Richardson, J. L. Gordon, and J. E. Miller. May

1967. 30 pp. 9 figs. Accurate measurements of physical dimensions of a section of stainless steel capillary tubing are presented and used to develop two final working equations for an absolute gas viscosimeter. The effects of pressure and temperature on these dimensions are considered. The internal surface finish and nonuniformity of the capillary bore are discussed, as well as entrance, kinetic energy, gas slippage, and gas compressibility correction factors.

RI 6950. Thermodynamic Properties of a Van Der Waals Fluid in the Two-Phase Region, by Robert E. Barieau. June 1967. 184 pp. 90 figs. General expressions for evaluating thermodynamic properties applicable to the van der Waals equation of state have been derived. These formulas were subsequently used to evaluate various thermodynamic functions in the two-phase region. The results indicate that, for a van der Waals fluid, there is a finite discontinuity in the second derivative of the vapor pressure curve, in the second derivative of the chemical potential or Gibbs free energy at the critical point, and in the heat capacity at constant volume measured at the critical density. Numerical values are tabulated and graphs are presented for all functions calculated.

RI 6951. Spark-Source Mass Spectra of Several Aromatic Hydrocarbons Using a Spinning Electrode, by T. Kessler, R. A. Friedel, and A. G. Sharkey, Jr. May 1967. 11 pp. 8 figs. The purpose of this investigation was to evaluate the application of a spark-source mass spectrograph equipped with a spinning-electrode system for the study of various high-molecular-weight materials derived from coal. Conclusions from the investigation of anthracene, phenanthrene, chrysene, coronene, truxene, a coal-tar pitch (80° to 85° C softening point), and anthracene-chrysene synthetic mixtures follow: 1. Simplified mass spectra of anthracene, phenanthrene, chrysene, coronene, and truxene, from which the molecular weights were easily determined, were obtained by the spinning-electrode system. 2. Eight structural types having molecular weights from 178 to 252 corresponding to compounds previously observed in an electron impact mass spectrum of a coal-tar pitch sample were affirmed by this technique. 3. Mass spectra obtained from synthetic mixtures of anthracene and chrysene demonstrated that the technique is applicable for semiquantitative analysis.

RI 6952. Pendulum Sclerometer for Surface Hardness Studies, by O. Terichow and W. C. Larson. May 1967. 19 pp. 9 figs. A pendulum sclerometer designed by the Bureau of Mines is described. Its method of operation is given, along with the results of tests made on representative mineral samples of Mohs' hardness scale to determine the applicability of the device for research on rock testing. The sclerometer hardness values obtained from the tests indicated that reproducibility and accuracy were good. A quantitative comparison of the pendulum hardness values with microhardness and surface energy values published by other investigators showed good agreement on minerals with Mohs' hardness numbers of 2 to 9.

RI 6953. Selective Flotation of a Fluorspar Ore From Illinois, by W. H. Eddy, James S. Browning, and James E. Hardemon. May 1967. 10 pp. 8 figs. The Bureau of Mines conducted laboratory batch flotation tests and continuous pilot plant flotation tests on a complex calcareous fluorspar ore from Cave-in-Rock, Ill., to determine the technical feasibility of producing commercial-grade concentrates by the sodium fluoride-calcium lignin sulfonate-fatty acid method of concentrating fluorspar previously developed by the Bureau. The continuous flotation tests, treating about 150 pounds of ore per hour, produced fluorspar concentrates assaying 96.4 percent CaF_2; 90 percent of the fluorspar was recovered. Work done in cooperation with the University of Alabama.

RI 6954. Reduction of Incendivity of Hot Gases to Methane and Coal Dust by Sodium Chloride and Sodium Nitrate, by Joseph M. Singer, Norman E. Hanna, Robert W. Van Dolah, and Joseph Grumer. May 1967. 15 pp. 5 figs. Having established that sodium chloride reduces the incendivity of explosives, the Bureau of Mines studied the effect of sodium nitrate in reducing ignition hazards. Gallery experiments showed that sodium nitrate reduced the incendivity of certain explosives to 8 percent natural gas in air but increased their incendivity to coal dust predispersed in air. Laboratory experiments using hot jets from explosions of stoichiometric mixtures of methane-oxygen-nitrogen showed that both sodium chloride and sodium nitrate reduced the incendivity to methane, to mixtures of coal dust and methane, and to coal dust. The difference between the gallery and laboratory results with respect to coal dust is attributed to temperature-time effects.

RI 6955. Assigning an Area of Influence for an Assay Obtained in Mine Sampling, by Scott W. Hazen, Jr. July 1967. 75 pp. 9 figs. Two statistical techniques, the mean-square-successive-difference test and correlation, are used to investigate the problem of assigning an area of influence to an assay. Data from five hydrothermal deposits, Climax molybdenum, Cebolla Creek titaniferous iron, San Manuel copper, Piedra Hueca copper, and Butte copper, are studied. Two groupings of the assays are used for the mean-square-successive-difference tests. One group involves an increasing sample volume by reaveraging assays to represent longer sample intervals, the other by regrouping assays to represent longer sample intervals without a change in sample volume. Each deposit has different mineralization characteristics, and although all test results are not entirely consistent, the results, as would be expected, are related to the nature of the mineralization and the structural environment. At Climax, the area of influence of an assay is less than 2 feet in the 0.2- to 0.4-percent grade zone studied. Breccialike characteristics of the deposit probably account for the small area of influence. The area of influence of an assay in the Cebolla Creek deposit ranges from 4 feet to 36 feet, depending on the sample volume used. Iron and titanium assays, although correlated, have different areas of influence. There is evidence of a cyclical trend in the area of influence along drill holes, probably resulting from the pod and lens type of mineralization in the deposit. Tests for the churn-drill holes and underground diamond-drill holes at San Manuel are inconclusive, because of a lack of sufficient assays to extend the tests for intervals greater than 100 feet. However, there is some evidence to indicate that the area of influence in the vertical churn-drill holes is about 100 feet. Correlation between assays in adjacent churn-drill holes indicates that the area of influence with the dip of the structure may be around 200 feet. At Piedra Hueca, assays from samples obtained by sample-plant processing of entire rounds of crosscuts driven along horizontal NX diamond-drill holes give high correlation with the drill-hole assays for sample intervals equivalent in length to the individual crosscut rounds. The area of influence of an assay is 16 to 20 meters (53 to 66 feet) in one crosscut and over 20 meters in the second crosscut. At Butte, the area of influence of an assay is 12 to 30 feet for weighted-average drift assays along one narrow vein and 8 to 32 feet in raises on this same vein. Assay data from the vein were too few for really conclusive results, indicating variability in mineralization along the vein. The area of influence is 6 feet or less for drift, raise, and stope assays in the horsetail-vein area. Tests with and without sample volume changes gave virtually the same results.

RI 6956. The Tungsten-Cobalt System for Compositions to 85 Atomic Percent Cobalt, by L. A. Neumeier and J. L. Holman. June 1967. 73 pp. 29 figs. A refinement of the tungsten-cobalt phase diagram is presented for compositions to 85 at. pct cobalt and for temperatures to the solidus. Preparation of alloys by powder metallurgy methods is described, and the results of studies made by a combination of techniques involving microscopy, X-ray diffraction, thermal analysis, and dilatometry are discussed. The existence of μ-W_6Co_7 is confirmed (rhombohedral $D8_5$ structure). The W_6Co_7 phase forms peritectically at 1,685°±15° C by reaction of liquid with primary W; the peritectic melt is at 71 at. pct cobalt. The homogeneity range of μ-W_6Co_7 extends to both sides of the ideal stoichiometric ratio, through a composition range of about 5 at. pct. The compositional limits for μ-W_6Co_7 vary slightly below 1,471°±5° C, the temperature of the eutectic reaction forming μ-W_6Co_7 plus α. The eutectic composition is at 79 at. pct cobalt. The existence of WCo_3 is confirmed (hexagonal DO_{19} structure). WCo_3 forms peritectoidally at 1,093°±5° C by reaction between α- and μ-W_6Co_7 and exists over a narrow homogeneity range of 0.5 to 0.6 at. pct. The solid solubility of cobalt in tungsten is low (maximum 0.9 at. pct cobalt) and results in contraction of the tungsten lattice. Tungsten is extensively soluble in α-Co at higher temperatures; the α-Co lattice is expanded by the presence of tungsten in solid solution. There was no indication of the formation of a σ-phase nor of any intermediate phases other than W_6Co_7 and WCo_3. The W_6Co_7 and WCo_3 phases are compared with similar phases in other systems.

RI 6957. Electrowinning High-Purity Neodymium, Praseodymium, and Didymium Metals From Their Oxides, by E. Morrice and T. A. Henrie. May 1967. 11 pp. 2 figs. High-purity neodymium, praseodymium, and didymium (a cerium-free mixture of light rare-earth elements) were prepared by electrolysis of the oxides in a medium consisting of the respective rare-earth fluorides and lithium fluoride. The metals were electrodeposited in the liquid state and collected as nodules on a skull of frozen electrolyte. Cells were operated from 1,000° to 1,100° C. The requisite temperature was maintained by passing alternating and direct currents through the bath. Graphite was used for the anodes and tungsten for the cathode. The metal products contained $<$0.02 percent each carbon and oxygen and $<$0.025 percent tungsten as major impurities. Analysis of typical didymium metal nodules showed an approximately twofold enrichment in neodymium and praseodymium over their respective concentrations in the cell feed. The lanthanum content of the metal was about one-half its content in the oxide.

RI 6958. Flame Characteristics Causing Air Pollution: Production of Oxides of Nitrogen and Carbon Monoxide, by J. M. Singer, E. B. Cook, Margaret E. Harris, Valeria R. Rowe, and J. Grumer. 1967. 34 pp. 4 figs. Methods are proposed for predicting concentrations of nitrogen oxides and carbon monoxide in the combustion gases of flames, specifically of lean, stoichiometric, and rich propane-air flames. Calculations are based on kinetic and thermodynamic theory. These theoretical data are compared with concentrations observed experimentally downstream of flat grid-type burner flames (approximately 25,000 Btu/hr) that were used to simulate gas appliances such as water and space heaters. Air pollutant concentrations are also computed for (1) flames chemically perturbed by recycling flue gases into the primary fuel-air mixtures; (2) flames thermally perturbed by cooling the burned gases at different rates; and (3) flames perturbed by combination of these two effects. In general, experimental and computed concentrations agree to within a factor of 2 to 7 with the experimental values always being higher than the theoretical. The theoretical analysis indicates that cooling the primary flame by recycling cold flue gases (with and without excess air) reduces the relative emission of nitric oxide and increases emission of carbon monoxide if the flame stoichiometry does not radically change. Cooling rates of about 5,500° to 10,000° R/sec starting at about 3,500° R generally suffice to prevent nitric oxide concentrations in lean flames from increasing much above the initial values at the combustion zone; these same cooling rates do not prevent oxidation of most of the initial carbon monoxide.

RI 6959. Bromide and Iodide in Oilfield Brines in Some Tertiary and Cretaceous Formations in Mississippi and Alabama, by A. Gene Collins, William P. Zelinski, and Cynthia A. Pearson. June 1967. 27 pp. 1 fig. The Bureau of Mines undertook research to determine the bromide and iodide content of Mississippi and Alabama oilfield waters of the Tertiary and Cretaceous Period to determine genetic relationships of the ions, to determine their origin, and to determine their genetic relation to petroleum. The 280 samples were analyzed after a pretreatment to remove interferences. The iodide was oxidized to iodate and was titrated with thiosulfate. The bromide was oxidized to bromate and was determined iodometrically. A computer was used to calculate the correlation coefficients of iodide to bromide and to other ions. The other ions are sodium plus potassium, calcium, magnesium, chloride, bicarbonate, and sulfate. The mineral content of the samples ranged from 52 to 1,760 mg/l for bromide and from 2 to 65 mg/l for iodide. The mean bromide-to-chloride and iodide-to-chloride ratios were 0.0065 and 0.0002, respectively. The correlation coefficient matrix and linear plots indicated a definite bromide-to-calcium relationship for the brines investigated.

RI 6960. Deposition of Barium Sulfate From Sea Water in Oil-Well Rotary Pumps, by G. L. Gates and W. H. Caraway. June 1967. 16 pp. 7 figs. The Bureau of Mines in cooperation with the City of Long Beach, Calif., studied some physical factors affecting the deposition of barium sulfate scale in oil-well rotary pumps. Freshly formed barium sulfate was obtained by combining sulfate in sea water with barium from a barium chloride solution. The rate of scale deposition was measured quantitatively by weighing the pump impellers and diffusers. The results of the tests showed that coating the impellers with plastic significantly reduced the rate of barium sulfate deposition.

RI 6961. Hydrogenation Studies of Distillate Fuels, by Charles S. Albright, Frank G. Schwartz, and Cecil C. Ward. June 1967. 25 pp. 6 figs.

This report describes hydrogenation of petroleum distillate fuels in bench-scale equipment and the effects of hydrogenation on the storage stability and the composition of the fuels. Two distillate fuels were hydrogenated in laboratory equipment using a commercially available cobalt molybdate catalyst. Reactor temperatures were varied from 600° to 850° F and pressures from 100 to 600 psig. Product fuels were analyzed by ASTM, Bureau of Mines, mass, and infrared methods. Hydrogenation of a catalytically cracked fuel from Oklahoma crude oil significantly improved the storage stability, reducing insoluble gum formed during 9 months of storage at 110° F from 19.0 to 1.3 mg per 100 ml fuel, average. Conversion of the olefins to other hydrocarbon types varied with the temperature of hydrogenation—at 700° to 850° F the conversion was mainly to aromatics, at 650° F about 50:50 to saturates and aromatics, at 600° F principally to saturates. Processing a fuel composed of a mixture of virgin distillate and catalytically cracked stock, both from Illinois crude, at 700° F and 200 psig effected marked improvement in stability; the buildup of insoluble gum in storage was lowered from 18.3 to less than 1 mg per 100 ml fuel. Work done, in part, under an agreement with the Bureau of Ships, U.S. Department of the Navy.

RI 6962. Thermodynamic Properties of Forsterite and Serpentine, by E. G. King, R. Barany, W. W. Weller, and L. B. Pankratz. June 1967. 19 pp. 4 figs. The Bureau of Mines made experimental determinations of the heats of formation of forsterite and chrysotile at 298.15° K. The heat capacities of two polymorphs of serpentine, chrysotile and antigorite, were measured over the temperature range from 50° to 298° K and the entropies at 298.15° K were evaluated. The heat content of antigorite above 298.15° K was measured to 850° K. These thermochemical data were combined with other pertinent data to give heat and free energy of formation values at high temperatures. Free energy values are given for the reaction, forsterite + water = brucite + serpentine at different temperatures and pressures.

RI 6963. Tests for Tin-Lead Solders and Solder Joints, by V. R. Miller, A. E. Schwaneke, and J. W. Jensen. June 1967. 27 pp. 21 figs. The Bureau of Mines investigated methods for testing the tensile and shear strength of cast specimens of bulk solder and of soldered joints in order to increase the strength and extend the useful temperature range of soft solders. A spread-area test for determining the wettability of solder on copper surfaces was developed. Mannitol was used as a flux in spread tests to control spreading and to avoid plating, etching, and other side effects of regular fluxes. Data on commercial and high-purity solders obtained by these methods show more consistency than those reported by others from similar tests.

RI 6964. Columbium and Tantalum Alloy Development, by H. R. Babitzke and H. Kato. June 1967. 18 pp. 9 figs. The purpose of this Bureau of Mines investigation was to develop columbium and tantalum alloys suitable for use at elevated temperatures. Columbium and tantalum were combined with tungsten, hafnium, zirconium, molybdenum, vanadium, and titanium, and the resulting alloys were evaluated with respect to workability, hardness, electrical resistivity, strength at elevated temperatures, oxidation resistance, and weldability. Cb-33Hf-10W-10Ti, Cb-20Hf-5Mo, and Cb-30Hf-5Mo exhibited superior high-temperature properties. Cb-33Hf-10W-10Ti had tensile strength values of 44,300 psi at 1,200° C and 16,500 psi at 1,400° C, Cb-20Hf-5Mo had values of 35,700 and 20,700 psi, respectively. The corresponding values for Cb-3Hf-5Mo were 38,900 and 17,800 psi. These alloys are fabricable by conventional methods with excellent strength at temperatures up to and including 1,400° C. An oxidation rate of 7 to 21 mg/cm^2/hr was observed up to 1,000° C.

RI 6965. Some Anisotropic Considerations in Rock Stress Determinations, by Robert M. Becker and Verne E. Hooker. June 1967. 23 pp. 5 figs. The evaluation of existing rock stresses from measurements of the change in diameter of a borehole that is stress relieved by overcoring has become a common practice. The stress evaluation has been generally based on isotropic relations whereas rock in varying degrees is anisotropic. A plane elasticity solution for a circular hole along one axis of an orthotropic medium is adapted for evaluation of in situ stress from borehole deformation measurements. A consistent triaxial testing approach for determining elastic properties of the overcore is also outlined. Comparison of isotropic with anisotropic interpretations of the state of stress show that large errors in evaluation may occur if the anisotropic character of the rock is neglected.

RI 6966. Clinton Hematitic Sandstone Deposits, Butt Mountain Area, Giles County, Va., by George E. Fish, Jr., with a section on beneficiation evaluation by W. E. Lamont, C. E. Spruiell, Jr., and I. L. Feld. June 1967. 39 pp. 11 figs. As a part of a study of iron ore resources in the Appalachians, nine diamond drill holes aggregating 1,580.7 feet were drilled in a portion of the Butt Mountain area of northeastern Giles County, Virginia. Three hematitic sandstone beds were intersected in the Clinton Formation but only one was consistent in thickness and grade in all nine drill holes. This bed averages 18.9 percent iron over an average thickness of 24 feet. The drill cores were logged and chemical analyses were made on 161 individual samples and 22 composite samples. Beneficiation studies were made of three composite hematitic sandstone samples each representing a separate bed containing 14.6, 19.8, and 20.0 percent iron. Major mineral constituents of the samples were hematite, quartz, and sericite. The easy sliming characteristics and the iron oxide mineralization of the samples precluded the use of conventional mineral dressing methods for producing high-grade iron ore concentrates with good iron recovery. Beneficiation techniques, such as sink-float, attrition scrubbing, dry magnetic separation, and flotation, failed to yield effective separation of the iron values. The best concentrates were obtained by reduction roasting, fine grinding, and magnetic separation. Magnetic concentrates were produced that contained 49.5, 53.9, and 56.7 percent Fe with recoveries of 89.0, 91.7, and 92.6 percent, respectively. These medium-grade concentrates contained a relatively large amount of phosphorus and also would require agglomeration before the material could be used as furnace feed.

RI 6967. Hot Rolling of Oxide-Glass Compositions, by Henry M. Harris, John E. Kelley, Paul H. Sunset, and Hal J. Kelly. June 1967. 41 pp. 17 figs. A study was made by the Bureau of Mines to determine if shapes of oxide-glass compositions could be roll-formed at high temperatures and to find the conditions required for adequate formability. A unit with directly connected furnaces and heated rolls that allowed forming of most of the compositions was developed. Glasses of the feldspar type were chemically unreactive with the alumina grains, and allowed the best roll forming. Optimum forming was attained at temperatures of 1,400° to 1,530° C, with compositions containing 30 or 40 percent feldspar and 60 or 70 percent alumina. Formability was better when compositions contained minus 325-mesh materials, rather than coarser or finer powders. In many cases, roll-formed shapes had physical properties equal to or better than the normally sintered shapes of the same composition.

RI 6968. Phase Relations in the Uranium Monocarbide Region of the System Uranium-Carbon-Oxygen at 1,700° C, by Jack L. Henry, Danton L. Paulson, Robert Blickensderfer, and Hal J. Kelly. July 1967. 42 pp. 16 figs. The monocarbide region of the ternary system U-C-O has been investigated at 1,700° C as the first phase of a more extensive study of a portion of the four-component system U-C-O-N. An area bounded by the following compositional limits in atomic percent was studied: U, 44 to 55; C, 30 to 60; O, 0.2 to 20. Compacts composed of mixtures of uranium, graphite, and uranium dioxide powders were sintered at 1,700° C under an equilibrium pressure of carbon monoxide to produce uranium oxycarbide specimens having a variety of compositions. Sintered specimens were evaluated by X-ray, chemical analysis, and ceramographic techniques. Solid-solution boundaries and phase relations have been established, and the effects of composition on the lattice parameter as well as the decomposition pressure have been investigated. Oxygen can be substituted for carbon in stoichiometric uranium monocarbide to the extent of about 17 atomic percent at 1,700° C. The composition range of the oxycarbide solid solution extends from about 48 to 51 atomic percent uranium in the low oxygen region. Above 10 atomic percent oxygen the composition range narrows to less than 1 atomic percent uranium. Carbon monoxide exists as a gaseous phase in equilibrium with all compositions which contain oxygen. Five separate phase fields were found bounding the solid-solution area. Other phases within this portion of the system include uranium, uranium dioxide, uranium dicarbide, and uranium sequicarbide. Decomposition pressures of oxycarbide compositions at 1,700° C have been found to vary from a few microns for stoichiometric and uranium-rich compositions to 35 torr for carbon-oxygen-rich specimens. Lattice parameters were found to depend upon the U to C + O ratio as well as upon the extent of substitution of oxygen into the stoichiometric monocarbide lattice. Work done under an agreement with the U.S. Atomic Energy Commission.

RI 6969. Heavy Liquid Cyclone Concentration of Minerals (in Two Parts). 1. A Study of Liquid Cyclone Variables Influencing the Concentration of Minerals, by R. B. Tippin and James S. Browning. July 1967. 36 pp. 19 figs. The heavy liquid separation (HLS) process was investigated by the Bureau of Mines to develop a means of concentrating minerals from natural ores. Various spodumene ores were tested in a 0.4-inch diameter cyclone using pure tetrabromoethane (TBE) as the heavy liquid. Studies were initiated to examine the influence of (1) pulp density, (2) feed grade, (3) cyclone pressure, (4) cyclone apex opening size, (5) cyclone vortex finder opening size, and (6) mineral particle size on the separation efficiency. Each of these factors were found to affect the heavy liquid separation in some degree; the mineral particle size exhibited the greatest effect and the ore feed grade the least. Conditions necessary to yield an 85 percent spodumene concentrate with an 85-percent recovery were determined to be 70 psig pressure, 10 percent solids, 0.08-inch apex opening, 0.11-inch vortex finder opening, and a minimum amount of minus 200-mesh fines in the feed. Operation of multiple cyclones in series resulted in spodumene concentrates assaying over 90 percent and indicated mineral recoveries exceeding 90 percent. Work done in cooperation with the University of Alabama.

RI 6970. Synthesis of Cyclic Sulfides, by R. L. Hopkins, R. W. Higgins, H. J. Coleman, C. J. Thompson, and H. T. Rall. July 1967. 20 pp. 7 figs. Some typical thiacyclopentanes and thiacyclohexanes were synthesized to provide reference compounds needed for the identification of sulfur compounds in crude oils. Two general methods of synthesis were employed: (1) cleavage of 2-alkyltetrahydropyrans with hydrogen bromide followed by the reaction of the resulting dibromoalkanes with sodium sulfide and (2) the catalyzed reaction of cyclic ethers or 1,4- or 1,5-alkanediols with hydrogen sulfide. Both methods produced mixtures of 2-alkylthiacyclopentanes and 2-alkylthiacyclohexanes with 2-alkyltetrahydropyran as the starting material. The structures of the reaction products were established by analysis for sulfur; desulfurization; gas-liquid chromatography (GLC); mass, infrared, and nuclear magnetic resonance (NMR) spectra; and an alternate synthesis. The synthesis of the cyclic sulfides contributed substantially to the identification of 10 members of this class of sulfur compounds in crude oil. Work done in cooperation with the American Petroleum Institute.

RI 6971. Investigation of Stress Distributions in Burst-Prone Coal Pillars, by A. J. Barry, A. Zona, J. L. Gilley, and R. H. Oitto, Jr. July 1967. 12 pp. 7 figs. Stress distributions induced in rectangular, burst-prone coal pillars by retreating pillar extraction lines were investigated. Pressure changes within two pillars were monitored continuously, using hydraulic pressure cells installed at depths of 10, 15, 20, and 25 ft in each pillar. This investigation was made in the Pocahontas No. 4 coalbed in southern West Virginia. Stress distributions were determined from pressure changes in 32 hydraulic pressure cells. The results indicated that (1) the stress distribution changed continually as pillar mining approached the test sites, (2) the maximum stress developed progressively deeper into the pillars and increased steadily in magnitude, and (3) the change in stress was influenced by the distance between the roof-cave line and extraction line. This investigation demonstrated that the hydraulic pressure cells are satisfactory for determining stress distributions in coal pillars.

RI 6972. An Electrolytic Process for Producing Ductile Vanadium, by K. P. V. Lei, F. R. Cattoir, and T. A. Sullivan. July 1967. 22 pp. 11 figs. The Bureau of Mines investigated molten salt electrorefining in helium atmosphere cells as a means for the production of ductile vanadium. Electrolytes composed of $NaCl-VCl_2$, $LiCl-NaCl-VCl_2$, $BaCl_2-KCl-NaCl-VCl_2$, $KCl-LiCl-VCl_2$, and $CaCl_2-NaCl-VCl_2$, were tested. Two electrolytes, $KCl-LiCl-VCl_2$ and $CaCl_2-NaCl_2$ were selected for laboratory-scale production tests. A molten salt electrorefining process was developed for the production of ductile 99.6 percent vanadium from a commercial 90-percent grade. Using the $CaCl_2-NaCl-VCl_2$ electrolyte, an 87-percent recovery of ductile vanadium was made; an 85-percent recovery was made with the KCl-LiCl-VCl_4 electrolyte.

RI 6973. Chloroform Extractions of Coals and Chars, by J. G. Walters, J. L. Shultz, and J. A. Glaenzer. July 1967. 28 pp. 6 figs. This report presents the results of an investigation in which the chloroform solubilities of coals and chars are related to rank, temperature of thermal treatment, time at a given temperature, vacuum thermal treatment, plasticity, oxidation, blending, and mass spectral analyses and molecular weights of the extracts. It was found that the quantity of chloroform extract obtained from chars can be altered by creating a vacuum above the charge during preparation of the char, increasing the time at temperatures within the plastic temperature range, and by utilizing different rates of heating to attain a given temperature. Relationships found between the chloroform solubilities of chars produced at temperatures within the plastic temperature range and the relative fluidities in this temperature range indicate that the chloroform-soluble portion of the char is a significant component of the plastic mass. Chloroform-extract yields from chars made from blends of coals cannot be calculated from chloroform-extract yields obtained from chars made from the component coals.

RI 6974. Noble Metals, Molybdenum, and Tungsten in Hydrocarbon Synthesis, by J. F. Shultz, F. S. Karn, and R. B. Anderson. July 1967. 20 pp. 12 figs. The Bureau of Mines extended its investigation of methanation catalysts. The noble metals (platinum, palladium, ruthenium, rhodium, osmium, and rhenium), molybdenum, and tungsten were tested in hydrogenations of carbon monoxide and carbon dioxide at 21 atmospheres in a temperature range between 200° and 600° C. From the 8 metals studied, 25 catalysts representing 5 catalyst types were prepared and tested. The impregnated 0.5-percent-ruthenium catalyst proved to be the most active and versatile of all the catalysts produced. Tungsten and the noble metals other than ruthenium were low in activity and usually required temperatures above 500° C for appreciable production of hydrocarbons. Molybdenum was moderate in activity, but further improvement in molybdenum catalysts seems possible.

RI 6975. Developing a Thermochemical Model for the Iron Blast Furnace. Mathematical Model of the Reduction Zone, by Hillary W. St. Clair. July 1967. 35 pp. 7 figs. The reduction zone of the iron blast furnace is represented by a mathematical model of the chemical reactions and heat transfer that occur between gas and solids during the deoxidation of iron oxide. The model consists of a set of equations and an algorithm whereby the equations may be solved to give the temperature and composition of gas and solids at any position in the reaction zone and at any time after a specified initial state. The model is applied to the special case in which ferric oxide is reduced by graphitic carbon and carbon monoxide produced by burning carbon in dry air. The rate of reduction, carbon consumption, and maximum temperature are shown as functions of the temperature and rate of flow of the incoming reducing gas and external heat loss. The model of the reduction zone is the essential part of a general mathematical model for simulation of the iron blast furnace. The simulation model will serve as a research tool to be used in conjunction with an experimental or operating furnace. After the simulation model has been correlated with the real furnace, it is proposed that further experimentation be done mostly with the model. The real furnace will then be operated primarily to test and confirm the model.

RI 6976. Laboratory and Pilot Plant Development of Flotation Procedures for Fine-Grained Hematitic Ores of Marquette Range, Michigan, by R. T. Sorensen and D. W. Frommer. July 1967. 34 pp. 5 figs. Bench-scale and continuous testing were performed to adapt the anionic process for flotation of calcium-activated silica to the fine-grained hematitic–goethitic jaspers from the Marquette range, Michigan. These ores typically contain about 35 percent Fe and require grinding to about 80 to 100 percent minus 400 mesh to insure an adequate liberation of gangue from the iron oxides. A method for removal of troublesome slime fractions without excessive iron loss, by first dispersing the quartz and then selectively flocculating the iron oxides, was evolved in the laboratory and successfully accommodated to pilot plant practice. The efficiency of the flotation process was improved with respect to both reagent usage and concentrate grade and recovery by using the selective flocculation-desliming technique as a pretreatment. The benefits of the combined desliming-flotation procedure were most evident in pilot plant processing. The best tests on two ores yielded recoveries of about 84 percent in concentrates containing 65.1 percent Fe and 4.8 percent SiO_2 and 66.2 percent Fe and 3.9 percent SiO_2, respectively. These results are in comparison to recoveries about 10 percent lower than the above and to concentrates containing 63.9 percent Fe and 6.6 percent SiO_2 in the one instance, and 63.6 percent Fe and 7.2 percent SiO_2 in the other, obtained by flotation without the prior desliming treatment. Reagent savings of about 25 cents per long ton of concentrate were counted as an additional benefit from use of the combination treatment. Work done in cooperation with the Cleveland Cliffs Iron Co.

RI 6977. Blast Furnace Operation With Natural Gas Injection and Oxygen-Enriched Blast, by R. J. Leary and P. L. Woolf. July 1967. 24 pp. 7 figs. The Bureau of Mines experimental blast furnace was blown with oxygen-enriched blast in combination with natural gas injected at the tuyeres. The air blast was augmented with oxygen to form an enriched blast containing 24.8 pct oxygen, and tests were run at natural gas injection rates of 4.5, 6.0, and 8.3 pct of the air blast. Similar enrichment to 26.8 pct oxygen was tested at natural gas rates of 7.2, 9.1, and 11.0 pct of the air blast. At intermediate proportions of natural gas to oxygen, (1) the fuel rate and the replacement ratio of coke by natural gas were unaffected by oxygen injections and (2) the productivity increased about 4 pct for each 1 pct oxygen added to the blast. The higher proportions of natural gas to oxygen were less efficient; in return for a lower coke rate, the fuel rate increased and productivity declined. A deficiency in reducing gas imposed a limit upon lower than normal proportions of natural gas to oxygen. Beyond this limit the formation of reducing gas was insufficient to support the rate of metal production. When this condition was encountered, the coke rate requirement for specification iron was abnormally high and production fell off badly. Adiabatic flame temperature is discussed as a means for proportioning oxygen and natural gas additions.

RI 6978. Effects of Ultrasonic Energy on Fluid Flow in Porous Media, by C. A. Komar and C. I. Pierce. July 1967. 12 pp. 2 figs. The Bureau of Mines conducted experiments on one synthetic and three natural sandstone samples to investigate the effects of acoustic energy on the flow of brine in porous media. Ultrasonic energy at a frequency of 20 kc per second and an intensity of 55 watts per cm^2 was irradiated in the direction of the fluid flow and in the opposite direction for distances of ½ and 2 inches between the vibrating device and the sample face and under conditions of suppressed and nonsuppressed cavitation. Forty tests were conducted: 32 with a pressure differential of 0.64 psi across the samples, 2 with 5 psi, and 6 with 15 psi. Acoustic waves altered the rate of flow of the brine through the samples, but this effect was observed only at low differential pressures and from a practical point of view was insignificant. As a result of irradiation, however, the samples exhibited reduced permeability. This reduction was probably caused by the shifting of solid particles dislodged by the acoustic waves.

RI 6979. Correction for Nonuniformity of the Bore of a Capillary Tube Viscosimeter, by John E. Miller, R. A. Guereca, H. P. Richardson, and J. L. Gordon. July 1967. 24 pp. 5 figs. Absolute viscosity values for gases usually are determined with a capillary tube viscosimeter. One of the correction factors applied to the experimental data is that for nonuniformity of the capillary bore. This report contains useful analytic expressions of the nonuniformity correction for the following cases: ellipse, cone, sine wave, sawtooth wave, square wave, and the general case. The methods herein described are applied to estimate the nonuniformity of a section of stainless steel capillary tubing to be used at the Bureau of Mines Helium Research Center. Several other examples are given to illustrate the usefulness of the present results.

RI 6980. Relative Pressure Changes in Coal Pillars During Extraction: A Progress Report, by Ernest A. Curth. July 1967. 20 pp. 13 figs. The Bureau of Mines studied pressure changes in coal pillars by using encapsulated hydraulic pressure cells to measure relative changes in stress developed during mining. The data indicate that (1) abutment stresses were detected when the pillar line is within 42 to 100 feet, (2) vertical pressure increases as coal is mined in the pillars, (3) at first pressure is higher at the edge of the pillar than in the core, but as mining progresses, the higher pressure is measured is the core of the stump, and (4) in the two instances where lateral pressures were measured, they remained lower than the vertical pressures during pillar extraction. The data also indicate that the mean vertical pressure increase, ΔP, in a pillar is roughly related to the percent of pillar extracted, A, by the empirical parabolic equation

$$\Delta P = -0.11\ A + 0.356\ A^2.$$

RI 6981. A Rapid Colorimetric Method for Field Determination of Nitrogen Dioxide in Fumes From Explosives, by E. J. Murphy. July 1967. 21 pp. 5 figs. The Bureau of Mines developed a fast, reliable modification of the Griess-Ilosvay procedure suitable for field analysis for NO_2 in the fumes from explosives. Known concentrations of NO_2-air mixtures were analyzed for the nitrous acid or nitrite formed in the reaction with three Griess-Ilosvay-type reagents by diazotizing and coupling. Comparison was made of the Rider-Mellon, Saltzman, and Patty-Petty procedures; the three procedures are in agreement if sufficient time of contact between NO_2 and the reagents is allowed. In experiments to obtain an accurate factor for converting NO_2 to nitrite, overnight contact was allowed in order to be sure conversion was complete. The factor was found to be 75 percent with a standard deviation of ±3.2. Low and erratic results were found using either the Saltzman or Patty-Petty reagents as absorbing liquids unless several hours' contact was allowed. If dilute NaOH solution was used as the absorbing liquid instead of a Greiss-Ilosvay-type reagent, 92 percent of the overnight conversion factor was found after a 3-minute shaking time and a 10-minute standby time. The Saltzman reagent was preferable for fieldwork with the dilute NaOH solution as the absorbent because of its easy application, rapid reaction, and intense color at low NO_2 concentrations.

RI 6982. Continuous Flotation of Fluorspar From a Calcareous Illinois Ore, by W. H. Eddy, James S. Browning, and James E. Hardemon. July 1967. 10 pp. 3 figs. The Bureau of Mines made small-scale continuous tests and large-scale commercial plant tests of a calcareous fluorspar ore near Cave-In-Rock, Ill., to determine if the application of the lignin-fluoride process of fluorspar flotation would be industrially feasible for treatment of fluorspar ores, and also to compare the lignin-fluoride process with the quebracho process, which is the method currently used for concentrating calcareous fluorspar ores. The small-scale continuous tests yielded fluorspar concentrates analyzing 93.6 percent CaF_2 with a recovery of 87.6 percent of the total fluorspar in the ore. In large-scale commercial plant tests, a fluorspar concentrate analyzing 93.3 percent CaF_2 with a recovery of 78.0 percent was produced by the quebracho method. About 86.0 percent of the fluorspar was recovered in a metallurgical-grade fluorspar concentrate from the lignin-fluoride circuit which analyzed 89.9 percent CaF_2, with a much simpler flowsheet than that in the current commercial application. Work done in cooperation with the University of Alabama and the Minerva Co..

RI 6983. The Hafnium-Carbon Phase Diagram, by D. K. Deardorff, M. I. Copeland, and R. P. Adams. July 1967. 16 pp. 8 figs. The purpose of this work was to investigate the hafnium-carbon phase diagram. Alloys used to study this system were prepared from high-purity components by both consumable- and nonconsumable-electrode arc melting. Data for the diagram were obtained on the alloys by metallography, optical pyrometry, thermal analysis, heat treatment, and X-ray diffraction. The data indicate that a carbide compound occurs over considerable range of composition and that one of each of the following types of reactions occurs in the hafnium-carbon system: peritectoid, peritectic, and eutectic. The maximum melting temperature of hafnium carbide is 3,840° C at 49 to 50 atomic percent carbon, and the composition range of hafnium carbide at temperatures of 2,150° to 2,380° C is from 37.0 to 48.5 atomic percent carbon. The hafnium α-β transformation temperature is raised on alloying with carbon from 1,750° to 1,890° C, where a peritectoid reaction isotherm occurs. Alloying hafnium with carbon increases the hafnium melting temperature from 2,190° to 2,250° C, at which temperature a peritectic reaction occurs. Hafnium carbide and carbon react at 3,055° C to form a eutectic of 68.3 atomic percent carbon.

RI 6984. Purification of Tungsten Hexachloride, by F. A. Skirvin, T. T. Campbell, and F. E. Block. July 1967. 17 pp. 7 figs. Purification techniques were investigated for removing low-level metallic impurities from tungsten hexachloride. These techniques included distillation, fused-salt scrubbing, zone refining, and adsorption. Fractional distillation of tungsten hexachloride was found to be an effective purification method. The impurity levels of molybdenum, iron, nickel, copper, magnesium, and manganese were reduced to provide a tungsten halide sample which contained a total of less than 10 ppm detectable metallic impurities. Purification by fused-salt scrubbing of tungsten hexachloride in a lithium chloride-potassium chloride eutectic produced a hexachloride product which was of approximately the same quality as that obtained by distillation. Zone refining and adsorption did not appear to be as effective as distillation of fused-salt scrubbing.

RI 6985. Spectrochemical Analysis of Coal Ash, by J. B. Zink, W. D. Washington, and M. J. Peterson. July 1967. 14 pp. The Bureau of Mines developed a spectrochemical method to determine six constituents in coal ash in the following concentration ranges: Silica, 9 to 63 percent; alumina, 7.5 to 35 percent; ferric oxide, 2 to 30 percent; calcium oxide, 1 to 29 percent; magnesium oxide, 0.5 to 6 percent; and titanium oxide, 0.5 to 4 percent. Samples of coal ash are fused with a mixture of lithium tetraborate and vanadium pentoxide. The resulting beads are crushed, mixed with powdered graphite, and briquetted. The pellets are analyzed spectrographically, using controlled high-voltage spark excitation. Vanadium serves as the internal standard. Effects due to matrix variations are minimized by fusion with lithium tetraborate. Intensity ratios of selected analytical lines are determined photometrically. Concentrations are read from analytical curves, prepared from synthetic standards, relating log intensity ratios to log concentrations. A combustion procedure is used to determine sulfur trioxide. The method is most useful when large numbers of coal ashes must be analyzed but a high degree of accuracy is not essential.

RI 6986. Projectile Impact Initiation of Condensed Explosives, by Milton L. Weiss and Elton L. Litchfield. July 1967. 17 pp. 8 figs. Studies were made on the projectile impact sensitivity of explosives by subjecting explosive samples to the impact of metal projectiles fired from a 0.50-caliber gun. The projectiles, in the form of right cylinders, made plane surface contact with the explosives. Pressures in the explosive were investigated with an expendable pressure transducer in some instances. The physical model of the projectile-explosive interaction describes, in principle, the duration of the peak shock pressure in terms of the projectile and explosive geometry and the steady-state penetration of the explosive. Of the explosives studied, liquid hydrogen-solid oxygen and liquid oxygen-solid or liquid hydrocarbon fuel were the most shock sensitive (requiring an initiating shock of about 1.0 kb or 987 atmospheres pressure); cast TNT was the least sensitive (requiring an initiating shock of more than 110 kb pressure). Measurements of pressure in the explosive showed some moderate space resolution by the transducer and gave pressure distributions in agreement with expectations from the model of the shock processes. The appearance of the recovered projectiles and the calculated initiation shock pressures indicate the solid explosives were initiated directly to high-order detonation, whereas the liquid explosives were probably initiated to low-order detonation —with a subsequent, later transition to high-order detonation.

RI 6987. Mine Water Research. Neutralization, by Maurice Deul and E. A. Mihok. 1967. 24 pp. 18 figs. A special short-term research project was initiated to develop plant design parameters for treating mine waters to yield an effluent acceptable for discharge into streams and a sludge amenable to effective and economical disposal. Neutralization was investigated to provide simple and direct treatment of ferruginous acid waters using lime, coarse limestone, and limestone followed by lime. Limestone treatment was accomplished using a small cement mixer as a simple reactor to provide abrasive agitation of limestone and mine water. Results from tests with nine mine waters encompassing a wide range of iron and acid concentrations showed that coarse limestone, one of the cheapest neutralizing agents known, is potentially useful for treating mine water discharges. However, process variables must be defined more completely before the practical applications and limitations of the process can be fully established. In all the tests a pH of >7.2 was obtained ultimately with limestone. Reaction time to reduce the iron content below 7 ppm in the water was dependent on the original ferrous iron concentration. For waters with high ferrous iron contents, treatment with limestone folowed by lime rapidly produced an acceptable treated water. Sludges with good settling and handling characteristics resulted when limestone was used for neutralization either alone or with subsequent treatment. Reaction rates are expressed graphically as pH change and iron depletion curves; characteristic solids-settling curves are shown. The temperature dependency of ferrous iron oxidation was verified.

RI 6988. Study of Columbium-Base Alloys, by Renpei Yoda, H. R. Babitzke, and H. Kato. July 1967. 30 pp. 30 figs. An investigation was conducted to develop columbium alloys with elevated-temperature strengths higher than those exhibited by more common commercial columbium alloys, and attention was given to improving the oxidation resistance and ease of fabrication. Additions of carbon, aluminum, and chromium were made to some columbium-base alloys, and their effects on workability, recrystallization, oxidation resistance, and mechanical properties at elevated temperatures were explored. The additions were made to take advantage of (1) solid solution strengthening and (2) precipitation hardening. Three alloys displayed good high-temperature properties with relatively good oxidation resistance at 1,000° C and tensile strengths from 26,000 to 32,200 psi at 1,400° C. When the properties of these alloys were compared with those of commercial alloys, B-66 and FS-85, the outcome was favorable for the alloys studied in this investigation.

RI 6989. Preparation Characteristics of Pennsylvania Anthracite From the Bottom Red Ash Bed, Northern Field, by W. S. Sanner. July 1967. 36 pp. 6 figs. Seven samples were analyzed from the major reserves of the Bottom Red Ash bed, Northern anthracite field. The data show variations in thickness and geologic structure and in the amount of coal that can be recovered. Recovery of market-grade (less than 17 percent ash) coal is high for all samples, ranging from 76 to 95 percent in the 3¼- by 9/16-inch sizes. The occurrence of coal containing less than 5 percent ash varies from 19.5 to as much as 57.5 percent. Crushing the coarse sizes to minus 9/16 inch increased recovery of market-grade coal in six of seven bed samples. Crushing released sufficient impurities to cause substantial increases in yield of coal containing less than 5 percent ash for all samples. Analyses of the float indicate that the quality of coal is comparable for all samples.

RI 6990. Estimation of Low-Temperature Carbonization Product Yields: Utah Coalfields, by Manual Gomez, W. S. Landers, and C. K. Boyd. July 1967. 32 pp. 7 figs. Low-temperature carbonization product yields for 129 coals representative of 12 Utah coalfields were estimated, using regression equations developed from heating value and proximate and ultimate analysis data. It was shown that yields of char, tar plus light oil, water of decomposition, and gas, as well as the gas volume and the heating value of the gas, could be predicted with reasonable accuracy. Published and experimental results from eight Utah coals carbonized at selected temperatures in the 450° to 1,000° C range were used to determine the effect of temperature on product yields. Carbonization temperature, heating value, oxygen, and volatile matter of coal appear to be the principal variables influencing carbonization product yields. Data presented show that the heating value and the residual volatile matter in low-temperature char may be predicted using relationships developed from proximate analysis data for 220 coals.

RI 6991. Lake Superior Iron Resources. Reexamination of Nonmagnetic Taconite Occurrences in the Hibbing, Minn., Area by Flotation, Magnetic Separation, and Petrographic Methods, by L. F. Heising, C. B. Daellenbach, and E. E. Anderson. July 1967. 21 pp. 8 figs. Ten composite samples of Mesabi range nonmagnetic taconite from the Hibbing, Minn., area were evaluated by flotation and by reduction roasting-magnetic separation to determine their potential as a future source of iron ore. Only one of the composites yielded concentrates that could be considered marketable, using as a criterion a 10-to-1 iron-to-silica ratio. Cursory petrographic examinations of all 10 composited samples and a detailed mineralogical study on 1 sample suggest that unfavorable mineralogical associations between iron and gangue minerals are responsible for their poor beneficiation characteristics.

RI 6992. Reservoir Study of the William Kaufman Lease, Clover-Rush Run Oilfield, Roane County, W. Va., by Karl-Heinz Frohne. July 1967. 17 pp. 7 figs. This report presents the findings of a study of a portion of the Clover-Rush Run oilfield located in Roane County, W. Va. The study was made to investigate the possibilities of secondary oil recovery in the Big Injun sandstone underlying the William Kaufman lease. Reservoir properties, original reserves, and primary oil recovery are also presented. The investigation is based on a core analysis and related laboratory tests, well records, field production data, and subsurface information from the Kaufman property. A theoretical primary oil recovery of 9.7 percent of original oil in place is predicted for the reservoir. A waterflood performance prediction of a hypothetical pilot area was made by use of a computer. The prediction showed that, based on laboratory oil-water relative permeability curves, the water-injection time needed to initiate oil production is excessive and that the stabilized water-injection and corresponding oil-production rates are very low. This precludes waterflooding the reservoir on an economic basis. A prediction for secondary oil recovery by gas injection was attempted but could not be completed because essential reservoir data were not available. In July 1965, the lease operator initiated, and is currently conducting, a gas-injection program, but there had been no increase in oil production up to November 1966.

RI 6993. Liberation and Concentration of Phosphate Minerals by Attrition Grinding and Sizing (Supplement to RI 6749), by J. W. Town, P. E. Sanker, and J. C. White. August 1967. 28 pp. 16 figs. Studies were made by the Bureau of Mines to determine the influence of textural features on the beneficiation of phosphate minerals (pellets) from selected bed and composite samples representing different rock types of the western Phosphoria Formation. The particle size of the samples were reduced by attrition grinding to minus 20, 28, or 48 mesh depending on ore grade and gangue matrix. Sizing of the ground material showed that the phosphate pellets would concentrate in the plus 200-, 270-, or 325-mesh size fractions sufficiently so that the phosphate content was above the 31.5 percent P_2O_5 required for acidulation. The phosphate content of essentially pure phosphate pellets was shown to range from 33 to 39 percent P_2O_5. Microscopic identification of the particles in each size fraction showed that the phosphate was either in the pellet form and readily liberated or so intimately associated with the gangue matrix that size reduction necessary to obtain liberation was impractical.

RI 6994. Hydrogen Cyanide From the Reaction of Coal With Ammonia, by Glenn E. Johnson, W. A. Decker, A. J. Forney, and J. H. Field. August 1967. 17 pp. 5 figs. The Bureau of Mines investigated the production of hydrogen cyanide by reacting powdered coal (minus 300 mesh) with ammonia at 1,250° C in a bench-scale study. Both metallic and ceramic reactors were used. Yields up to 0.7 cubic foot of hydrogen cyanide per cubic foot of ammonia consumed were obtained. The resulting ammonia conversion of about 75 volume-percent approximates conversion obtained commercially in processes utilizing natural gas and platinum catalysts. The coals that had higher volatile-matter contents gave the best yields of hydrogen cyanide. Allowing the coal to absorb ammonia before reaction resulted in increased yields of hydrogen cyanide. Cost studies for a plant with 40-million-pound-per-year capacity indicate that hydrogen cyanide can be profitably coproduced wth carbon black, from coal and ammonia, at the current market price of hydrogen cyanide (11.5 cents per pound). These figures are based on heating the reactor electrically. If a cheaper heating method were devised, the economics of the process would be more favorable.

RI 6995. Steady-State Laminar Flow Boundary Conditions for a Stainless Steel Coiled-Capillary Viscosimeter, by R. A. Guereca, H. P. Richardson, and L. M. Walker. August 1967. 15 pp. 6 figs. The Bureau of Mines conducted an analysis to determine criteria for steady-state laminar flow boundary conditions for a coiled-tube gas viscosimeter by comparing experimental data from a thick-walled, stainless steel capillary in a horizontal, straight-tube condition, with similar data taken after the same capillary was formed into a helix. Overlapping volumetric flow-rates and pressure drops are covered for both configurations at pressure levels of 28, 225, and 1,000 psia at 300° K. Friction factor, Reynolds number, and Dean number correlation plots show conditions where the coiled-tube flow deviates from straight-tube flow. The coiled-tube data indicate departure from Poiseuille steady-state laminar flow at a Reynolds number close to 390 and a Dean number of about 15. Below these conditions and consistent with the data reported, Dean's circulation appears negligible. For the particular coil used, a conservative upper limit of 10 is chosen for the Dean number corresponding to an upper limit of about 250 for the Reynolds number.

RI 6996. Fracturing a Deposit With Nuclear Explosives and Recovering Copper by the In-Situ Leaching Method, by William R. Hardwick. November 1967. 48 pp. 24 figs. Present information indicates that a copper deposit can be safely fractured with a nuclear explosive and the copper successfully recovered by the in situ leaching method. The process is not yet at the stage where it can be presented to the mining industry as a technique proven in all its aspects, but it is a method with high success potential. Unknown factors must be evaluated by a full-scale test before the economics or the extent of the use of the method by the mining industry can be predicted. Preliminary calculations indicate that the cost of fracturing a copper deposit with nuclear explosives may range from 1.8 to 55.2 cents per ton or in some cases less than a cent per pound of recoverable copper. Copper may be recovered at less cost than by conventional methods. Deposits with 4 pounds of recoverable copper may be economic and production from a deposit may begin in less than half the time required for conventional methods. Work done under an agrement with the San Francisco Operations Office, U.S. Atomic Energy Commission.

RI 6997. Stress Ellipsoid Determination in a Rock-Burst-Prone Area at a 4,000-Foot Depth, Galena Mine, Wallace, Idaho, by Robert W. Ageton. August 1967. 23 pp. 10 figs. Optimal planning for mining the deep lead-zinc-copper deposits of the Coeur d'Alene mining district, Shoshone County, Idaho, could be facilitated by a knowledge of the magnitude and direction of the pressure acting in the virgin rock. The distribution of primary stresses should be considered in order to prevent possibly destructive mining-induced stress concentrations. This particular investigation was concerned with determining stress in a zone 4,000 feet below the surface and known to be under stress concentrations due to mining operations. Disking of the stress-relief cores obtained in a vertical down hole permitted qualitative evaluation from visual observations; the results indicate that a high lateral stress existed at the time the measurements were made. Stress-ellipsoid determinations gave a compressive principal stress of −13,000 psi oriented about N 45° W and nearly horizontal, a compresive principal stress of −11,000 psi oriented about S 45° W and about 60° off the vertical pointing away from the vein, and a compressive principal stress of −7,000 psi oriented N 45° E and about 60° off the vertical pointing toward the vein. Subsequent to the overcoring stres-relief drilling, a rock burst occurred about 100 feet northwest of the test site.

RI 6998. Reaction of Tungsten-Cobalt Alloys With Oxygen at 1,000° and 1,100° K, by Robert M. Doerr, L. A. Neumeier, and J. W. Jensen. August 1967. 22 pp. 9 figs. The purpose of the investigation was to determine the oxidation behavior of selected tungsten-cobalt alloys. Specimens of W and W-Co containing 0.7, 1.7, 3.4, and 9.7 weight-percent Co were subjected to pure O_2 at 1,000° and 1,100° K, and specimens of W-Co containing 29.8 weight-percent Co, at 1,100° K. Reaction kinetics were determined volumetrically. For specimens other than those containing 29.8 percent Co, the reactions proceeded at about a constant rate at either temperature, indicating the formation of a scale of constant protectivity; the reaction rates were essentially independent of the Co concentrations. The scales on these alloy specimens consisted principally of WO_3 and $CoWo_4$. Specimens of a 29.8 weight-percent Co alloy, consisting primarily of the W_6CO_7 phase, oxidized with only slight deviations from the parabolic rate law at 1,100° K. The protective scale on these specimens consisted chiefly of Co_3O_4, $CoWO_4$, and $W_{18}O_{49}$; Co_3O_4 was outermost, and the $W_{18}O_{49}$ was adjacent to the alloy. The results suggest that the Co-rich outer scale inhibited the inward transport of O to an extent sufficient to greatly limit the amount of the nonprotective WO_3 formed, so that protective $W_{18}O_{49}$ formed instead.

RI 6999. Electric Smelting of Complex Lead-Zinc Sinter, by Richard N. Spencer, Seth C. Schaefer, and James E. Mauser. August 1967. 28 pp. 7 figs. Electric-furnace smelting for simultaneous recovery of zinc spelter and lead bullion from complex lead-zinc sinter was investigated. Reduction of lead and zinc was satisfactory. Condensation of lead and zinc vapor to pyrophoric metal powder in a water-cooled, shock-condensing system produced excellent recoveries. Metal-splash condensation to produce zinc spelter was unsatisfactory. Special smelting experiments differentiated the effects of several smelting parameters on zinc metal recovery. The principal cause for unsatisfactory zinc metal recovery was transfer of iron to the condenser and subsequent degradation of zinc in a mixture composed of lead and an iron-zinc intermetallic compound. Limitations of the process were determined. Slag-resistance open-bath electric smelting of complex lead-zinc sinter is not considered feasible.

RI 7000. Mass Spectrometric Analyses of Coal-Tar Distillates and Residues, by J. L. Shultz, R. A. Friedel, and A. G. Sharkey, Jr. August 1967. 14 pp. Mass spectrometric analyses were obtained for naphthalene and anthracene oils, heavy creosote, and three fractions of a pitch. The average molecular weight, aromaticity, and mean structural unit were determined for each fraction. The investigation of these fractions of coal tar has resulted in semiquantitative data for 38 structural types and carbon number distribution data for their alkyl derivatives. The molecular weights of 10 of these structural types indicate ring systems not previously reported in products from high-temperature carbonization of coal. Two of these structures are polynuclear aromatic hydrocarbons, two are oxygen-containing compounds, one contains sulfur, and five are nitrogen-containing compounds.

RI 7001. Thermodynamic Properties of Three Lithium-Aluminum Silicates, by L. B. Pankratz and W. W. Weller. August 1967. 13 pp. 2 figs. The Bureau of Mines measured heat capacities of alpha and beta spodumene ($LiAlSi_2O_6$) and of beta eucryptite ($LiAlSiO_4$) over the temperature range 51° to 298° K. The entropies at 298° K were found to be 30.9 ± 0.2 cal/deg mole for alpha spodumene, 36.9 ± 0.3 cal/deg mole for beta spodumene, and 24.8 ± 0.2 cal/deg mole for beta eucryptite. High-temperature heat content measurements above 298° K were conducted for the same compounds. Measurements were made to 1,150° K for alpha spodumene, 1,600° K for beta spodumene, and 1,470° K for beta eucryptite. Tables of heats and free energies of formation are given from the elements and from the constituent oxides.

RI 7002. Stresses and Displacements Surrounding an Open Pit in a Gravity-Loaded Rock, by Wilson Blake. August 1967. 20 pp. 7 figs. The Bureau of Mines used a mathematical model based on the finite element method of stress analysis to calculate stresses and displacements surrounding an open pit mine in a gravity-loaded rock mass. Comparison of the finite element solution for a semicircular notch in a gravity-loaded plate with the theoretical solution for a semicircular notch in a plate under uniform compression parallel to the free boundary demonstrates the inapplicability of the latter method to openings at the free surface of a gravity-loaded medium. High stress concentrations are formed at irregularities along the boundary of an open pit in a gravity-loaded continuous competent rock; however, for this type of rock the magnitudes of the stresses are too low to be considered a major factor in open pit slope stability. High stress magnitudes will occur if, in addition to the gravity stress field, a large horizontal stress field exists.

RI 7003. A Two-Constant Equation for Helium From 30° to 1,473° K, by Jonnie M. Estes and Philip C. Tully. August 1967. 18 pp. 3 figs. A two-constant equation is presented for helium from $30^\circ \leq T \leq 1{,}473^\circ$ K. This equation is developed by modifying a generalized equation of state originally presented by Redlich and Kwong. The modification consists of setting $B = 0.06372\ T_c/P_cT$. This modified equation represents the compressibility factors of each of 80 isotherms tested in this temperature range to less than 1-percent average deviation.

RI 7004. Preparation Characteristics of Coal From Upshur County, W. Va., by A. W. Deurbrouck. August 1967. 32 pp. 3 figs. This Bureau of Mines report describes the preparation characteristics of the significant coalbeds from which samples could be obtained in Upshur County, W. Va. One of the 14 samples collected was of metallurgical quality as received, 6 could be sufficiently upgraded to provide acceptable products, and 7 could not be upgraded to metallurgical quality because of their high sulfur contents.

RI 7005. Reaction Rates of the Titanium-Oxygen Alloy System and Titanium Chlorides in Molten Sodium Chloride, by E. K. Kleespies, J. Jackson, Jr., and T. A. Henrie. August 1967. 12 pp. 4 figs. The rate of the heterogeneous reaction between titanium-oxygen solid solutions and titanium trichloride in molten sodium chloride was determined at high temperatures. In the alpha phase, the reaction rate decreases uniformly with the increasing concentration of oxygen. The gamma crystalline form of titanium (above 33 atomic percent oxygen) was much less reactive than the alpha phase, and the reaction rate approached zero at 50 atomic percent oxygen. The activation energy for the reaction of titanium-oxygen solution containing 22.8 percent oxygen was 11.7 kcal/mole of $TiCl_3$ as compared with 8.3 kcal/mole of $TiCl_3$ for pure titanium.

RI 7006. Unique Properties of Permeability Curves of Concern to Reservoir Engineers, by R. V. Higgins, D. W. Boley, and A. J. Leighton. August 1967. 19 pp. 16 figs. The Bureau of Mines investigated the use of electronic computers for obtaining more information about relative permeabilities of reservoir rock to oil and water. It was found that there are many possible combinations of relative permeability curves that will result in virtually the same recovery versus injection, but they require different times and rates to recover the oil even with different mobility ratios. Permeability curves obtained by the use of nonviscous oil and employed for calculating the waterfloods of viscous oils can lead to serious inaccuracies. For viscous oils, the wettability characteristics in the middle portion of the permeability curve affect recovery nearly as much as other portions of the curve; this, however, is not true for nonviscous oils in water-wet reservoir rock.

RI 7007. Prospects for Secondary Recovery of Oil by Waterflooding. Mitchell and Berea Sands, Lower Newport Field, Newport Township, Washington County, Ohio, by James A. Wasson. August 1967. 22 pp. 6 figs. The Mitchell and Berea sands were cored and logged in Fred Link well K-1, Lower Newport field, Washington County, Ohio. Core and reservoir fluid analyses and available field data were studied to determine if these sands could be successfully waterflooded. The results of the study indicate that there is insufficient oil in place to form an oilbank in either the western Mitchell pool or the Berea sand, and that no commercial recovery of oil by waterflooding can be obtained in these reservoirs.

RI 7008. Reaction Rate of Solid Yttrium Metal With Molten Lithium Fluoride, by Bernard Porter, R. E. Meaker, and T. A. Henrie. August 1967. 13 pp. 4 figs. The rate of the heterogeneous reaction between reactor-grade yttrium and lithium fluoride in lithium fluoride-yttrium fluoride mixtures was measured using a quartz spring balance. At 950° C the magnitude of the rate of reaction is 10^{-5} grams of yttrium/cm^2-sec. The heat of activation for the reaction is 38.3 kilocalories per mole of LiF. A surface-controlled mechanism is proposed in which LiF is adsorbed on the yttrium metal surface. An activated complex is formed when additional LiF reacts with the adsorbed LiF-metal site. The activated complex then decomposes to the products, which are lithium metal and YF_3. The importance of the reaction in the electrowinning of yttrium metal from fluoride electrolytes is discussed.

RI 7009. Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures. Techniques and Apparatus, by E. L. Litchfield, M. H. Hay, T. A. Kubala, and J. S. Monroe. August 1967. 11 pp. 5 figs. Descriptions are given of the techniques and apparatus used by the Bureau of Mines for determinations of flat plate ignition quenching distance and minimum spark ignition energy. The descriptions include discussions of reaction vessel materials, shapes, and sizes and discussions of electrode configurations. Spherical, hemispherical, or flat plate electrodes are recommended. The preferred metal in electrodes and electrode supports is stainless steel; the flat plate electrodes incorporate flanges of low electrical conductivity which are most frequently formed from glass. Various aspects of the electrical energy supply system are discussed and suitable arrangements of components are indicated. The concept of a thermal relaxation time is introduced as a basis for the choice of a minimum interspark time during the testing of a gas mixture. The following indicate the varied conditions under which these techniques were utilized: Mixture pressures between 10 mm Hg and 45 psig, initial temperatures between −78° and +198° C, and gaseous mixtures representing wide ranges of chemical reactivity and corrosiveness. Minimum ignition energies were determined which varied from about 10^{-7} joule to nearly 10^3 joules.

RI 7010. Pulverizing Lignite in a Ball Mill, by Leroy Dockter, J. W. Belter, and R. C. Ellman. August 1967. 13 pp. 5 figs. The grinding characteristics of lignite in a ball mill were investigated. The variables studied were initial lignite moisture content, degree of in-the-mill drying, and lignite source. The mill tested was a pilot-plant-size conical ball mill which had a maximum output of from 80 to 180 lb/hr pulverized product depending on the lignite and test conditions. The capacity of the test mill ranged from 82 to 103 lb/hr, depending upon mine source, in pulverization of as-mined lignite with minimum drying. The capabilities of the ball mill could not be correlated to Hardgrove index of the individual lignites or other observed physical properties. Predrying lignite from its 35 to 40 percent raw moisture content to about 10 percent moisture before grinding improved the mill capacity 87 percent, compared to an increase in capacity of 74 percent with in-the-mill drying to the same product moisture.

RI 7011. Computer Techniques for Predicting Three-Phase Flow in Five-Spot Waterfloods, by R. V. Higgins and A. J. Leighton. August 1967. 45 pp. 7 figs. This report presents computer instructions for calculating the performance of three-phase flow of gas, oil, and water. The calculated results for an illustrative example are presented. The example is the waterflood of a reservoir containing free gas in the reservoir as a result of the partial depletion of the oil by the expansion of the gas initially in solution. The flood pattern for the example is a five-spot.

RI 7012. Dewatering Anthracite Slurry, by G. A. Brady, Harold H. Griffiths, and J. W. Eckerd. August 1967. 13 pp. 3 figs. Laboratory tests were conducted to determine the technical feasibility of separating anthracite particles from a water-anthracite slurry by atomizing the water and removing the resulting mist in an air current. Products containing 21 percent or less moisture were obtained from slurries made with minus 60-mesh anthracite. Typical recoveries ranged between 67 and 79 percent of the feed when the slurries were atomized in air currents with velocities below 70 ft/min.

RI 7013. Gas-Reservoir Properties From Pressure-Buildup Data, by George L. Gates and W. Hodge Caraway. September 1967. 19 pp. 5 figs. The Bureau of Mines studied pressure-buildup data from a number of California gas wells to determine if the reservoir properties calculated from these data correlated with field-observed reservoir properties. Pressure-buildup curves from 24 wells showed distinct changes in slope, indicating changes in permeability of the reservoir rock. Calculated distances from the wells to indicated permeability changes were in fair agreement with distances determined in the field. Presure-buildup curves from three wells had more than one distinct change in slope, indicating multiple permeability changes. Thus field data supported the theoretical relations used to calculate reservoir properties from pressure-time relations measured in gas wells.

RI 7014. Electron-Beam Purification of Vanadium, by W. E. Anable. September 1967. 24 pp. 7 figs. The Bureau of Mines studied the purification of commercially available vanadium in the 100-kw electron-beam furnace. Purification studies were conducted on a 100-gram-button scale by melting and holding the liquid vanadium at temperatures ranging from 2,060° to 2,080° C at a pressure of $5(10)^{-5}$ torr for periods ranging from 5 to 20 minutes. The effect of doping vanadium with carbon and metallic additions was determined. This study demonstrated that hydrogen was readily removed to 3 ppm or less, oxygen and carbon were reduced to less than 100 ppm each, and the metallic impurities were reduced to the range of 10 to 500 ppm. The nitrogen content was not reduced in any of the buttons; rather, the nitrogen concentration generally increased as samples were held for successively longer periods. Oxygen was removed much faster and more completely when vanadium was doped with small carbon additions or one of several dopes prior to melting.

RI 7015. Three-Component Borehole Deformation Gage for Determining the Stress in Rock, by Robert H. Merrill. August 1967. 38 pp. 23 figs. This Bureau of Mines report summarizes the design and tests of a gage that will simultaneously measure the deformation of a borehole along three diameters 60 degrees apart; the measurements are in a single plane normal to the axis of the borehole. The inherent errors in measurement are considered together with the problems associated with the use of the gage in the relatively severe environments in and around mine openings. These problems were treated in the design and tests of the gage and the results establish that the gage can be used to satisfactorily determine estimates of the stresses in rock.

RI 7016. Electrodeposition of Thick Coatings of Platinum and Palladium on Refractory Metals From Aqueous Electrolytes, by Stephen D. Cramer, Charles B. Kenahan, Richard L. Andrews, and David Schlain. September 1967. 64 pp. 27 figs. The objective of the present studies was to develop thick adherent and coherent coatings of platinum and palladium on refractory metals and other substrates of industrial and engineering importance. Existing platinum and palladium electrolytes were modified to make them suitable for the electrodeposition of thick deposits. The optimum operating conditions for these electrolytes were established. Pretreatment procedures for columbium, copper, graphite, molybdenum, nickel, stainless steel, tantalum, titanium, tungsten, vanadium, and zirconium substrates were studied. New pretreatment procedures for columbium, molybdenum, stainless steel, tantalum, tungsten, and nickel were developed. The internal stress and hardness of selected electrodeposits were measured. The effects of heat treatment upon the properties of electrodeposits were studied.

RI 7017. Electrochemical Reduction of Coal, by Heinz W. Sternberg, Raymond E. Markby, Charles L. Delle Donne, and Irving Wender. September 1967. 38 pp. 7 figs. A method for the electrochemical reduction of the benzene ring was developed and applied to the electrochemical reduction of coal. Successive electrochemical reductions of a vitrain from low-volatile bituminous coal in ethylene-diamine saturated with lithium chloride resulted in the addition of 53 hydrogens per 100 carbon atoms. Ultimate analyses and pyridine solubility of the vitrain recovered after each reduction showed that hydrogen added at the beginning has a much greater effect on solubility than hydrogen added at a later stage. Surprisingly, the removal of sulfur from the vitrain takes place only after the more reactive aromatic rings are reduced. Nuclear magnetic resonance analysis and average molecular weight determination of the extracts of the reduced vitrain samples, representing about 18 percent of the vitrain, showed that these fractions had 95 percent of their hydrogen content on saturated carbon atoms and an average molecular weight of 800 to 900. A study of the effect of operating variables on current efficiency showed that current efficiency is highest with aluminum as cathode material and with lithium chloride as electrolyte. A substantial increase in current efficiency of difficultly reducible olefinic double bonds was achieved by adding a proton donor. This result is significant in connection with the electrochemical reduction of coal which proceeds from readily reducible aromatic double bonds to difficultly reducible isolated double bonds. It is proposed that reduction is achieved by electrolytically generated and subsequently solvated electrons and hence does not require prior adsorption of the substrate at the electrode surface. This offers a distinct advantage for electrolytic reduction of sparingly soluble or insoluble substrates such as coal.

RI 7018. Electrorefining Yttrium, by C. C. Merrill and M. M. Wong. September 1967. 10 pp. 3 figs. Studies were made to determine the amenability of yttrium to fused-salt electrorefining in a controlled atmosphere. Tests were conducted in a $LiCl\text{-}YCl_3$ electrolyte system at 710° C. The major variables studied were the YCl_3 content of the electrolyte, from 1.7 to 13.4 mole-percent, and the initial cathode current density, from 410 to 1,630 amperes per square foot. Vacuum distillation was employed to remove salt from the deposited metal. Metallic impurities, except for lithium, could be reduced to near or below their lower analytical limits, ranging from 10 ppm for Cu to 300 ppm for Ta; reduction of oxygen content, however, was accomplished only in metal produced from electrolytes with 5.4 mole-percent YCl_3 or less. Initial cathode current density had little effect on the purity of the product.

RI 7019. Power Required To Circulate Gas-Solids Suspensions, by C. N. Rosenecker, N. H. Coates, and H. G. Lucas. September 1967. 10 pp. 8 figs. The power required to circulate a gas-solids suspension was determined using a centrifugal compressor and a closed system. The suspension consisted of 18- to 40-micron glass beads in a mixture of 89 percent N_2 and 11 percent CO_2 at 20 psig. Solids-to-gas (S/G) ratios were 0 to 2.2 lb/lb; gas flow rates were 1.2 to 2.5 lb/min. Power requirement was found to follow the relationship $hp_t = hp_g \left(\frac{G}{S} + 1\right)$, where hp_t = the total power, and hp_g = the power required for pure gas. Work done under an agreement with the U.S. Atomic Energy Commission.

RI 7020. A Method for Treating PVT Data From a Burnett Compressibility Apparatus, by Robert E. Barieau and B. J. Dalton. September 1967. 34 pp. This report describes a method for treating pressure-volume-temperature (PVT) data obtained with a Burnett compressibility apparatus. The method makes use of a general nonlinear least-squares technique developed at the Bureau of Mines Helium Research Center. It is assumed that an adequate functional form is available for the expression of the compressibility factor as a function of either the molal density or the pressure. The functional form of the compressibility factor can be either linear or nonlinear in the parameters to be evaluated. Formulas are given for calculating variances and covariances of all parameters evaluated and for calculating the variance of calculated quantities of interest.

RI 7021. Process Development in Removing Sulfur Dioxide From Hot Flue Gases (in Four Parts). 3. Pilot Plant Study of the Alkalized Alumina System for SO_2 Removal, by D. Beinstock, J. H. Field, and J. G. Myers. July 1967. 52 pp. 36 figs. The use of alkalized alumina in removing sulfur dioxide from a coal-combustion flue gas at 625° F was investigated on a pilot plant scale. The absorber was 26 feet long and 1.6 inches ID. Countercurrent gas-solids flow at gas velocities of 8 to 15 ft/sec in the presence and absence of baffles, as well as solids entrainment at gas velocities of 20 to 23 ft/sec with solids recycle, were employed. The spent absorbent was regenerated as a fixed bed with the reducing gases—reformed natural gas and hydrogen. Twenty cycles of absorption-regeneration were successfully completed using the alkalized alumina rolled into spherical granules 10 to 16 mesh. There was no loss in activity of absorbent toward SO_2 with a modest attrition equivalent to 0.1 percent of the solids fed. Supporting studies were conducted on the effect of the sodium content in the absorbent, the composition of the reducing gas, thermal treatment to increase absorbent hardness, and removal of absorbed chlorine from the absorbent. A mathematical model was formulated to describe the removal of SO_2 by alkalized alumina from fixed and falling beds.

RI 7022. Vapor Pressure of Metal Halides. The $SnCl_2\text{-}ZnCl_2$ Binary System, by L. C. George, J. W. Jensen, and Robert M. Doerr. September 1967. 22 pp. 8 figs. The Bureau of Mines measured vapor pressures of selected mixtures in the binary system $SnCl_2\text{-}ZnCl_2$ by the static pressure method. Equations expressing the vapor pressure and the heat and free energy of vaporization as functions of temperature were developed by numerical analysis based on the sigma-plot method. It was found that the vapor pressure of any $SnCl_2\text{-}ZnCl_2$ mixture, at any temperature within the range of this investigation, could be accurately calculated from the derived values for the heat and free energy of vaporization for the mixture, with a probable error of 0.01 cm Hg or less.

RI 7023. Electrodeposition of Iridium From Fused Sodium Cyanide and Aqueous Electrolytes. A Preliminary Study, by R. L. Andrews, C. B. Kenahan, and David Schlain. September 1967. 12 pp. 4 figs. The Bureau of Mines investigated means of electrodepositing iridium to form thick coatings suitable for the protection of such metals as tungsten and molybdenum, which oxidize rapidly at high temperatures. Using a fused sodium cyanide bath, thick, adherent, and coherent deposits of iridium up to 15 mils thick were plated on tungsten and molybdenum substrates at 600° C and current densities of 10 to 100 ma/cm^2. Limited oxidation testing of molybdenum encapsulated with pure iridium indicates that the coating may offer protection to approximately 1,000° C in flowing air, but that at higher temperatures, the volatility of its oxide limits use of pure iridium. Alloy coatings of iridium with platinum, palladium, and rhodium up to 4 mils thick were formed from a fused sodium cyanide electrolyte; because their oxides are less volatile, these alloys may protect substrates at higher temperatures. Deposits made from aqueous electrolytes either had very low rates of deposition or were highly stressed and cracked when heavy deposits were made.

RI 7024. The Effect of Carbonization Conditions and Coal Properties on Coke Size and Strength Parameters, by Manuel Gomez, J. G. Walters, and J. B. Gayle. September 1967. 34 pp. Published experimental coke data from a pilot plant slot-type oven were examined by statistical regression analysis. Quantitative relationships were found to exist between the coking rate, bulk density, and fine grinding of the coal, sole-oven expansion, volatile matter, moisture, ash, and carbon content of the coal and coke parameters indicative of size and strength. Regression equations developed from coke data were shown to yield computed values that were in good agreement with experimental results for 11 coke properties. Prediction equations developed were evaluated with an independent set of data. Present results indicate that the variables cited undergo much interaction and the sum of these interactions determines coke size and strength.

RI 7025. Thermoelectric Properties of Yttrium-Group V and Yttrium-Group VI Binary and Ternary Compounds, by Timothy J. Driscoll, Jr., and Lindsay D. Norman, Jr. September 1967. 14 pp. 6 figs. The thermoelectric properties of yttrium monoarsenide, yttrium monoantimonide, and ternary materials from the Y-As-Se and Y-Sb-Te systems were investigated by the Bureau of Mines from room temperature to 1,000° C. The maximum calculated figure of merit for yttrium monoarsenide and yttrium monoantimonide was 2×10^{-5} ° C^{-1}. YAs and YSb were semimetallic conductors with low Seebeck coefficients and electrical resistivities. The values of the Seebeck coefficient and electrical resistivity of the Y-As-Se and Y-Sb-Te materials were between those of the yttrium selenides and tellurides and of YAs and YSb, respectively. The maximum power factor calculated for the Y-As-Se materials was 2×10^{-5} watt/cm ° C^2 which yielded an estimated figure of merit of 6×10^{-4} ° C^{-1}. Most of the Y-As-Se compounds had high Seebeck coefficients and moderately low electrical resistivities. The Y-Se-Te materials were degenerate semiconductors with power factors of 6×10^{-6} watt/cm ° C^2. The Y-As-Se materials consisted of a YSe_x major phase with 1 percent arsenic and $1.25 < X < 1.45$. The minor phase was primarily a solid solution of YAs and YSe containing approximately 25 percent arsenic. The materials that displayed power factors greater than 10^{-6} watt/cm ° C^2 contained 10 to 20 percent of the minor phase. The Y-Sb-Te materials were two-phase, consisting of YSb and Y_2Te_3.

RI 7026. Thermodynamic Data for Cuprous and Cupric Oxides, by Alla D. Mah, L. B. Pankratz, W. W. Weller, and E. G. King. September 1967. 20 pp. 2 figs. Heat content and entropy data at high temperatures were obtained for cuprous oxide (Cu_2O) and cupric oxide (CuO). Experimental results and smooth values are reported. Equations are given for heat content increments and heat capacities above 298° K. Low-temperature heat capacity data were obtained for cuprous oxide. Evaluation of the 298° K entropy gave

$$S^\circ_{298.15}(Cu_2O) = 22.08 \pm 0.10 \text{ cal/deg mole.}$$

Heat of formation values were determined for cuprous and cupric oxides. The values are:

$$\Delta H^\circ_{298.15}(Cu_2O) = -40{,}830 \pm 300 \text{ cal/mole,}$$

and

$$\Delta H^\circ_{298.15}(CuO) = -37{,}230 \pm 150 \text{ cal/mole.}$$

Heat and free energy of formation data are tabulated for cuprous oxide (298°-1,600° K) and for cupric oxide (298°-1,400° K). Heat, free energy, and equilibrium pressure values are given for the dissociation of cupric oxide (298°-1,400° K).

RI 7027. Chemical Reactions Produced by Exposing Coal Derivatives to Ultrasonic Energy, by Theodore Kessler, A. G. Sharkey, Jr., and R. A. Friedel. October 1967. 11 pp. 4 figs. The purpose of this Bureau of Mines investigation was to determine what new organic compounds or high concentrations of a particular organic species can be formed by exposure of coal derivatives to ultrasonic energy. Tetralin, 1-methylnaphthalene, and pyridine were used as model compounds. Gaseous and solid reaction products resulting from the ultrasonic irradiation of these coal derivatives were determined using mass spectrometry. Products from the irradiation of tetralin were studied as a function of time, atmosphere, and sample size. The sonolysis (chemical reactions produced by ultrasonic energy) of tetralin and 1-methylnaphthalene produced C_2H_2, HCN, CH_4, H_2, CO, and CO_2, depending upon the experimental conditions. The ultrasonic irradiation of tetralin also produced diacetylene under certain experimental conditions. The cleavage of organic chemical bonds by ultrasonic cavitation in the absence of water was also observed in this study.

RI 7028. A Statistical Evaluation of Some Factors in the Preparation of Boron by Fused-Salt Electrolysis, by James H. Russell and Hal J. Kelley. October 1967. 16 pp. 4 figs. The Bureau of Mines used a statistical approach to evaluate the effects of temperature, current density, and composition of the electrolyte on the purity of boron prepared by electrolysis of a fused mixture of boric oxide in potassium fluoborate. The quadratic equation which best fits the data was calculated for a temperature of 650° to 850° C, a cathode current density of 40 to 1,150 amp/ft², and a boric oxide content of 0.3 to 7.1 molal. The best products, better than 95 percent boron, were obtained when the current density was less than 100 amp/ft² and the boric oxide content was less than 2 molal.

RI 7029. Design and Development of a Lightweight Recoverable Hydraulic Prop, by Webster S. Anderson. October 1967. 19 pp. 12 figs. The design, development, and testing of hydraulic props to provide a lightweight, high-strength, recoverable unit is described. Modifications in design incorporating threaded components resulted in the development of a lightweight hydraulic prop fabricated from aluminum alloy tubing. This new design facilitates interchange and replacement of component parts, and the physical properties of the material are not changed as they are when welding is required. This new prop has a maximum load capacity of 65,000 pounds and has a lower weight-to-load capacity ratio than the hydraulic props now available.

RI 7030. Nonuniform Radial Loads Applied to the Boundary of a Circular Hole in an Infinite Plate, by Wilbur I. Duvall and Wilson Blake. October 1967. 16 pp. 5 figs. In this report, the Bureau of Mines presents a theoretical solution for the stresses and displacements in an infinite elastic plate containing a circular hole the boundary of which is loaded by applied radial stresses over four separated arcs. The problem solved is a two-dimensional approximation of the stresses and displacements developed by a large tunnel-boring machine anchored in a circular tunnel. Analysis of the solution shows that the tangential tensile stresses induced on the boundary of the circular opening can be minimized in the roof and maximized in the floor of the opening by proper spacing and loading of the four arcs.

RI 7031. Developing a Thermochemical Model for the Iron Blast Furnace. Measurement of Rate Coefficient for Reduction of Iron Ore Pellets in a Packed Bed, by Hillary W. St. Clair. October 1967. 20 pp. 5 figs. The effective coefficient for rate of reduction of a sample of granular iron ore may be determined by passing the reducing gas through a bed of the ore at constant flow rate and periodically analyzing the effluent gas. The method of analyzing the data is based on a mathematical model that takes into account the variation in composition of the gas and solids with time and position in the bed. A method is described for determining the value of the rate coefficient that gives best agreement between the observed and calculated analyses of the effluent gas.

RI 7032. Reservoir Evaluation, I. D. Morgan Lease, Smithfield Oilfield, Grant District, Wetzel County, W. Va., by Charles E. Whieldon, Jr., and C. David Locke. October 1967. 17 pp. 7 figs. This report presents the results of a study on part of the Smithfield oilfield, Wetzel County, W. Va. The primary purpose of the investigation was to determine the original and the present volume of stocktank oil in the formations and to investigate the feasibility of waterflooding the Gordon Stray, Gordon, and Fourth sands underlying the I. D. Morgan lease. The study was based on laboratory core analyses, geophysical well logs, geologic considerations, and various field prediction data from the I. D. Morgan lease. The Bureau found that, of the three sands cored, the Gordon Sand was the best prospect for waterflooding and that a properly engineered waterflood should recover 136 to 230 barrels of oil per acre-foot from this formation.

RI 7033. Synthesis of High-Btu Gas in a Raney-Nickel-Coated Tube-Wall Reactor, by J. J. Demeter, A. J. Youngblood, J. H. Field, and D. Bienstock. October 1967. 17 pp. 9 figs. A tube-wall reactor with a Raney nickel catalyst deposited on the outer wall of the tube by flame spraying is effective in the practically complete conversion of $3H_2+1CO$ synthesis gas to a high-Btu gas (methane) at an hourly space velocity of 7,000 volumes of gas (NTP) per hour per volume of annular volume. Partially reacted synthesis gas containing an appreciable amount of methane can also be treated in this reactor to increase the heating value to over 900 Btu per cubic foot. Excellent heat removal through the metal wall to a coolant and temperature control were obtained. The heat transfer coefficient from the catalyst to the coolant was about 275 Btu per hour per square foot per ° F. Synthesis tests were conducted with tubes 1.2 inches in od by 6 inches long, and 1.3 inches in od by 36 inches long. When operating at a synthesis gas rate of 100 to 120 scfh per square foot of catalyst-coated tube, catalyst life was long enough to realize a catalyst coat for the raw Raney nickel alloy of about 0.3 cent per 1,000 cubic feet of pipeline gas (900 to 950 Btu per scf). Gas recycling at ratios of 1:1 to 3:1 was effective in increasing conversion and in extending the life of the catalyst to about 16 weeks. In cost and in operating characteristics the tube-wall reactor compares favorably with the fluidized-bed and hot-gas-recycle reactor systems for the synthesis of high-Btu gas from H_2+CO.

RI 7034. Laboratory Study of Factors Influencing Waterflow in Mine Backfill. Classified Mill Tailings, by Robert C. Bates and William R. Wayment. October 1967. 45 pp. 16 figs. Variations in water percolation rates through saturated cohesionless hydraulic backfill (mill tailings) have been studied in relation to the many physical aspects of the system to determine the most important factors in causing these variations. A multivariable least-squares regression analysis of 135 separate tests shows that a reliable estimate of the water percolation rate through typical hydraulic backfill can be made if the bulk density (unit weight), specific gravity, and grain-size distribution are known or can be estimated. Equations for predicting percolation rate, coefficient of permeability, and seepage velocity are developed both for the range of data analyzed and for extrapolation. The prediction equations for use within the range of data studied are quite accurate, while the ones developed for extrapolation are less accurate but still give reasonable approximations of flow rates. The equations given are valid for cohesionless materials that are free of clays and micas, exemplified by classified mill tailings. The prediction equation for percolation rate is rather complicated, so for practical use a nomograph that simplifies the solution of the prediction equation was developed.

RI 7035. A Study of Heat Transfer to Water-Cooled Copper Crucibles During Vacuum Arc Melting, by P. G. Clites and R. A. Beall. October 1967. 36 pp. 21 figs. This study was conducted to determine the patterns of heat transfer to water-cooled copper crucibles during vacuum arc melting. Values of heat flux from the ingot to the crucible were determined during nonconsumable electrode vacuum arc melting of zirconium and during consumable electrode vacuum arc melting of titanium, zirconium, and steel. The results of these studies confirm the existence of a high thermal resistance between the ingot and the crucible wall which results from the shrinkage of the ingot as the metal solidifies. Maximum heat flux occurs near the top of the ingot where maximum values of heat flux of 1.4×10^6 Btu/ft^2 hr were observed during small-scale consumable electrode arc melting of zirconium and titanium. The maximum heat flux for consumable electrode arc melting of 8-inch-diameter ingots was 0.5×10^6 Btu/ft^2 hr. The effects of electrode material, electrode diameter, arc current, and arc potential on heat flux from the ingot to the crucible were studied. Data were also obtained on crucible wall temperatures and on the effect of very narrow annular water jackets. Work done under an agreement with the U.S. Atomic Energy Commission.

RI 7036. Molten-Salt Electrorefining Vanadium Scrap, by K. V. P. Lei and T. A. Sullivan. October 1967. 18 pp. 7 figs. The Bureau of Mines investigated molten-salt electrorefining as a practical method for reclaiming vanadium from vanadium scrap. An electrolytic process utilizing a KCl-LiCl-VCl_2 electrolyte at 615° C was developed for producing ductile vanadium with a purity over 99.9 percent. The recovery of the vanadium in the cell feed ranged from 88 to 93 percent with a current efficiency from 83 to 95 percent.

RI 7037. Long-Term Storage of Lignite at Garrison Dam, Riverdale, N. Dak., by Robert C. Ellman, John W. Belter, and Leroy Dockter. October 1967. 56 pp. 14 figs. Stockpiles containing 2.3 million tons of lignite constructed in the period 1948-56 in conjunction with the construction of Garrison Dam on the Missouri River demonstrate successful stable long-term storage of lignite. Uniform and thorough compaction of each of the 1-foot-thick layers by which the piles were constructed produced a bulk density of 70 lb/cu ft. Air penetration into the stockpiles was restricted to a degree that prevents spontaneous heating or deterioration of the stored lignite. A continuing record of observations beginning with stockpiling operations in 1948 has been accumulated. This includes periodic fuel analysis, analysis of pile gases, and measurement of pile temperatures on the first large stockpile, pile 5. This report describes the stockpiling method, the changes in heating value, pile gas composition, and pile temperature and summarizes observations from 1953 to 1964. Data accumulated attest to the stability of the stored lignite. The varaition of the average heating value of periodic pile-depth samples is only 160 Btu/lb (11,990 to 11,830) on the moisture- and ash-free (maf) basis during almost 10 years of storage. Temperature levels of the pile interior are progressively decreasing. At pile surface, cyclic variations occur with the season. The only problem encountered with the large stockpiles is wind and water erosion of the pile surface. The partially successful control measures used are described.

RI 7038. Load-Displacement Measurement in a Backfilled Stope of a Deep Vein Mine, by D. R. Corson and W. R. Wayment. November 1967. 51 pp. 42 figs. The Bureau of Mines instrumented an operating stope in a deep vein mine to determine the amount of wall closure and the magnitude of loads imposed on a backfilled stope. Hydraulic pressure cells used to monitor pressures in the fill, with bolt closure points to measure vein-wall movement and the procedure for their installation, are described, and the results of the laboratory calibration analysis of the reliability of these cells are given. An attempt to monitor density and moisture changes in the backfill with a nuclear density-moisture device was only partly successful, owing to either deformation of access tubing or relative displacements of the vertical vein walls relative to the emplaced tubes. Data from the instrumentation indicate vein-wall closure in excess of 20 inches and pressures within the fill approaching 600 psi. Analysis, incorporating field data with results of laboratory tests of the compressibility of timber and tests defining the constrained moduli of the fill, points out the limited restraint to vein closure offered by timber sets. Ground movement induced by mining activity could be more effectively controlled by the use of densely compacted backfill.

RI 7039. Reaction Rate of Titanium-Iron Alloys and Titanium Trichloride in Molten Sodium Chloride, by E. K. Kleespies and T. A. Henrie. October 1967. 11 pp. 4 figs. The Bureau of Mines determined the kinetics of the reaction of titanium-iron alloys with titanium trichloride dissolved in sodium chloride to provide a basis for understanding the reactions occurring in metallurgical processes involving reduction of the metal halides or alloy refining in fused salts. The rate of the heterogeneous reaction was determined between titanium-iron alloys and titanium trichloride to elucidate the effects of alloy composition on the rate. Measurements were made in an inert atmosphere with a high-temperature thermobalance using high-purity reactants. The rates of the reactions were about 1×10^{-5} g Ti/cm^2-sec, and the reaction was phase-boundary controlled. Titanium alloys of the body-centered cubic beta structure reacted faster than those with the hexagonal close-packed alpha structure. The intermetallic compound, TiFe, reacted very slowly, whereas $TiFe_2$ was inert. Alloys containing above 89 atomic percent iron gained weight by reacting with titanium species in the salt solution and depositing titanium in the alloy. The effect of $TiCl_3$ concentration on the reaction rate was determined from 2 to 12 weight-percent $TiCl_3$ and at various alloy compositions. At high iron contents, above 50 atomic percent, the $TiCl_3$ concentration effect was small. At lower iron contents, the $TiCl_3$ concentration effect was greater for beta-crystalline alloys than for alpha-crystalline alloys. The temperature dependence of the reaction between titanium alloy containing 8.7 atomic percent iron and titanium trichloride was measured over the temperature range 1,062° to 1,220° K, and the energy of activation was 7.7 kilocalories for the reaction.

RI 7040. High-Temperature Heat Contents and Entropies of Sodium Bromide and Sodium Iodide, by T. Estelle Gardner and A. R. Taylor, Jr. October 1967. 8 pp. 2 figs. The Bureau of Mines made enthalpy measurements on sodium bromide and sodium iodide in the temperature range 400° to 1,200° K using an ice calorimeter. Equations representing enthalpy as a function of temperature were derived from the data by the method of least squares. These equations were used to calculate smooth values of heat capacity, enthalpy, and entropy at 50° K intervals from the ice point to 1,200° K. The melting point determined for sodium bromide was 1,020° K; the melting point of sodium iodide was 934° K. The heats of fusion of sodium bromide and sodium iodide were calculated to be 6,270 and 5,680 cal/mole, respectively. Work done in cooperation with the University of Alabama.

RI 7041. Electrical Resistivity of Fly Ash at Temperatures to 1,500° F, by C. C. Shale, J. H. Holden, and G. E. Fasching. March 1968. 17 pp. 8 figs. Electrical resistivities for various coal ashes in air and in a nitrogen atmosphere are given over the range 100° to 1,500° F. Resistivity of low-carbon ash in air is very high at low temperature, rises to a maximum at about 250° F, decreases very rapidly with increasing temperature to about 800° F, then decreases gradually to approach an asymptote at 1,500 F. Resistivity of high-carbon ash in air follows this same general trend at values which are much lower and are proportional to the carbon content. After the carbon has been burned off, resistivity of the remaining ash approaches the high values corresponding to low-carbon ash of similar chemistry. Two factorial experiments show the effects of temperature, particle size, chemical content, and compressibility on the resistivities of four fly ashes of widely different chemical composition in the temperature range proposed for coal-fired turbines. Resistivities of all low-carbon ashes tested fall in the range 10^6 to 10^7 ohm cm at 1,500° F and should be removable by electrostatic precipitators. Ashes containing carbon in excess of about 8 percent, however, have low resistivity (as determined in nitrogen), especially at high temperatures. Therefore, high-carbon materials may not be collectable in precipitators, because the resistivity is below the minimum value necessary for precipitation. Consequently, high-carbon residues from partial combustion of coal probably could not be removed effectively at high temperatures.

RI 7042. Recovery of Lead and Copper From Blast Furnace Matte, by D. A. Wilson and P. M. Sullivan. November 1967. 21 pp. 6 figs. A process was developed on laboratory scale in which a solid-waste byproduct from refining of secondary lead was converted into three valuable products. Roasted lead blast furnace matte was leached with water to recover copper. This was followed by brine leaching to recover lead. Residues were finally smelted to yield pig iron. Copper was precipitated as cement copper, and the lead product obtained was a mixture of pure $3PbO.PbCl_2.xH_2O$ and Pb(OH)Cl. Copper recovery was 89 percent and lead recovery was 96 percent.

RI 7043. Leonardite and Other Materials as Drilling-Fluid Dispersants and Viscosity Control Agents, by M. L. Odenbaugh and R. C. Ellman. November 1967. 22 pp. 12 figs. The viscosity reduction effect of varied concentrations of leonardite (a naturally oxidized form of lignite) and leonardite-caustic on the rheological properties of a standard bentonite drilling fluid was studied and evaluated. The minimum plastic viscosity was found to occur at application rates of 4 lb of leonardite and 1.33 lb of caustic per barrel of drilling fluid. Leonardite-caustic treatment was not beneficial in treatment of salt-contaminated drilling fluids. Although filter loss rate was reduced, both yield values and gel strength were increased. Compared with other viscosity control agents, including quebracho, lignosulfonate, humic acids extracted from leonardite, as well as other reaction products of lignite, leonardite is less effective at low application rates but is an effective treating agent at rates of 2 lb/bbl or more. Considering the comparable merits of the substances tested, the major factor in determining which agent to use should be based on cost consideration.

RI 7044. Laboratory Investigation of the In Situ Combustion Process for Recovering Pennsylvania Grade Crude Oil, by T. E. Sterner and W. T. Wertman. November 1967. 30 pp. 11 figs. A laboratory investigation was conducted to determine the applicability of the thermal oil-recovery method as a means of increasing ultimate oil recovery in the Appalachian region. The primary objective was to establish self-sustained combustion in consolidated and unconsolidated sand test assemblies saturated with various amounts of Pennsylvania Grade crude oil and synthetic brine. Tests using blocks of sandstone were unsuccessful because of sealing problems and fracturing of the rock due to thermal stresses. A combustion wave of about 700° F was propagated through the sand-oil-water packs in the linear tube tests. The high air flux used resulted in high oil consumption and rapid movement of the combustion wave through the tubes. Analytical tests on the sand pack showed that sufficient fuel was deposited during the linear tube experiments for a self-sustained combustion wave.

RI 7045. Talc and Asbestos at Dadeville, Ala., by Thornton L. Neathery, Herbert P. LeVan, H. William Ahrenholz, and James F. O'Neill. November 1967. 57 pp. 24 figs. Geologic investigation of a mineralized zone in eastern Alabama indicates that large quantities of talc and soapstone are scattered over a wide area close to the surface. Laboratory experiments show that this material may be upgraded to a high-quality talc. A market survey indicates that the talc deposits may be of current and long-range interest. The anthophyllite asbestos which is associated with the talc does not appear to occur in sufficient quantities to be considered as a primary commercial source.

RI 7046. Heats of Formation of Holmium and Terbium Trichlorides, by J. M. Stuve. November 1967. 7 pp. The standard heats of formation ($\triangle H^\circ_f$) of holmium trichloride and terbium trichloride were measured by solution calorimetry. Heats of solution of holmium and terbium metals and their anhydrous chlorides were measured in 4.360 molal HCl at 298.15° K. From these measurements $\triangle H^\circ_f$ for $HoCl_3$ (c) was calculated as $-240{,}290 \pm 1{,}700$ cal/mole, and $\triangle H^\circ_f$ for $TbCl_3$ (c) was calculated as $-238{,}330 \pm 1{,}500$ cal/mole at 298.15° K.

RI 7047. The Cause of Fuming in Oxygen Steelmaking, by J. P. Morris, J. P. Riott, E. G. Illig, and R. H. Jefferson. November 1967. 24 pp. 12 figs. The Bureau of Mines investigated the mechanics of fuming of iron-carbon melts during top-blowing with oxygen. Melts weighing 45 lb were prepared in an induction furnace and blown with oxygen by means of water-cooled lances. The rate of fuming was measured and correlated with the operating variables. The data showed that the primary cause of fuming was a boil at the bath surface in the impingement zone of the oxygen jet. Nucleation of the carbon monoxide bubbles producing the boil was apparently brought about by the precipitation of an oxide phase. The actual fuming mechanism involved partial oxidation and vaporization of bubble films and fine metal spray generated by the bursting of the bubbles. Bubbles that formed outside the impingement zone produced little fume. The distribution of trace elements between the metal and fume strongly indicated that the fume contained fine spray particles as well as particles that had condensed from vapor. The rate of fuming was found to be proportional to the carbon content of the metal, the concentration of oxygen in the jet, and the bath temperature, provided that a continuous boil occurred. In the absence of a boil, very little fume was produced.

RI 7048. Zeta Potential and Pendulum Sclerometer Studies of Granite in a Solution Environment, by W. W. Engelmann, O. Terichow, and A. A. Selim. November 1967. 16 pp. 8 figs. The electrokinetic (zeta) potentials of a charcoal granite in an aluminum chloride solution and in an oleylammonium acetate solution have been correlated with the specific damping values as measured by the pendulum sclerometer. This investigation shows that the pendulum specific damping attains a minimum at the isoelectric point for the charcoal granite-aluminum chloride and charcoal granite-oleylammonium acetate systems, and thus indicates that the penetration of the diamond points is a maximum at the isoelectric point.

RI. 7049. Secondary Oil-Recovery Possibilities in the Basal Greenbrier Dolomite Zone, Sycamore-Millstone Field, Sherman District, Calhoun County, W. Va., by James A. Wasson. November 1967. 20 pp. 8 figs. This report analyzes the petroleum-production potential of the basal Greenbrier dolomite zone, Sycamore-Millstone Field, Sherman district, Calhoun County, W. Va., through the application of certain secondary-recovery methods. The well logs obtained and the core recovered from a well in this formation permitted an evaluation of the productive capability of the reservoir. Approximately 120,000 stb of oil may be produced from a 20-acre five-spot unit at breakthrough if the property is waterflooded. At an assumed limiting producing gas-oil ratio of 20,000 scf/stb, approximately 69,000 stb of oil should be recovered by low-pressure gas drive.

RI 7050. Effect of Operating Variables on the Production of Chemical Coke by the Traveling-Grate Process, by M. J. Kovalik and D. E. Wolfson. November 1967. 20 pp. 4 figs. The effects of the process variables on the production of chemical coke on a chain grate stoker, a type of traveling grate, were studied. Six bituminous coals, ranging in volatile matter from 16.7 to 43.8 percent, were successfully carbonized, yielding chemical coke with acceptable physical properties. The coke yields were dependent on the volatile-matter content of the coal. The air-fuel ratio had the most marked effect on the yield and characteristics of the resultant coke, and the general furnace performance. Results can only be predicted; the actual yield and quality of coke obtained from any given coal can only be determined by actual tests using the optimum processing variables to obtain a coke with minimum volatile-matter content and to retain as much of the fixed carbon in the original coal as possible.

RI 7051. Oil Yields of Sections of Green River Oil Shale in Colorado, 1957-63, by K. E. Stanfield, J. W. Smith, and L. G. Trudell. December 1967. 284 pp.

103 figs. Oil-yield results are presented for 65 oil-shale sections in Piceance Creek basin, Colorado, sampled during the period 1957 through 1963. Including previously published data, oil-yield results for 203 sampled sections have now been released by the Bureau of Mines to aid in appraising the shale oil potential of the basin. Oil yields of core samples (135 sets) were regarded as reliable bases for appraising the Mahogany-zone interval, but only five sets of cores sampled the deeper, lower zone oil shales. Drill cuttings (68 sets) sampled the lower zone oil shales, but their oil yields are principally indicative and should be confirmed by analyses of cores. More complete core sampling of the lower zone oil shales is needed.

RI 7052. Gravitational Pressure Gradient in Oil Reservoirs Containing Free Gas. Model Studies of the Elk Hills Oilfield, California, by O. C. Baptist. December 1967. 19 pp. 6 figs. The gravitational pressure gradient (GPG) in porous sandstone containing free gas was determined to define the proper GPG to use when calculating the rate of downdip flow of oil in the Sub-Scalez No. 1 sand, Elk Hills field, Naval Petroleum Reserve 1. The GPG was determined at several gas saturations using long, artificially consolidated sandstone models that were mounted vertically in some tests and horizontally, with rotation, in others. Also determined by laboratory and field tests were relative permeabilities, capillary pressure relations, critical gas saturation, water sensitivity, and depletion drive performance. The critical gas saturation in the models having an absolute permeability of 1 to 2 darcys was about 2 percent of pore volume. The GPG with the critical gas saturation was that due to the weight of the gas-saturated oil. The GPG in the upper part of the models was reduced as gas saturation increased to a value considerably larger than the critical. The exact gas saturation at which the GPG became less than that due to the weight of the oil could not be determined but was estimated to be of the order of 10 percent of pore volume. Tests indicate that the rate of oil production is not permanently reduced by exposure of the sand to fresh water but that the rate of injection of fresh water will be considerably less than that of brine. Methods for determining the factors mentioned above are discussed. Work done in cooperation with the University of Wyoming.

RI 7053. Fire Hazard of Conveyor Belts, by Donald W. Mitchell, Edwin M. Murphy, Allan F. Smith, and Samuel P. Polack. December 1967. 14 pp. 4 figs. The fire hazard of neoprene, polyvinyl chloride, and rubber conveyor belts was studied at the Bureau of Mines Experimental Coal Mine. The effects of intensity of ignition source, velocity of ventilating air, and type of belt were investigated at three levels in small-scale gallery experiments. Studies were made in the mine on the effects on ignition and flame propagation of belt-entry dimensions, belt widths, and belt configuration. Methods for extinguishing belt fires were also investigated under simulated mining conditions, and during these trials coal dust and grease were placed on the belt. The research showed that conveyor belts will burn. Neoprene, polyvinyl chloride, and rubber belts, with and without carcass, ignited and propagated flame. The highest rate of flame propagation was obtained on rubber belt. The fire hazard increased with increase in intensity of ignition source and air velocity. Flame propagated only when air was forced through the test zone; propagation was not obtained when forced ventilation was not used, as would exist in a neutral entry in a mine. Automatic water sprays and high-expansion foam effectively arrested flame propagation; direct application of water and bicarbonate dusts was ineffective.

RI 7054. Method for Determination of Fluorine in Coal, by R. F. Abernethy and F. H. Gibson. December 1967. 13 pp. 1 fig. The work discussed in this report was done by the Bureau of Mines to develop a method for determining trace amounts of fluorine in coal. Samples of coal mixed with calcium oxide as a fixative agent for fluorine were ashed at 600° C and the residue was fused with sodium carbonate. The melt was dissolved in phosphoric and sulfuric acids and distilled to separate the fluorine, which was determined in the distillate by a SPADNS-zirconium spectrophotometric method. Fluorine determinations of 83 commercial coals ranged from 0.001 to 0.019 percent.

RI 7055. Lightweight Aggregates. Expansion Properties of Selected Michigan Shales, by James H. Aase. December 1967. 23 pp. 5 figs. Shales from 10 locations in Michigan were sampled, tested, and evaluated to determine their suitability as raw materials for producing lightweight aggregate by rotary-kiln methods. Sampling procedures and the geology of the shale units tested are discussed. Preliminary testing in a muffle furnace preceded extensive testing in a 16-inch by 14-foot rotary kiln. Rotary-kiln products from these shales ranged in weight from 35.5 to 61.2 pounds per cubic foot (pcf). Concrete test specimens made with selected aggregates were evaluated to determine the qualities of the concrete. Compressive strengths of the concrete ranged from 2,830 to 4,240 psi after 28 days of curing. Unit weight of the concrete ranged from 94.8 to 101.5 pcf. Lightweight aggregate suitable for use in structural concrete meeting ASTM standards was produced by the rotary-kiln method using shale samples from two locations.

RI 7056. Waterflooding of Oilfields in Nebraska, by Joseph N. Harstead, Donald P. Blasko, and Paul Biggs. 97 pp. 51 figs. This Bureau of Mines report provides information on the first 49 waterflood projects (or units) in Nebraska. All injection was in the "D" or "J" Cretaceous sands of western Nebraska. Specific data presented include location, map, discovery and development, water supply and injection, oil and water production, estimates of oil in place, and primary and secondary recoveries. The 49 projects studied, including four dual-zone projects, should recover about 126.5 million barrels of oil. Eighty-six percent of the estimated oil had been recovered by the end of 1966. Abundant water was found near most projects.

RI 7057. Heat Transfer Coefficients for Continuously Recirculated Gas-Solid Suspensions, by Dean E. Bluman, A. F. Galli, N. H. Coates, J. D. Spencer, and C. N. Rosenecker. December 1967. 19 pp. 9 figs. The Bureau of Mines investigated the convective heat transfer coefficients for recirculated suspensions of 30-micron glass beads in inert gas. Coefficients for the suspensions were not significantly higher than coefficients for the pure gas. Reynolds numbers of the suspensions were 20,000 to 35,000; solids loadings ranged from 0.0 to 0.7 pound per pound of gas. Comparison of the results with published data showed the direction of heat flow to have no effect at the test conditions.

RI 7058. Calcium Vanadate Precipitation and Processing, by C. J. Chindgren, L. C. Bauerle, and B. K. Shibler. December 1967. 17 pp. 1 fig. The Bureau of Mines investigated the technical problems involved in recovering commercial-grade vanadium products from alkaline solutions of low vanadium content. Conditions were defined for precipitating calcium vanadates from sodium vanadate solutions with calcium chloride and calcium hydroxide and for dissolving the precipitates with acid, sodium carbonate, and sodium bicarbonate to obtain vanadium-enriched solutions from which either red cake or ammonium metavanadate was recovered. Calcium vanadates with $CaO:V_2O_5$ mole ratios of 2, 3, and 4 were produced with recoveries of 93 to 100 percent. Optimum recovery of the low-lime variety of calcium vanadate was obtained by employing excess calcium chloride and adjusting the pH to a range of 8.0 to 8.5. High vanadium extractions were obtained in concentrated solutions by dissolving the calcium vanadate precipitates with any of the reagents tested. The resulting extracts contained 25 to 125 grams V_2O_5 per liter. Conventional procedures used to precipitate either red cake or ammonium metavanadate from the enriched solutions gave excellent vanadium recoveries.

RI 7059. Sulfur Content of Crude Oils of the Free World, by C. M. McKinney and Ella Mae Shelton. 1967. 36 pp. 4 figs. Sulfur content data from Bureau of Mines routine analyses of 1,060 United States crude oils were used with crude oil production data for the years 1956-66 to prepare tables and charts that illustrate the volume and percentage distribution according to sulfur content of crude oil produced in 10 geographical areas of the United States. Similar relationships for foreign crude oils based on analyses of 201 crude oils and production during 1966 are illustrated for Africa, Canada, Middle East, and South America. Tables are included giving field name, sulfur content, geologic name and age of producing formation, depth of producing formation, and production during 1966 for 882 United States crude oils and 201 foreign crude oils. Between 1955 and 1966 the average sulfur content of crude oils produced in the United States decreased from 0.73 to 0.67 percent. (*Out of print.*)

RI 7060. Physical Strength of Iron Ore Pellets at Elevated Temperatures, by J. L. Reuss and M. M. Fine. January 1968. 24 pp. 8 figs. The Bureau of Mines investigated the softening characteristics of both unfired and indurated iron ore pellets as measured by hot compression strength in a laboratory study. A surprisingly high hot strength (240 lb per ½-inch spheroid) was developed by unfired magnetic pellets near 900° C; lesser maxima were developed by pellets made from hematite and specularite concentrates near 1,000° C. Those from goethite remained weak throughout the preinduration heating. Fully indurated commercial pellets retain a high resistance to softening when heated in air. On the contrary, in a hot reducing atmosphere their high cold crushing strength dissipates rapidly. At 1,000° C, for example, the average compression strength of seven different commercial pellets was 110 lb; at 1,100° C, the hot strength was only 60 lb. After a rather sharp initial drop, the loss of strength with increase of temperature was gradual. There was no sudden collapse nor any significant difference in behavior of commercial pellets whether made from magnetite or hematite concentrates.

RI 7061. Initiation of Spherical Detonation in Acetylene-Oxygen Mixtures, by Elton L. Litchfield, Marilyn H. Hay, and David J. Cohen. 6 pp. 1 fig. The Bureau of Mines determined minimum energies for direct initiation of expanding gaseous detonation waves in acetylene-oxygen mixtures. Composition limit ranges for the initiation of detonation with fixed energies have been compared to data in the literature. Assuming that the stored electrical energy is completely converted to thermal energy, the agreement between the energy of primary explosive initiators and the energy of electrical discharge initiators was good. Minimum energies for initiation of detonation in the most sensitive composition (40 percent C_2H_2 plus 60 percent O_2) were 0.64 joule at an initial pressure of ¼ atmosphere, 5.0×10^{-2} joule at ½ atmosphere, and 3.7×10^{-3} joule at 1 atmosphere. Fuel concentrations in mixtures initiated to detonation by 4.9×10^{2} joules ranged from 10 to 65 percent C_2H_2 at ¼ atmhophere, 10 to 67 percent C_2H_2 at ½ atmosphere, and 9 to 68 percent C_2H_2 at 1 atmosphere.

RI 7062. Optical Properties of Glass: Transmission Losses of Eyepieces Used in Mine Environment, by C. Gary Reiness and Carmon L. Marano. January 1968. 9 pp. 6 figs. A safety glass eyepiece which had been repeatedly exposed to mine environment over a number of years was studied to determine some of its optical properties. In the regions from 385 to 400 $m\mu$ and from 625 to 760 $m\mu$, the transmittance was less than the 89 percent required by the American Standard Safety Code for Head, Eye, and Respiratory Protection. From 200 to 320 $m\mu$ the relative transmittance of two parts of the eyepiece was found to vary widely, having a maximum of 38 percent difference at 315 $m\mu$. Irradiation of the glass by ultraviolet light caused enhanced absorption in the range from 200 to 1,200 $m\mu$. There was a time-dependent increase of 10^{16} color centers per cubic centimeter throughout this range after 36.5 hours of irradiation. The rate-of-growth curve for the optical density, at 243.5 $m\mu$ and 23° C, was resolved into linear and saturable components, indicating zero order and first order kinetics.

RI 7063. Vapor Pressures of Liquid Molybdenum (2,890° to 2,990° K) and Liquid Zirconium (2,229° to 2,795° K), by R. K. Koch and W. E. Anable. January 1968. 22 pp. 5 figs. The vapor pressures of liquid molybdenum and liquid zirconium were determined by the Langmuir free-evaporation method. An electron-beam furnace with a water-cooled copper crucible was used for melting. Temperature was measured with a two-color ratio pyrometer. The vapor-pressure data led to the following equations:

$$\log p\ (\text{atm}) = 5.429 - \frac{28{,}380}{T}$$

for liquid molybdenum in the range 2,890° to 2,990° K, and

$$\log p\ (\text{atm}) = 6.521 - \frac{30{,}940}{T}$$

for liquid zirconium in the range 2,229° to 2,795° K. Third-law evaluations of each data set gave mean heats of sublimation (298.15° K) of 157.6 ± 1.8 kcal/mole and 148.4 ± 2.4 kcal/mole for molybdenum and zirconium, respectively, where the uncertainties are two standard deviations. Second-law standard heats of sublimation determined from sigma plots and tabulated enthalpies were 143.5 ± 2.7 kcal/mole and 149.2 ± 3.8 kcal/mole for molybdenum and zirconium, respectively. The better agreement in heats of sublimation for zirconium is attributed to the 566° K temperature range studied which permitted a more accurate definition of the vapor-pressure curve than could be obtained from the 100° K span for molybdenum. This supposition was verified by making a sigma-prime plot which utilized solid vapor-pressure data for molybdenum to extend the evaluation range by 800° K. This gave a standard heat of sublimation of 155.2 ± 1.6 kcal/mole which is in good agreement with the third-law value. The plot also gave a standard entropy of sublimation (298.15° K) of 35.73 ± 0.48 eu.

RI 7064. Kinetics of Formation of Carbon Dioxide and Carbon From Carbon Monoxide in Presence of Iron Pellets, by L. A. Haas, S. E. Khalafalla, and P. L. Weston, Jr. January 1968. 29 pp. 17 figs. A kinetic study of the carbon deposition reaction was undertaken by the Bureau of Mines as part of a broad investigation of metallurgical reactions in the iron ore blast furnace. The disproportionation of carbon monoxide on iron pellets was investigated at carbon monoxide pressures between 0.5 and 2 atmospheres (absolute) and temperatures from 400° to 1,075° C. Gas flow in the range from 0.25 to 0.85 standard liter per minute was found to have little effect on the reaction velocity. The addition of nitrogen and helium to carbon monoxide exerted only a dilution effect on the rate of carbon deposition. However, an addition of 1 percent hydrogen increased the rate about 100 times. Small amounts of carbon dioxide in the inlet gas exerted little effect on the rate of carbon deposition. The maximum rate for carbon deposition in the first 2 hours occurred at 550° C. The apparent molar activation energies at various stages of the reaction were found to vary from 13 kcal initially to 36 kcal during the latter stages of the reaction. The reaction rate behavior was tentatively explained by an adsorption step followed by the diffusion of iron through a shell of inactive iron carbide.

RI 7065. Piezoelectric Pulsing Equipment for Shear Wave Velocity Measurements in Rock Samples, by Francis X. Cannaday. January 1968. 25 pp. 27 figs. Equipment and techniques were developed with Bureau of Mines facilities for measurement in the laboratory of sonic shear wave velocity in variously shaped rock specimens in a wide range of sizes. A variety of rock types was tested. The shear wave front is produced by electronically excited, piezoelectric ceramic, disk-shaped transducers. Transmitter and receiver are interchangeable. Special equipment components were Bureau produced; other components were commercially available. The equipment permits quick measurement of shear wave velocity on variously shaped specimens with a minimum of specimen preparation. The technique, under favorable conditions, allows for determination of the moment of arrival of the shear wave when it is superimposed on a weak longitudinal wave.

RI 7066. Thermodynamics of Nonlinear Electromagnetic-Fluid Systems, by W. F. Hughes. January 1968. 8 pp. The thermodynamics of an electromagnetic field-fluid interaction system are discussed. A review of the thermodynamics of linear media (the permittivity and permeability taken as functions of density and temperature) is presented; then an extension is made to nonlinear media (the permittivity and permeability taken as functions of the fields). Expressions for thermodynamic properties and reversible work are derived and the first law of thermodynamics for magnetohydrodynamic flow is discussed.

RI 7067. Performance of the Hydrocyclone as a Fine-Coal Cleaner, by Paul Sands, Michael Sokaski, and M. R. Geer. January 1968. 38 pp. 12 figs. Single- and two-stage tests were made with 6-inch coal-cleaning hydrocyclones to determine the effect of hydrocyclone geometry, operating conditions, and feed composition on performance. Most of the testing was conducted in an open-circuit pilot plant that had a maximum capacity of about 9 tons per hour. The coals used in the investigation had top sizes of ¼ inch and 28 mesh. Considerable latitude was found in the range of geometry variables that could be used without affecting performance adversely, although a certain minimum ratio of overflow to underflow openings had to be maintained for best operation. Two-stage cleaning proved distinctly better than operation with a single hydrocyclone, because clean coal lost in the refuse product of the primary unit can be partly recovered in the secondary. There is an unusually great difference in the specific gravities at which the individual sizes of the feed are separated in the hydrocyclone. This militates against high efficiency because maximum yield occurs when all sizes are cleaned at the same specific gravity. The size composition of the feed and, more particularly, the size composition of the impurity have a greater influence on the efficiency attainable in the hydrocyclone than in most other types of fine-coal cleaners.

RI 7068. Methods for Producing Alumina From Anorthosite. An Evaluation of a Lime-Soda Sinter Process, by Paul W. Johnson and Frank A. Peters. January 1968. 42 pp. 16 figs. An evaluation is made of a lime-soda sinter process for extracting alumina from anorthosite. In this process, alumina is extracted by sintering anorthosite with soda ash and limestone, and then leaching the sinter with a dilute sodium carbonate solution. The sodium aluminate solution formed during leaching is separated from the residue and treated with lime in autoclaves to remove dissolved silica before alumina trihydrate is precipitated with carbon dioxide. The trihydrate is then calcined to α-alumina. Two options, dry grinding and wet grinding, are used in the sintering step. This process is not competitive under present economic conditions with the Bayer process of treating bauxite to produce alumina.

RI 7069. Parameters Affecting Reduction-Induration of Unfired Magnetite Pellets, by R. B. Schluter and M. M. Fine. January 1968. 22 pp. 19 figs. Magnetite pellets were simultaneously reduced and indurated on a laboratory scale in order to determine the effects of temperature, induration time, degree of metallization, and sulfur content upon the physical and chemical properties of prereduced pellets. The reductants were commercially pure tank gases. Among the findings were these: 1,000° C is the minimum temperature that will produce acceptably hard pellets using carbon monoxide as the reducing gas. Prolonged treatment time improves the pellets' crushing strength, but the rate of improvement falls off sharply after 2 hours' induration. At 1,120° C, 75-percent metallization produces the maximum crushing strength; there was no corresponding peak at 900° or 1,050° C. Sulfur in the furnace atmosphere lowers the required induration temperature. A few tenths of 1 percent sulfur in the pellet increases the sintering rate of metallic iron in pellets by forming a liquid FeS phase that facilitates iron transfer.

RI 7070. New England Beryllium Investigations, by William R. Barton and Carl E. Goldsmith. 1968. 177 pp. 64 figs. Sampling to determine development potential of beryllium deposits was conducted in 31 New England localities. A total of 54 additional areas where the geochemical environment appeared favorable were sampled to determine if economically interesting percentages of beryllia (BeO) might occur. Newry Hill-Plumbago Mountain, Maine, Iron Mountain, N. H., and Long Island, Maine, were investigated in some detail to determine the size and grade of deposits. The mineralized pegmatites at Newry Hill-Plumbago Mountain are extensive but very low grade; at Iron Mountain the ore bodies are very rich but of small volume; at Long Island beryl occurs with molybdenite, wolframite, and scheelite, but the tonnage of ore was not determined.

RI 7071. Oil Yields of Green River Oil Shales From Colorado Corehole No. 1, by John Ward Smith, Laurence G. Trudell, and George F. Dana. January 1968. 28 pp. 7 figs. Oil-yield data are presented for core samples from Colorado Corehole No. 1, drilled by the Bureau of Mines and the Atomic Energy Commission in a previously untested oil-shale area near the northern edge of Colorado's Piceance Creek basin. Continuous oil shale 2,068 feet thick, averaging 18.41 gallons of oil per ton of shale and representing 1.8 billion barrels of oil per square mile, occurs at the core site. Work done in cooperation with the University of Wyoming.

RI 7072. Extraction of 8-Hydroxyquinoline Complexes of Trace Elements From Tungsten Solutions, by Thomas E. Green. February 1968. 17 pp. 2 figs. A solvent extraction procedure using 8-hydroxyquinoline and chloroform was investigated by the Bureau of Mines as a preconcentration technique for the determination of aluminum, calcium, cobalt, copper, iron, lead, magnesium, manganese, nickel, and zinc in large samples of high-purity tungsten. X-ray spectrographic and atomic absorption methods were used to determine the trace metals after preconcentration. The presence of 10 grams of tungsten had a pronounced effect on the distribution of 8-hydroxyquinoline between the aqueous and chloroform phases. This change in the 8-hydroxyquinoline distribution in turn had an adverse effect on the extraction of the trace metals. Extraction efficiencies can also be adversely affected by an increase in the quantity of extractable metals present, as shown by radiotracer tests using zinc-65. Excess 8-hydroxyquinoline in the extracts did not interfere with the determination of the extracted metals by atomic absorption, but caused serious interference in the combined ion-exchange paper-X-ray spectrographic method. Although preconcentration by 8-hydroxyquinoline extraction was found to be partially successful, other preconcentration methods based on ion exchange and dithizone extraction were found to be superior.

RI 7073. High-Temperature Heat Contents and Entropies of Dehydrated Analcite, Kaliophilite, and Leucite, by L. B. Pankratz. February 1968. 8 pp. 1 fig. The Bureau of Mines conducted heat-content measurements above 298.15°K for dehydrated analcite ($NaAlSi_2O_6$) to 1,000° K, kaliophilite ($KAlSiO_4$) to 1,800°K, and leucite ($KAlSi_2O_6$) to 1,800 K. Heat content and entropy increments were tabulated, and the heat content data were given in equation form. A first-order transition was noted for kaliophilite near 810° K with a heat absorption of 160 cal/mole. Leucite had a second-order transition which became complete near 955° K. In this transition a crystal change occurred from tetragonal (low-temperature form) to cubic (high-temperature form).

RI 7074. Diesel Exhaust Contamination of Tunnel Air, by John C. Holtz and R. W. Dalzell. February 1968. 23 pp. 9 figs. The Bureau of Mines studied air contamination caused by diesel exhaust in a 10,000-ft ventilated tunnel. Sequential air samples were taken at the ends and middle of the tunnel during an operating cycle. Observed and calculated results for carbon dioxide, carbon monoxide, and nitrogen oxides were essentially in agreement. Nitrogen dioxide was present only in trace amounts. It was found that contamination was related to the volume of ventilating air, the number of haulage trips, train speed, and engine load.

RI 7075. Revegetation Studies at Three Strip-Mine Sites in North-Central Pennsylvania, by M. O. Magnuson and R. L. Kimball. February 1968. 8 pp. As part of an experiment in the restoration of lands strip-mined for coal, revegetation studies were conducted at three backfilled strip-mine sites in north-central Pennsylvania. The sites were subdivided into plots that were given varying amounts of lime and fertilizer. In tests conducted cooperatively with State and Federal agronomy experts, the plots were then planted with a variety of trees, shrubs, and grass-legume mixtures. Initial tree and shrub survival was not appreciably affected by lime and fertilizer applications where the spoil pH was above 4.5. Of 14 species of trees and shrubs tested, Norway spruce, black locust, Japanese larch, pitch pine, and white pine were the hardiest. The ground-cover percentage of grass-legume mixtures in the second growing season was substantially increased by using lime and fertilizer. Mixtures comprised partly of fescue were the most satisfactory.

RI 7076 Equations for Calculating Various Thermodynamic Functions of a Two-Component System From an Empirical Equation of State, Including Liquid-Vapor Equlibria Data, by B. J. Dalton and Robert E. Barieau. February 1968. 69 pp. This report gives general expressions for evaluating various thermodynamic properties applicable to a two-component system, including liquid-vapor equilibria. In addition, expressions are developed for some of the quantities useful in making thermodynamic consistency checks on phase equilibria data. These formulas were developed from the general principles of thermodynamics and are expressed in terms of the compressibility factor, which is assumed to be an explicit function of the molal density, the absolute thermodynamic temperature, and the composition.

RI 7077. Performance of Open-Circuit Self-Contained Breathing Apparatus at −25° F, by E. J. Kloos, L. D. Raymond, and L. Spinetti. February 1968. 16 pp. 5 figs. Bureau of Mines-approved self-contained breathing apparatus of the compressed air demand type were evaluated for performance at low temperature. Apparatus durations, breathing resistances, and airflow rates were measured on machine tests at room temperature and −25° F. Man tests under actual wearing conditions verified the machine test results. Many serious functional changes in apparatus performance occurred at low temperature. Pressure regulators malfunctioned when diaphragms lost flexibility. Under certain conditions frozen condensed moisture sealed exhalation valves and fogged eyepieces. High-pressure leaks, not encountered at ordinary temperatures, developed at low temperature. Tests results are discussed generally and specifically for each apparatus. Recommendations are given to obtain optimum performance from demand-type breathing apparatus at low temperatures.

RI 7078. Investigation of Flame Propagation Characteristics in Layered Gas Mixtures, by Israel Liebman, Henry E. Perlee, and John Corry. February 1968. 35 pp. 22 figs. The Bureau of Mines conducted an investigation to determine those factors that are significant in affecting the velocity of flames propagating along the boundary separating gaseous fuel and air. In addition the aerodynamic motion of the gases in the vicinity of such interfacial flames was delineated. Parameters in the study included flammable zone thickness, flammable zone concentration of gradient, fuel type, and position of the flame relative to various environmental surfaces. Of all these factors, the flammable zone thickness and burning velocity of the stoichiometric mixture were found to have the most significant effect on the flame speed. Motion of the gases in the vicinity of the interfacial flames was examined by particle track and interferometric techniques. The relative velocity of the interfacial flame with respect to the unburned gas on the central streamline was found to equal the burning velocity of a stoichiometric homogeneous fuel-air mixture. In addition, it was observed that the composition of the lean fuel-air mixture at the boundary of the combustion zone appears to be less than that defined as the fuel's lower flammable limit.

RI 7079. Recovery of Alumina and Iron From Pacific Northwest Bauxites by the Pedersen Process, by Oliver C. Fursman, Henry E. Blake, Jr., and James E. Mauser. February 1968. 22 pp. 4 figs. The Bureau of Mines undertook this investigation in order to determine the feasibility of producing commercially acceptable alumina and iron by application of the Pedersen process to high-silica, high-titania, ferruginous bauxites of the Pacific Northwest. Calcium aluminate slags were produced by smelting bauxite with coke and lime in an electric-arc furnace. Over 90 percent of the total alumina can be extracted by sodium carbonate solution from slags of properly controlled ternary-phase composition (CaO-Al_2O_3-SiO_2) that are cooled slowly enough to permit adequtae crystallization of the $2CaO$-SiO_2 and the calcium aluminate compounds. Most of the iron charged was recovered in the regulus; the slag contained about 2 percent iron (as iron oxide), regardless of smelting time.

RI 7080. Kinetics of the Initial Reduction Stages of Magnetite in Hydrogen, by T. N. Rushton and S. E. Khalafalla. February 1968. 28 pp. 12 figs. Rate minima are encountered in the reduction of magnetite with hydrogen. In a certain temperature zone, the reaction rate decreases with rise in temperature. This is inexplicable by classical kinetic theories; neither is a transition in reduction mechanism suitable for interpreting the observed behavior. This anomaly can be fully explained by hypothesizing two species of chemisorbed hydrogen with different adsorption coefficient and activation energies for adsorption. Competition between two energetic states of adsorption occurs with temperature rise, with the low energy state predominating below the anomalous temperature zone and the high energy state above it. The presence of two possible adsorption sites appears to be characteristic for oxidic adsorbents.

RI 7081. Liquidus Temperatures of Titaniferous Slags (in Three Parts). 1. TiO_2-Al_2O_3-SiO_2-CaO-MgO, by Wesley T. Holmes II, Lloyd H. Banning, and Lawrence L. Brown. February 1968. 21 pp. 4 figs. This report describes the first phase of an investigation aimed at obtaining a wider knowledge of the problems involved in smelting titaniferous magnetites. Liquidus temperature measurements were made on selected slag compositions in the titania-alumina-silica-calcia-magnesia system. Both the melting-holding-quenching method and the hot-stage microscope method were used in the tests. Liquidus temperatures of slags studied ranged from 1,217° to 1,667° C. The lowest liquidus temperature of the slags occurred when the difference between CaO plus MgO and SiO_2 was less than 12 weight-percent. Liquidus temperatures were also lowered when SiO_2 was substituted for TiO_2 plus Al_2O_3 when CaO and MgO levels were held constant. Improved methods for the measurement of liquidus temperature on very small samples are described.

RI 7082. An Electrolytic Process for Separating Nickel and Cobalt, by T. A. Sullivan, B. E. Barton, and F. R. Cattoir. February 1968. 17 pp. 7 figs. Refining in a molten-salt electrolyte was investigated as a means of recovering nickel containing less than 1 percent and preferably less than 0.2 percent cobalt from nickel products containing up to 5 percent cobalt. Electrolytic separation of nickel and cobalt was accomplished in a molten KCl-$LiCl$-$NiCl_2$ electrolyte. Nickel containing less than 0.10 percent cobalt was routinely prepared. Factors that influenced the transfer of cobalt to the refined product were the nickel concentration of the electrolyte, the cobalt concentration of the electrolyte, the ratio of nickel to cobalt in the electrolyte, and the cathode current densities. A method of recovering the cobalt from the electrolyte was developed. The possibility of preparing high-purity nickel by this process was shown, as well as the preparation of various cobalt-nickel-tungsten alloys.

RI 7083. Liquidus Temperatures of Titaniferous Slags (in Three Parts). 2. TiO_2-Al_2O_3-FeO-SiO_2-CaO-MgO, by Wesley T. Holmes II, Lloyd H. Banning, Lawrence L. Brown, and Gerald G. Thompson. February 1968. 17 pp. 23 figs. This report describes the second phase of an investigation aimed at obtaining a wider knowledge of the problems involved in smelting titaniferous magnetites. Liquidus temperature measurements were made on selected synthetic slag compositions in the TiO_2-Al_2O_3-FeO-SiO_2-CaO-MgO system. Both the hot-stage microscope and the strip furnace (melting-holding-quenching technique) were used during test procedure to determine the effects of CaO, MgO, and SiO_2 on the liquidus temperature of slags.

The liquidus temperatures of slags studied ranged from 1,241° to 1,900° C. The lowest liquidus temperature for each TiO_2 plus Al_2O_3 plus FeO weight-percent generally occurred when the difference between CaO plus MgO and SiO_2 was less than 12 weight-percent. In this investigation substitution of either CaO or MgO for SiO_2 and MgO for CaO raised the liquidus temperature of more than 50 percent of the reported base slags when TiO_2, Al_2O_3, and FeO contents were held constant. The results of this investigation may serve as guidelines for determining flux requirements in smelting a wide variety of titaniferous magnetite concentrates or ores.

RI 7084. Storage Stability of Gasoline, Comparison of Storage and Rapid Bomb Aging, by Charles S. Allbright, Frank G. Schwartz, and Cecil C. Ward. February 1968. 33 pp. 18 figs. To develop a method for predicting the stability of a fuel during long-term storage from rapid aging tests at 200° F, the Bureau of Mines determined the stabilities of three gasoline base stocks and an alkylate blending stock in both sealed storage and aerated storage at 110° F for periods extending to 32 weeks. Stabilities of samples contining gasoline-additive compounds were compared by aging, using two methods—rapid aging in a bomb at 200° F for intervals up to 16 hours and storage at 110° F. The additives used were an uninhibited tetraethyllead motor mix, *N*,*N*'-di-*sec*-butyl-*p*-phenylenediamine and 2,6-di-*tert*-butyl-4-methylphenol. Results were related by graphs that enable predictions of gum and sediment formation during storage from data obtained in bomb tests.

A premium-gasoline base stock and the alkylate proved to be stable, but the two regular-grade gasoline base stocks were found to be unstable. Addition of the diamine antioxidant improved the stability of both of the regular gasoline base stocks, while the phenol antioxidant improved only one of them. The presence of the tetraethyllead decreased the storage stability of all four fuels, both with respect to formation of gum and precipitation of inorganic sediment. The rapid test at 200° F appears to offer promise as a basis for a method of predicting gasoline stability in long-term 110° F storage. Work done under an agreement with the Research Division of the Army Materiel Command.

RI 7085. Face Ventilation in Underground Bituminous Coal Mines. Airflow Characteristics of Flexible Spiral-Reinforced Ventilation Tubing, by R. G. Peluso. February 1968. 13 pp. 7 figs. Methods and results of studies to determine friction and shock losses encountered in auxiliary face ventilation systems utilizing flexible, spiral-reinforced ventilation tubing are presented. The results, tabulated in graphic form, simplify fan selection and enable mine operators to design adequate auxiliary ventilation systems. A sample problem illustrates the use of graphs.

RI 7086. Properties of Anthracite From the Bottom Ross Bed, by G. A. Brady and H. H. Griffiths. February 1968. 29 pp. 3 figs. Seven samples of Pennsylvania anthracite from the Bottom Ross bed were analyzed and tested to obtain data on cleaning characteristics, proximate and ultimate analyses, specific gravity, grindability, heating value, and ash softening temperature. Ash content of the samples varied irregularly from 9.0 to 34.4 percent, the range being narrowed to an upper limit of 14.8 percent ash by removing impurities dense enough to sink in a medium with a specific gravity of 1.90. Ash content of the sink material with specific gravity greater than 1.90 ranged from 56.4 to 80.4 percent; corresponding specific gravities were 2.095 to 2.534. Volatile matter contents were indicated to be higher for the ash-forming minerals than for the pure coal substance in the various specific gravity fractions of a given sample. Specific gravities of anthracites with comparable ash contents but from different locations in the bed varied as much as 0.06. The grindability index increased significantly with increasing ash content of specific gravity fractions from all the samples.

RI 7087. Transverse Force Produced by Tensioned Expansion-Shell-Type Rock-Bolt Anchors, by Edward W. Parsons and Lars Osen. March 1968. 10 pp. 6 figs. The transverse force developed by expansion-shell rock-bolt anchors on the wall of a drill hole as the bolt is tensioned was measured by the Bureau of Mines using a device specially designed and fabricated for attachment to a universal testing machine. Load cells equipped with electrical-resistance strain gages provided the data from which the transverse force, in pounds, was calculated. Seven different expansion-shell anchors were tested, and the ratio of transverse force to bolt-tension load was found to range between 0.98 and 1.94. The drag load appeared to be the major cause of the transverse-force variation, but the relative effects of individual factors that affected the ratio between the transverse force and the bolt tension were not determined.

RI 7088. Low-Temperature Chlorination of Ferrochromium. Preliminary Studies, by R. L. de Beauchamp and T. A. Sullivan. March 1968. 8 pp. 2 figs. A preliminary investigation was made of the extraction of chromium from ferrochromium by low-temperature chlorination in the 340° to 525° C range. The objective was to devise a method for separating chromium from iron in high-carbon ferrochromium produced from domestic chromite concentrates. The majority of iron was removed as a volatile chloride; chromium was contained in the residue as a nonvolatile chloride, which was separated from carbon and unattacked ferrochromium by dissolution. A small rotary chlorination apparatus was designed, built, and used for the chlorination tests, and samples of commercial-grade high- and low-carbon ferrochromiums were chlorinated for comparison of chlorination characteristics. Low-temperature chlorination of three types of ferrochromium resulted in the removal of 81.9 to 91.6 percent of the iron content as sublimed $FeCl_3$. Recovery of chromium in a leach solution of the reactor product varied from 82.4 to 93.1 percent.

RI 7089. Evaluation of Rolling Slabs of Zinc-Copper-Titanium Alloys Cast Under Semicontinuous Conditions, by L. A. Neumeier, J. T. Dunham, and P. G. Barnard. March 1968. 24 pp. 20 figs. Sound experimental ingots of zinc alloys for use as rolling slabs were cast with a specially constructed, semicontinuous casting machine. Nominal alloy compositions of Zn-1.0 percent Cu, Zn-0.12 and 0.36 percent Ti, and Zn-1.0 percent Cu-0.03 to 0.36 percent Ti were cast. This Bureau of Mines study was conducted to evaluate the suitability of the casting procedure for providing stock for rolling into sheet. Microscopic examination of ingot sections revealed structures in which grain size varied from the outer to center ingot zones. Columnar grains present in the center zone of the Zn-1.0 percent Cu ingot were absent in the titanium-containing ingots. The ingots with titanium displayed a finer grain size and eutectic structure in the center ingot zone than in the outer zone; the transition in grain size between the two zones was quite abrupt in some ingots. The overall grain size of the titanium-containing ingots was finer than that of alloys cast by more conventional methods. Chemical analysis revealed that compositional segregation is not a significant factor in the formation of the ingot structure. Microstructural studies of small ingots of similar alloys solidified at slow, fast, and intermediate rates confirmed that the ingot structure in the semicontinuous-cast ingots is related to cooling rate, which is, in turn, related to the particular casting machine design and the influx of cooling water on the withdrawing ingots. Microstructures of thin sheet hot-rolled from slabs of the semicontinuous-cast ingots demonstrated that the ingot structure does not preclude the rolling of sheet having a uniform microstructure. Results of hardness surveys of the semicontinuous-cast ingots demonstrated that copper and titanium exert essentially additive hardening effects in these cast alloys.

RI 7090. Hydraulic Coal Mining Research, Assessment of Parameters Affecting the Cutting Rate of Bituminous Coal, by R. S. Fowkes and J. J. Wallace. March 1968. 23 pp. 12 figs. Jetstream pressure distributions and coal cutting rates were determined for a number of nozzles and under different operating conditions. The jetstream pressure distribution data were fitted to an assumed curvilinear equation by the utilization of a numerical least-squares technique with the aid of a digital computer. Subsequent manipulation of the approximation equation showed that the total force of the jetstream, rather than its maximum pressure or total kinetic energy per unit time, was the most significant quantity affecting the coal cutting rate. A shorter method for assessing the ability of a nozzle to cut coal was found.

RI 7091. Effects of Adding Rare-Earth Silicides, Aluminum, and Cryolite to Molten Steel, by R. J. Leary, R. T. Coulehan, H. A. Tucker, and W. G. Wilson. March 1968. 42 pp. 16 figs. This investigation was conducted to determine the effects of various rare-earth metal addition practices upon the macrostructure and the pattern of sulfur distribution in steel ingots. Heats of plain carbon steel were melted in a 1-ton, basic electric-arc furnace. Melts were treated with mixtures of rare-earth silicides, aluminum, and cryolite either in the furnace before tap or in the ladle after tap to determine the effects of this form of rare-earth treatment upon ingot macrostructure. Steels thus treated with rare earths in the furnace were characteristically free of the gross subsurface nonmetallics which typically result from conventional rare-earth treatments. Steel treated in the ladle showed only a few such nonmetallics, and practical techniques were developed for eliminating most of these. Results showed that furnace deoxidation was controlled by the concentration ratio of rare earths to aluminum. During casting, deoxidation was controlled by the concentration of rare earths. Oxygen contents equivalent to vacuum ladle degassing resulted from air-melt furnace treatments with the rare-earth mixtures described. Rare earths in steel inhibited the onset of equiaxed grain formation during ingot freezing and also virtually prevented interdendritic segregation of sulfides. Work done in cooperation with the Molybdenum Corporation of America, New York.

RI 7092. Changes in Breaking Strength of Model Rock Pillars Resulting From End Constraint, by Clarence O. Babcock. March 1968. 19 pp. 9 figs. Model pillars of limestone, marble, sandstone, and granite having length to diameter ratios of 3:1, 2:1, 1:1, and 0.5:1 were broken in axial compression to determine whether lateral end constraint affected the breaking strength. Steel rings bonded to the ends of the model pillars with epoxy provided, during the loading cycle, a lateral end constraint of about 17 to 30 percent of the average axial stress. The effect of this constraint was to increase the breaking strength of the rock as compared to cylindrical pillars without constraint. The percentage increase in breaking strength varied with rock type and increased as the length to diameter ratio decreased. The maximum increase in breaking strength was 35 percent for marble pillars having a length to diameter ratio of 0.5:1. A theory was developed which relates the expected constraint to the physical properties of the ring and rock.

RI 7093. Dependence of Coking Time on Coal Properties and Carbonization Parameters, by Manuel Gomez, J. G. Walters, and John B. Gayle. March 1968. 28 pp. 5 figs. Coking time was investigated as a function of coal properties, carbonization parameters, and the interaction between these variables. The results indicate that coal properties and carbonization conditions interact to influence the coking time, and these interactions may be determined quantitatively. Prediction equations were developed and used to simulate the effects of bulk density, flue temperature, and oven width on coking times for coals having a wide range of properties. The data presented provide additional information on the carbonization process to permit the coke oven operator to maintain closer control of coke production and coke uniformity.

RI 7094. Measurement of Oleic Acid on Mineral Surfaces Using a Radioactive Tracer, by J. Vance Batty, W. W. Agey, and B. F. Andrew. March 1968. 24 pp. 4 figs. Two methods were devised and evaluated for quantitatively measuring the amount of oleic acid on flotation products and in flotation waters. One method involved use of an organic solvent to remove carbon-14-tagged oleic acid from mineral surfaces and flotation water phases with subsequent radiometric analysis of the extracts. Studies showed this method to be slow and subject to large variations in accuracy and reproducibility. In the second procedure, tagged oleic acid was measured directly on the surfaces of dried mineral products. Oleic acid in the water phase was determined by adsorbing it on fine mineral, drying, and radiometric counting. Quantitative analysis of oleic acid on flotation products from bench-scale flotation tests with synthetic mixtures of ore minerals and quartz and with natural ores showed this method to be fast, accurate, and reproducible.

RI 7095. A Method of Measuring Surface Texture of Rock, by Frank G. Horino, John R. Hoskins, and Merlyn L. Ellickson. March 1968. 14 pp. 8 figs. This report describes an instrument designed by the Bureau of Mines for quantitatively identifying texture of rock surfaces produced by grinding or extremely rough surfaces beyond the range of commercial surface measuring instruments. The transducer for the instrument is a linear variable differential transformer that converts mechanical motion caused by surface roughness, wavines, and lay to an electrical output. The electrical output is recorded graphically as an X-Y plot of the line traversed on the rock surface. Details of the synthesized device and its calibration are given. The sensitivity of the unit is 2 percent of the scale setting of the amplifier. The horizontal scale is adaptable from ¼ inch to 15 inches of specimen length with a sensitivity of 0.01 inch if a 10 to 1 magnification is used and 0.1 inch if a 1 to 1 magnification is used.

RI 7096. Determination of the Heat of Formation of Vanadium Trichloride, by R. V. Mrazek, D. W. Richardson, H. O. Poppleton, and F. E. Block. March 1968. 15 pp. 2 figs. The heat of formation of vanadium trichloride was determined at 298.15° K. Measurements were made in a solution calorimeter in which an aqueous hydrochloric acid-potassium dichromate solvent was employed. Data are presented for the heats of solution of vanadium trichloride and the vanadium trioxide "backup" compound, and for appropriate dilution reactions needed to preserve stoichiometry. The resulting heat of formation of vanadium trichloride (VCl_3) at 298.15° K was found to be $\Delta H^\circ_{298.15^\circ K} = -138.89 \pm 0.37$ kcal/g mole.

RI 7097. Two Borehole Photograph Goniometers, by Perry N. Halstead, Richard D. Call, and S. Jackson Hubbard. April 1968. 22 figs. This report describes two goniometers that, by simple manipulation, can be used to ascertain the attitude of a joint, vein, or fracture plane observed on the planar projection of a borehole photograph taken with an NX borehole camera of the type developed by the U.S. Army Corps of Engineers. One goniometer was designed to interpret photographs taken in vertical drill holes and the other for photographs taken in inclined drill holes. In practice, several measurements are made on each photograph with the goniometer. These data are then substituted into mathematical equations, which are derived in this report, and the attitudes of fracture planes are determined. Work done in cooperation with the Kennecott Copper Corp., Western Mining Divisions, Engineering Department.

RI 7098. Predicted Results of Cleaning Appalachian Coals at Low Density for Sulfur Reduction, by M. R. Geer. March 1968. 20 pp. 1 fig. The Bureau of Mines examined the washability data for 25 Appalachian coals requiring low-density washing to reduce sulfur content to 1 percent, using the distribution-curve method. The purpose was to estimate how closely theoretical sulfur values could be approached, what yields of washed coal could be expected, and the recovery efficiencies that might be achieved. Assuming that the run-of-mine coal would be crushed to ⅜ inch and cleaned in dense-medium cyclones, the calculations indicate that theoretical sulfur contents could be approached closely when cleaning at a specific gravity of separation as low as 1.30. With coals that have favorable specific gravity compositions, the recovery efficiency anticipated for cleaning at 1.30 specific gravity is surprisingly high. Similar calculations for cleaning with concentrating tables at intermediate specific gravities indicated that theoretical sulfur contents at 1.50 specific gravity could be approached closely with some coals but not with others. The calculations suggest that operating a table at a specific gravity of separation much lower than about 1.50 probably would be unsatisfactory with most coals.

RI 7099. Modified Redlich-Kwong Equations for Hydrogen and for Neon, by Philip C. Tully and Jonnie M. Estes. April 1968. 27 pp. 5 figs. These modifications to the Redlich-Kwong equations for pure hydrogen and neon were developed after an unsuccessful attempt to generalize a modification technique previously developed for helium. New coefficients of the B terms were developed by minimizing the residual. No changes were made in the coefficients of the A terms. For normal hydrogen, B was changed to

$$\frac{0.08063T_c}{P_cT}$$

for temperatures from 98° to 423° K and pressures up to 1,050 atm. The average deviation in Z was 0.36 percent with maximum deviations less than 1 percent for all but a few low-temperature points. For neon, B was changed to

$$\frac{0.1025T_c}{P_cT}$$

for temperatures from 120° to 973° K and pressures up to 1,500 atm. The average deviation in Z was 0.34 percent with maximum deviations less than 1 percent for all but a few high-pressure and low-temperature points. Efforts to attain a lower temperature range to comparable accuracy with this type of modification were unsuccessful. In the range of applicability, these equations should be used with caution when calculating derived thermodynamic functions, such as the isobaric specific heat.

RI 7100. Extraction Behavior of Cerium-Group Lanthanides in a Primary Amine-Chelating Agent System, by D. J. Bauer, R. E. Lindstrom, and K. B. Higbie. February 1968. 12 pp. 6 figs. A primary amine extraction system was investigated for fractionating a cerium-group, lanthanide sulfate mixture. Addition of diethylenetriaminepenta-acetic acid (DTPA) to the amine extraction system resulted in separation factors as high as 5.4 for lanthanum-cerium, 8.0 for cerium-praseodymium, 3.7 for praseodymium-neodymium, and 7.0 for neodymium-samarium. In multistage studies of a cerium-free lanthanide mixture, 96 percent of the lanthanum was recovered with a purity of 95 percent.

RI 7101. Evaluation of Continuous Recording X-Ray Ash Meter, by J. Hudy, Jr., and A. W. Deurbrouck. April 1968. 2 pp. 4 figs. An investigation has been made to determine the applicability of the Cendrex X-ray instrument for the measurement of the ash content of washed bituminous coal products. The results obtained for selected products from six preparation plants in the Appalachian region and one preparation plant in the midwestern region are described. Emphasis of the study was placed on low-ash bituminous coal products suitable for utility or metallurgical markets. There was good agreement between the results obtained by conventional ash-determination methods and by ash determination using the Cendrex for all products tested.

RI 7102. Evaluation of Synthetic Organic Flocculants in the Treatment of Coal Refuse Slurries, by Kenneth J. Miller and A. W. Deurbrouck. April 1968. 14 pp. 6 figs. To determine the effectiveness of the many new flocculants available to the coal industry, 20 of these reagents were evaluated treating slurry feeds to four refuse thickeners. Settling rates and supernatant liquid clarities were determined for each of the flocculants on the four slurries, and zeta potential measurements of the slurry solids were made. The test results showed that the flocculants provided comparable results when judged categorically as anionic, nonionic, or cationic. It was also apparent that control of zeta potential insures maximum benefit from a flocculant.

RI 7103. Limits of Flame Propagation of Coal Dust-Methane-Air Mixtures, by J. M. Singer, A. E. Bruszak, and J. Grumer. April 1968. 12 pp. 4 figs. Flame propagation of lower limit hybrid coal dust-methane-air mixtures in vertical and horizontal flame ducts of 15.2 cm id and 1.8 m length has been investigated to provide information bearing on safety in mines. Fuel concentrations at lower limits of flame propagation and equivalences of coal dust and methane are much higher for continuing flame propagation than for short-span flame propagation in the vicinity of an "overdriving" ignition source. As the energy of the ignition source was increased, the flame speed and the distance of flame propagation from the ignition source increased, whereas the total fuel concentration at the lower limit decreased. *(Out of print.)*

RI 7104. Analyses of Tipple and Delivered Samples of Coal Collected During Fiscal Year 1967, by S. J. Aresco and J. B. Janus. 1968. 43 pp. The Bureau of Mines has been active in promoting the purchase of coal for Government use under specifications that define the requirements in terms of the heating value of the coal, expressed in British thermal units, and the composition as shown by proximate analyses. To these, when required, are added the ash-softening temperature, the free-swelling index, and the Hardgrove grindability index. Under most of these specification contracts the bidders guarantee the quality of the coal and that guaranteed by the successful bidder becomes the standard of his contract. The samples are analyzed by the Bureau of Mines to determine whether the coal is of the quality guaranted by the contractor; if it is not, a price adjustment is made. Analyses of the delivered coal and tipple samples provide valuable data for use in evaluating future bids. In addition the continuous sampling of coal as delivered is a check on the practical results obtained in burning the coal. 30 cents.

RI 7105. Analyzing Midget Impinger Dust Samples With an Electronic Counter, by Floyd G. Anderson, Thomas F. Tomb, and Murray Jacobson. April 1968. 8 pp. 4 figs. Bureau of Mines studies show that an electronic counter can be used for determining dust concentrations from midget impinger samples collected in bituminous coal mines. A sample correlation coefficient of 0.91 for data obtained using the electronic counter and the Bureau of Mines microprojector procedures indicates a significant linear relationship between the methods. The electronic counter provides better counting precision and reduces analytical time.

RI 7106. A High-Temperature, Two-Phase Extraction Technique for Tungsten Minerals, by John M. Gomes, Kneji Uchida, and Don H. Baker, Jr. April 1968. 13 pp. 6 figs. A two-phase molten halide-silicate technique for extracting tungstic oxide (WO_3) from scheelite ($CaWO_4$) and wolframite ($(Fe, Mn)WO_4$) was investigated. The halide phase extracted over 99 percent of the WO_3 whereas the lower silicate phase retained about 90 percent of the calcium, iron, or manganese oxides. The most efficient extraction and separation of tungsten from scheelite was accomplished at 1,080° C in a molten system containing, in mole-percent, 9 calcium tungstate ($CaWO_4$), 42 sodium chloride (NaCl), 28 sodium fluoride (NaF), 17 sodium metasilicate (Na_2SiO_3), and 4 alumina (Al_2O_3). Wolframite was also treated at 1,080° C; the molten system contained, in mole-percent, 11 $(Fe, Mn)WO_4$, 74 NaCl, and 15 Na_2SiO_3.

RI 7107. Ferrite Control by Cobalt Additions to a Semiaustenitic Stainless Steel, by M. M. Tilman. April 1968. 14 pp. 8 figs. The objectives of this research were to determine the practicability of using cobalt as a means of controlling the amount of ferrite in the microstructures of semiaustenitic stainless steels and to determine the effects of reduced ferrite content on mechanical properties of these steels. Cobalt additions of up to 3 weight-percent were made to type 17-7 PH (AISI 631) stainless steel. Ferrite contents were determined for alloys in the aged condition and for alloys quenched from the hot working temperature. Ferrite can be completely eliminated from the microstructure of 17-7 PH stainless steel by additions of cobalt, but complete elimination of the ferrite phase results in lower tensile strength, yield strength, and hardness. Tensile properties, hardness, and impact strength were determined for aged material. A subzero temperature treatment before heattreating was necessary to obtain maximum strength in the alloys containing cobalt. Addition of 2 weight-percent cobalt enhances mechanical properties of 17-7 PH stainless steel.

RI 7108. Sampling and Analysis of Flue Gas for Oxides of Sulfur and Nitrogen, by J. F. Smith, J. A. Hultz, and A. A. Orning. April 1968. 21 pp. 5 figs. A series of studies of emissions from large coal-fired steam generators have included measurements of the concentrations of oxides of sulfur and oxides of nitrogen. The sampling equipment, method of sampling, and analytical techniques used for processing of these samples are detailed. A method based on the precipitation of benzidene sulfate was developed for determining both SO_3 and total oxides of sulfur in the presence of interfering acidic components in the stack gases. In addition, difficulties encountered with sampling and analytical techniques are also described. Work done under an agreement with the U.S. Department of Health, Education, and Welfare.

RI 7109. Recovery Percentage of Bituminous Coal Deposits in the United States (in Two Parts). Part 1. Underground Mines, by Raymond L. Lowrie. April 1968. 19 pp. 2 figs. For many years it has been considered that an average of 50 percent of the coal in the deposits exploited has been recovered. Owing to many changes in mining methods during the past two decades, this study was initiated to obtain an up-to-date measurement of recovery percentage and thus establish part of the basis from which presently recoverable reserves may be estimated. Recovery percentages were determined within mined areas of 200 underground coal mines. These comprised a statistical sample selected to be representative of operating mines in relation to their significance to depletion of reserves. The results ranged from 29 to 91 percent and averaged 57.0 ± 1.7 percent (95-percent confidence limit). Six factors were identified mathematically as significantly affecting recovery percentages: (1) Pillaring system, (2) top rock and conditions, (3) bottom rock and conditions, (4) marketability, (5) coalbed thickness, and (6) productivity. Skill and attitude of mine operators toward recovery, although not measured, were probable factors. Five other variables that were tested did not show any significant relationship with recovery percentages. Also, five mining equipment features were identified, through discussions with mine officials, as affecting adversely recovery percentage at some mines.

RI 7110. Dewatering Coal Flotation Tailing by the Admixture of Crushed Washery Refuse, by M. R. Geer, P. S. Jacobsen, and M. Sokaski. April 1968. 15 pp. 1 fig. The ever-increasing need to guard against stream pollution has intensified interest in the problems of handling and disposing of flotation tailing. Therefore, the Bureau of Mines investigated the possibility of using crushed washery refuse to adsorb the free water in thickened flotation tailings on a bench scale and then in a pilot plant because the conventional methods of disposing of coal flotation tailings—impounding them or filtering them so they are dry enough to be conveyed to the refuse dump—are sometimes either impractical because of space limitations or costly because of low filter capacity. Most of the refuse samples tested were of similar mineralogical composition and exhibited similar water retention capability. The amount of crushed refuse required to adsorb the water in a particular tailing was influenced greatly by the fineness of the solids in the tailing and hence the percentage of solids to which it could be thickened. The ratio of crushed refuse to tailing solids required to provide a mixture dry enough to be carried on an inclined conveyor belt varied from 2.4 to 6.4. Several chemical agents that were tested were very effective in turning the free water in tailings into a stable gel. Fly ash also was very effective in adsorbing water.

RI 7111. Improved Method for Calculating Areas and Shape Factors of Flow Nets, by R. V. Higgins and A. J. Leighton. April 1968. 32 pp. 3 figs. This paper describes a method and a computer program for calculating shape factors and areas of channels that turn more than 90° and conduct fluids into the backs of wells. The program represents an improvement over a previous Bureau of Mines investigation by using a 4-point Lagrange interpolation equation instead of a 3-point and by summing areas of trapezoids with either x altitudes or y altitudes. Some of the techniques reported in this paper can also be used to compute the areas between contours and the lengths of lines that turn more than 90°.

RI 7112. Chromium by Thermal Decomposition of Bisbenzene Chromium, by B. D. Nash, T. T. Campbell, and F. E. Block. April 1968. 19 pp. 8 figs. The object of this research was to investigate the technical feasibility of preparing chromium metal by the thermal decomposition of bisbenzene chromium. Bisbenzene chromium, a pi-bonded sandwich type organometallic compound, was thermally decomposed under reduced pressure to form a metal plate on a heated substrate. Metal recovery was close to 100 percent of theoretical, with deposition rates up to 20.8 mg/hr/cm². Metal purity was dependent not only upon the purity of the starting material but also upon the sublimation rate of bisbenzene chromium. Total detectable metallic impurities ranged from a low of 18 ppm to several hundred ppm. In general, metallic impurities were less than 100 ppm. Carbon, the major nonmetallic impurity, ranged from less than 0.3 percent to more than 10 percent. The carbon contamination is most likely a result of the decomposition of the organic portion of bisbenzene chromium. An unusual property of some of the deposits was their outstanding corrosion resistance. Unlike pure electrolytic chromium, which dissolves readily, these deposits were insoluble in hot mineral acids.

RI 7113. Effects of Boron and of Boron With Carbon on the Mechanical Properties of Vanadium, by H. G. Iverson, D. R. Mathews, and J. S. Winston. April 1968. 18 pp. 12 figs. The effects of adding boron and boron plus carbon to electrorefined vanadium were evaluated with respect to mechanical properties at low temperatures and response to heat treatment. Grain size was significantly decreased with the addition of 0.05 percent boron, the decreases ranging from 30 percent at 800° C to 75 percent at 1,100° C. Increasing the boron content resulted in only a small increase in strength at room temperature, but at 77° K boron contents of 0.005 to 0.076 percent increased the yield strength of vanadium over 50 percent, from 70,000 psi to 110,000 psi. When boron and carbon were present together, the individual grain-refining effects obtained with either element were retained. Approximately a twofold increase in strength was obtained by age-hardening the alloys containing both boron and carbon. Alloys with only boron additions did not age-harden.

RI 7114. Three-Piece Concrete Sets for Small Openings. A Progress Report, by K. R. Dorman, M. E. Poad, and M. O. Serbousek. April 1968. 51 pp. 28 figs. To develop the potential of precast concrete sets as a support medium in underground mines, a three-piece precast concrete drift set was designed for a small opening and tested to destruction in an underground straining frame. Thirty-six tests were made with three sizes of members using three different loading conditions. In addition, 14 members were tested individually in the laboratory. Test results are compared with theoretical calculations. A cost comparison shows the use of concrete sets would be advantageous where conventional wooden timber requires excessive replacement.

RI 7115. Preparation of Biodegradable Synthetic Detergents From Low-Temperature Lignite Tar, by John S. Berber and Robert V. Rahfuse. April 1968. 8 pp. 4 figs. Olefin and paraffin mixtures (C_{10}-C_{16} and C_{10}-C_{22}) were separated from low-temperature lignite tar by urea adduction and sulfated to yield secondary alkyl sulfate detergents. The C_{10}-C_{16} secondary alkyl sulfate showed a 99.3 percent biodegradability, and the C_{10}-C_{22} fraction showed a 96.8 percent biodegradability, exceeding the required standard of 80 percent for the biodegradability of anionic detergents in washing and cleaning compounds. Chlorination of paraffins yielded a detergent of 93.2 to 93.4 percent biodegradability.

RI 7116. Study of Columbium and Tantalum Alloys, by Herbert R. Babitzke and Jack G. Croeni. April 1968. 16 pp. 8 figs. The purpose of this investigation was to optimize the high-temperature properties of columbium and tantalum. Columbium and tantalum were combined with selected alloying elements to achieve solid solution and dispersion strengthening. Fifty-six alloys were evaluated to determine their formability, hardness, strength at elevated temperatures, and oxidation resistance.

The following six alloys showed high-temperature strength:

Cb-15Hf-5W-2Zr-4Al-4Ti-2N	Ta-20Hf-4Al
Cb-15Hf-5W-5Zr	Ta-30Hf-4Al
Cb-15.3Ti-4.1Zr-13.7Hf	Ta-20Hf-5W-4Al

At 1,200° C the columbium alloys had strength values of 40,000 psi or greater, and the tantalum alloys had strength values from 50,000 to 58,000 psi. For a 2-hour test period at 1,000° C, weight gains of only 9 and 8 mg/cm², respectively, were observed on oxidation testing of two alloys, Cb-15Hf-5W-2Zr-4Al-4Ti-2N and Ta-20Hf-4Al.

RI 7117. Silver Recovery From Waste Photographic Solutions by Metallic Displacement, by R. O. Dannenberg and G. M. Potter. April 1968. 22 pp. 5 figs. A metallic displacement process, utilizing easily available steel wool or steel window screen, was devised and successfully used for the recovery of silver from waste photographic fixing solutions. Laboratory and prolonged commercial-scale testing established that the iron filament type unit will efficiently precipitate silver, as a high-grade sludge, from acidic waste photographic fixing solutions ranging in grade from les than 1 to over 10 grams of silver per liter. Data and design information are presented to facilitate the construction and operation of a practical unit of any desired size. A smelting process for recovering pure silver from precipitated sludge containing 27 to 80 percent silver was devised.

RI 7118. Tungsten Whiskers by Vapor-Phase Growth, by A. G. Starliper and H. Kenworthy. April 1968. 13 pp. 11 figs. Laboratory studies were made to produce whiskers of tungsten over a wide range of operating temperatures. Hydrogen reduction of tungsten hexachloride in a vacuum furnace at temperatures from 2,700° to 3,300° C yielded a small quantity of tungsten whiskers, provided a low degree of supersaturation was maintained. Direct measurements of 3,000,000 to 4,000,000 psi were obtained for the ultimate tensile strengths of individual whiskers averaging 3 to 4 microns in diameter with average aspect ratios of 1,000. This compares with strengths of 300,000 to 400,000 psi for 13-micron-diameter commercial filaments.

RI 7119. Nonpyritic Smelting of Copper Concentrates, by J. L. Reuss and M. M. Fine. April 1968. 10 pp. 2 figs. The Bureau of Mines investigated the technical feasibility of smelting copper concentrates containing chalcocite (Cu_2S) and native copper using nonpyritic sulfur-bearing materials to aid matte formation. The procedure consisted of combining various proportions of commercial chalcocite concentrate, smelter slag, fluxes, and matte-forming constituents to produce charges of comparable compositions. The mixtures were charged in fire-clay crucibles and smelted in an induction furnace at 1,300° C. The research proved that either sulfur or gypsum can replace pyrite as a matte-forming material and that gypsum produces an exceptionally high-grade copper matte. The addition of small quantities of metallic iron to the nonpyritic smelting charge furthers the removal of sulfur, improves the recovery of copper, and makes it possible to utilize gypsum as the exclusive flux and matte-forming ingredient, thereby eliminating the necessity of adding limestone.

RI 7120. Hydraulic Mining of Anthracite. Analysis of Operating Variables, by Wilbert T. Malenka. April 1968. 19 pp. 10 figs. A modified factorial experiment was used to determine the effect of operating factors in hydraulic mining of anthracite. Seven basic factors at various levels were considered. The significant factors were found to be pressure-volume, pattern, and jet traverse speed. Mining data were programed for computer, and a prediction equation was determined from printout information based on the hydraulic "jumbo" operating parameters and characteristics of anthracite. The source of error is discussed. The prediction equation is general in nature and might be useful in delineating performance characteristics in the design of equipment and/or more effective utilization in a medium with characteristics similar to those of anthracite. Work done in cooperation with the Glen Alden Coal Corp. (now Blue Coal Corp.).

RI 7121. Effects of Cobalt on Precipitation Hardening of AM 350 Stainless Steel, by M. M. Tilman. April 1968. 6 pp. 3 figs. A series of alloys was laboratory prepared by adding up to 4 weight-percent cobalt to the basic composition of type AM 350 (AISI 633) stainless steel. Aging curves were established for each alloy at 750°, 850°, and 950° F for lengths of time up to 100 hours. A series of annealed steels containing as much as 1 weight-percent cobalt was cold-rolled 50 percent and aged for 3 hours at 850° F. No improvement in hardness due to cobalt was observed in the steels transformed by heat treatment. Slight improvements in hardness were observed in the steels transformed by cold working.

RI 7122. Similar Compositions of Alkanes From Coal, Petroleum, Natural Gas and Fischer-Tropsch Product. Calculation of Isomers, by R. A. Friedel and A. G. Sharkey, Jr. April 1968. 10 pp. Data on compositions of natural substances are important in the study of possible interrelationships. The similarity of the low-molecular-weight alkane isomers from crude oil and Fischer-Tropsch catalytic synthesis product has been reported. A similar composition for the alkane isomers from high-temperature coal carbonization has been found. The composition of the C_4 to C_7 alkane isomers from these three sources can be calculated quantitatively with the equations previously developed to calculate alkane isomers in Fischer-Tropsch products. An interesting reversal of the concentrations of the monomethyl isomers from C_6 (2 Me > 3 Me) to C_7 (3 Me > 2 Me) occurs in all three products; fragmentary comparisons at higher carbon numbers indicate some dissimilarities.

Naphthene isomers in the C_6 to C_7 range for crude oil and high-temperature coal carbonization also have similar compositions. Aliphatic hydrocarbons from low-temperature coal carbonization processes are considerably different, consisting mainly of normal alkanes.

RI 7123. Recovery of Cerium and Lanthanum by Ozonation of Lanthanide Solutions, by D. J. Bauer and R. E. Lindstrom. May 1968. 9 pp. 2 figs. Oxidation of mixed lanthanide solutions with ozone at pH 4.5 and at ambient temperature resulted in precipitation of 98 percent of the original cerium present. Corresponding cerium purity was increased from 50 to 98 percent. A second ozone oxidation-precipitation step produced cerium of 99.9-percent purity in high yield from the 98-percent-pure material. Alternately, ozonation at pH 6.5 and 85° C differentially precipitated cerium and rare-earth elements heavier than cerium and left 89 percent of the original lanthanum in solution at a purity of 95 percent. Subsequent recovery of cerium from the heavier rare-earth elements in the precipitate was accomplished by dissolving the precipitate in dilute mineral acid and reoxidizing the cerium with ozone at pH 4.5 and at ambient temperature. The filtrate contained an enriched praseodymium-neodymium-samarium-europium mixture that is amenable to separation by ion-exchange or solvent extraction.

RI 7124. Analysis of Mineral Matter in Coals by X-Ray Fluorescence, by Martin Berman and Sabri Ergun. May 1968. 20 pp. 9 figs. The Bureau of Mines investigated the mineral matter content of 38 American coals using X-ray fluorescence. Measurements of the $K\alpha$ intensity for magnesium, aluminum, silicon, sulfur, calcium, and iron permit the determination of those elements as well as an indirect determination of the ash content of the coals. The percentage of each of the six elements was corrected for absorption by all six elements as well as by hydrogen, carbon, nitrogen, and oxygen. It made little difference whether the values used for hydrogen, carbon, and nitrogen were obtained from chemical analysis or whether average values for all coals were used. In all cases, oxygen was obtained by difference. The correction for absorption by all these elements involved the inversion of a 6×6 matrix and was performed by computer. Assuming that the elements magnesium, aluminum, silicon, calcium, and iron were present in the ash as oxides, the quantity of ash was determined. The results for the mineral elements as well as for ash and oxygen were in good agreement with chemical results.

Particle size was found to have a significant effect on fluorescence intensities. A study of size effects was made for pyrite particles, since the sulfur content of coals is of particular interest. Theoretical equations were derived and verified relating the intensity to particle size. It was found that the coal samples must be ground to less than 2 microns. Sulfur appears in several forms in coal, and the effect of sulfur form on intensity was investigated. It was found that the $K\alpha$ intensity was independent of sulfur form but the $K\beta$ intensity varied with the type of sulfur. Thus, the $K\alpha$ intensity was used for determination of the quantity of sulfur present. Utilization of the sulfur $K\beta$ intensity did not permit a determination of the proportions of sulfur forms present in coal. However, for synthetic mixtures of cystine and pyrite in carbon black, measurement of sulfur $K\alpha$ and $K\beta$ permit determination of each constituent from measurements of sulfur intensities alone.

RI 7125. Vapor Pressures of Liquid Columbium (2,740° to 3,140° K) and Liquid Hafnium (2,500° to 2,810° K), by R. K. Koch, W. E. Anable, and R. A. Beall. May 1968. 24 pp. 11 figs. The vapor pressures of liquid columbium and liquid hafnium were determined by the Langmuir free evaporation method as a part of the Bureau of Mines program on the study of transition metals. An electron-beam furnace with a water-cooled copper crucible was used for melting. Temperature was measured with a two-color ratio pyrometer. Least-squares analyses of the vapor pressure data gave the following equations:

$$\text{Log } p \text{ (atm)} = 5.429 - \frac{31{,}310}{T}$$

for liquid columbium in the range 2,740° to 3,140° K, and

$$\text{Log } p \text{ (atm)} = 5.690 - \frac{28{,}850}{T}$$

for liquid hafnium in the range 2,500° to 2,810° K. Third-law evaluations of each data set gave mean heats of sublimation (298.15° K) of 175.1 $\pm$ 3.2 kcal/mole and 148.3 $\pm$ 1.2 kcal/mole for columbium and hafnium, respectively. Second-law standard heats of sublimation determined from sigma plots and from sigma-prime plots agreed fairly well with the third-law values. The sigma-prime plots gave standard entropies of sublimation of 30.96 $\pm$ 0.84 eu and 33.56 = 0.44 eu for columbium and hafnium, respectively.

RI 7126. Oxidation of Lead Blast Furnace Matte by *Ferrobacillus Ferrooxidans* or a Dilute Acid Solution, by John D. Corrick and Joseph A. Sutton. May 1968. 19 pp. 8 figs. A dilute sulfuric acid leach was developed for extracting lead and copper from lead blast furnace mattes and the chemistry was defined. The possible application of *Ferrobacillus ferrooxidans* to the problem of salvaging lead and copper from blast furnace mattes was also investigated. Operating conditions were varied to determine their effect on the oxidation and hence extraction of lead and copper from the matte. Conditions varied were temperature, pH, reaction time, aeration in the slurry, and particle size of the matte.

A set of optimum conditions was developed that resulted in maximum lead and copper sulfide oxidation. Tests employing these optimum conditions resulted in 82.3 percent of the lead and 98.7 percent of the copper being extracted by a dilute acid leach, while maximum lead and copper extracted using *F. ferrooxidans* was 69.8 percent of the lead and 78.4 percent of the copper. Tests conducted with a different sample of blast furnace matte indicated that the dilute acid leach might have wide application in extracting lead and copper from other such blast furnace mattes.

RI 7127. The Incendivity of Permissible Explosives in Coal Dust-Gas-Air Mixtures, by C. M. Mason, P. A. Richardson, and R. W. Van Dolah. May 1968. 12 pp. 2 figs. Mechanical mining produces large quantities of very fine coal dust called float dust. The associated increase in hazard requires a reexamination of the Bureau of Mines method of evaluating the incendivity of explosives in coal dust-gas-air mixtures. A technique recently developed by Bureau of Mines laboratories for evaluating the incendivity of explosives in coal dust-air mixtures was applied, with modifications, to coal dust-air-natural gas mixtures. A series of permissible explosives were evaluated by this modified technique. Results indicate that the modified technique could be the basis of a more discriminatory procedure than that presently in use.

RI 7128. Developing a Thermochemical Model for the Iron Blast Furnace. Rate of Reduction of Granular Ferrous Oxide by Carbon Monoxide in a Packed Bed, by Hillary W. St. Clair. May 1968. 13 pp. Reaction rate coefficients were determined from analyses of the effluent gas for the reduction of granular ferrous oxide to metallic iron by passing carbon monoxide through a packed bed of oxide at a controlled rate in the temperature range 1,000° to 1,300° C. Coefficients were determined by the comparison of observed analyses and calculated analyses using a mathematical model that takes into account the nonuniform composition of both the solid oxide and the gas. A method is also given for finding the value of the rate coefficient that best fits the observed data.

RI 7129. Shales for Lightweight Aggregate in Appalachian Region, Kentucky and Tennessee, by Ronald P. Hollenbeck and M. E. Tyrrell. May 1968. 54 pp. 14 figs. Shales in the Appalachian region of Kentucky and Tennessee were sampled and tested to determine their use as raw materials for the manufacture of lightweight aggregate by the rotary-kiln method. Nine samples were obtained from eastern Kentucky and 143 samples were obtained from eastern Teneessee. As a result of preliminary testing of these samples, two sources in eastern Kentucky and 11 sources in eastern Tennessee were resampled for rotary-kiln tests. The rotary-kiln tests showed the two sources in Kentucky and seven sources in Tennessee contained shale that would produce satisfactory aggregate. Lightweight aggregate processed from these nine sources was tested in concrete shapes and was found to be suitable for use in structural concrete.

RI 7130. Application of Filiform Tungsten To Reinforce Metals, by A. G. Starliper and H. Kenworthy. May 1968. 18 pp. 12 figs. The Bureau of Mines made laboratory investigations to determine the feasibility of utilizing fine tungsten wires to reinforce a number of nonferrous metals and alloys and a superalloy, S-816. The composites of tungsten filament and metals were chosen to attain elevated temperature strength and corrosion resistance. Oriented clean or precoated tungsten wires were incorporated with the other metals by extrusion, swaging, and infiltration casting. Although widely varying characteristics were found in the composites, none were considered satisfactory for high-temperature use, chiefly because of reactions between the matrix metal-tungsten surface. Diffusion, solution, and chemical reactions between matrix and tungsten wires were sufficiently slow for some combinations, such as 15 v/o S-816, to exhibit increased high-temperature strength for a limited time. A few metals failed to wet or bond to the tungsten surfaces, while a few responded after precoating with a third metal.

RI 7131. Carbonizing Properties of Coals From Fayette, Greene, and Washington Counties, Pa., by D. E. Wolfson and C. Ortuglio. May 1968. 14 pp. 1 fig. The Bureau of Mines carbonized 21 coal samples from Fayette, Greene, and Washington Counties, Pa., at 900° C, using the Bureau of Mines-American Gas Association (BM-AGA) method, and determined yields of products and physical properties of the coke. These samples represented high-volatile A Pittsburgh, Sewickley, Waynesburg, and Upper Freeport and medium-volatile Upper Freeport and Lower Kittanning coals. About 20 percent of all coals presently carbonized in commercial coke ovens in the United States are mined in Greene and Washington Counties, principally from the Pittsburgh seam. Sulfur content of the Pittsburgh coals in these counties is moderately high (1.0 to 3.2 percent) but, because of extremely large reserves, accessibility to Eastern United States markets and excellent blending characteristics to yield strong coke, these counties will continue to be an important source of metallurgical coals in the future. Most coals from the other seams contained more than 2 percent sulfur, which would limit their use as metallurgical coals.

RI 7132. Dust Explosibility of Chemicals, Drugs, Dyes, and Pesticides, by Henry G. Dorsett, Jr., and John Nagy. May 1968. 23 pp. 1 fig. Dust explosion data obtained in laboratory tests by the Bureau of Mines are presented for 73 chemical compounds and mixtures, 29 drugs, 27 dyes, and 46 pesticides. Information is given on ignition temperatures of cloud and layer, minimum igniting energy, minimum explosive concentration, percent of inert dust required to prevent flame propagation, limiting oxygen concentration in the atmosphere to prevent ignition, and pressures and rates of pressure rise at dust concentrations of 0.1, 0.2, 0.5, 1.0, and 2.0 ounces per cubic foot. Explosibility indexes are computed where data are available to permit comparison of the relative explosion hazard. Variations of explosibility parameters with chemical compositions are discussed. General means for minimizing the dust explosion hazard are reviewed.

RI 7133. Methods for Determining Nitrogen Oxides in Automotive Exhausts, by Basil Dimitriades. May 1968. 29 pp. 9 figs. Five recently developed methods for determining nitrogen oxides in automotive exhausts have been evaluated from the standpoint of accuracy and applicability in current exhaust studies. Results showed that methods requiring conversion of nitric oxide to nitrogen dioxide as a part of the analytical procedure are subject to errors introduced by the instability of NO_2. The extent of some of these errors has been determined and procedures have been developed to minimize undesirable influences. On the basis of the results obtained from this study, recommendations are made regarding procedures for batch type or continuous measurement of nitrogen oxides in exhaust streams. Work done in cooperation with the Coordinating Research Council, Inc.

RI 7134. Heavy Liquid Cyclone Concentration of Minerals (in Two Parts). 2. A Study of Liquid Cyclone Concentration of Various Mineral Systems, by R. B. Tippin and James S. Browning. June 1968. 53 pp. 25 figs. Research investigations conducted on five ore samples show the applicability of heavy liquid separation (HLS) techniques to mineral processing. Under proper operating conditions, semicontinuous tests in small fluid cyclones yielded 90 percent sink-float concentrates with recoveries exceeding 90 percent on minus 35-mesh ore samples of kyanite, potash, spodumene, fluorspar, and beryl. Although none of the ores were examined in detail, their response to this novel concentration method provides basic examples that are typical of the process.

Various aspects of cyclone design and operational characteristics of heavy liquid cyclone circuits were studied which demonstrated the flexibility of HLS by using multiples units connected in series. A comparison of two heavy liquid solutions, tetrabromoethane and methylene bromide, exhibited their individual advantages and limitations. Unique problems relative to this process are discussed including liquid viscosity, mineral composition of the ore, toxicity, and material handling hazards. Work done in cooperation with the University of Alabama.

RI 7135. Measurement of Oleic Acid on Mineral Surfaces Using a Gas-Liquid Chromatograph, by Jerry L. Huiatt, J. Vance Batty, and B. F. Andrew. May 1968. 22 pp. 2 figs. An accurate and reproducible procedure was developed using the gas-liquid chromatograph to quantitatively measure oleic acid on flotation products and in flotation water phases. The method comprised extraction of the oleic acid from the mineral surfaces with alcoholic NaOH, esterification of the extracted oleate, and chromatography of the methyl ester with an internal standard. Quantitative analysis of oleic acid on flotation products from test tube and bench-scale flotation tests with pure minerals and with natural ores proved the applicability of the method on a variety of minerals. The accountability of oleic acid added was 100 percent ± 5 percent.

RI 7136. Elastic Pressure Distortion of the Volumes of a Burnett Compressibility Apparatus, by Ted C. Briggs and Robert E. Barieau. June 1968. 32 pp. 1 fig. Equations for the elastic pressure distortion of the volumes of a Burnett compressibility apparatus are developed and presented in this report for volumes under internal and external applied pressures. An experimental method for the determination of the external-pressure distortion coefficients is presented. Young's modulus and the internal-pressure distortion coefficients are computed from the experimentally determined external-pressure distortion coefficients. The temperature dependence of the pressure distortion coefficients and of Young's modulus is evaluated for the temperature range 0° to 80° C.

RI 7137. Cast Hafnium Carbide-Carbon Alloys: Preparation, Evaluation, and Properties, by R. P. Adams, M. I. Copeland, D. K. Deardoff, and R. L. Lincoln. June 1968. 50 pp. 26 figs. Because of the extreme interest in materials with high melting temperatures and the advantages offered over the powder route for making high-density material, arc-melting and centrifugal-casting methods were investigated for preparing shapes of hafnium carbide with and without excess carbon. Highly satisfactory equipment was constructed and efficient operating procedures were established. Also, methods for preparing consumable electrodes and shrink-tolerant graphite molds were developed. Although crack-free hafnium carbide (6.3 weight-percent carbon) shapes were not made, coherent castings containing 9 to 13.5 weight-percent carbon were produced; the same compositions were shown to be resistant to thermal shock. Selected physical and chemical tests were performed on castings chosen for investigation by chemical and nondestructive inspection techniques. Electrical conductivity and thermal expansion measurements were made. Measurable oxidation of all the compositions studied was observed to start between 500° and 600° C. Attack by nitrogen, however, did not occur until temperatures exceeded 2,000° C. A linear relationship of the logarithm of the diamond pyramid hardness to the temperature was noted. Considerable scatter of the bend-rupture strengths at room temperature and of the tensile strengths up to 2,000° C was found. However, at the latter temperature and above, a definite relationship of strength to temperature was observed and some ductility was noted. Work done under an agreement with the U.S. Atomic Energy Commission.

RI 7138. Effect of Ammonia in Cyanide Solution on Copper Extraction From a Michigan Ore, by A. F. Colombo. May 1968. 7 pp. 1 fig. Bench-scale research was undertaken to determine if adding ammonia to cyanide leaching solutions would enhance the extraction of copper from an argillaceous Michigan copper ore. Two leaching techniques, (1) rolling using a tumbling bottle and (2) aerating using a modified Buchner funnel, and variations in pulp temperature were employed in evaluating the effect of ammonia concentration on copper extraction. Under these experimental conditions, the extraction of copper was shown to be independent of ammonia concentration and entirely dependent on cyanide concentration.

RI 7139. Electrification of Ammonium Nitrate in Pneumatic Loading, by E. L. Litchfield, M. H. Hay, and J. S. Monroe. June 1968. 19 pp. 6 figs. The electrification of ammonium nitrate-fuel oil (AN-FO) blasting agents by pneumatic loaders is described and discussed. The consequences of the electrification are considered in light of the initiation requirements of electric blasting caps. It is recommended (1) that semiconductive loading tubing be utilized and (2) that the resistivity of the AN-FO be controlled; it is further recommended that the operator (3) test to assure continuity of the electric detonator legwire-bridgewire-legwire circuit prior to insertion of the cap into charge or borehole, (4) keep the legwires shunted but not otherwise connected to ground during loading of the blasting agent into the borehole, (5) assure that the borehole is discharged prior to hooking up the detonator leads, (6) assure that he is himself discharged prior to handling the detonator leads, and (7) assure that the blasting cap leads are never carried to the AN-FO loader. The basis and significance of these recommendations are explained.

RI 7140. Centrifugal Dewatering of Jamaican Red Mud, by Philip C. Good and O. C. Fursman. June 1968. 10 pp. 1 fig. Red mud residue from Bayer process treatment of Jamaican bauxite was dewatered in batch and in continuous centrifuges. Solids content of the residue was increased from its original value of 20 to 25 percent to about 40 percent by centrifuging. Clear effluent amounting to approximately 40 percent of the slurry liquid was recovered containing dissolved alumina and soda values for potential recycle to the alumina plant. Addition of a chemical flocculant to the centrifuge increased capacity by about 35 percent. Manufacturer's estimate of large-scale equipment requirements, based on data collected in this investigation, was that a proposed installation for dewatering 16,000 tons per day of Jamaican red mud would require twenty-two 24- by 60-inch solid-bowl-type centrifuges. Cost analysis of a proposed installation, based on a Jamaican red mud tonnage of 16,000 per day, is included also.

RI 7141. Entrained-Bed Carbonization of Highly Fluid Bituminous Coals, by Manuel Gomez, W. S. Landers, and E. O. Wagner. June 1968. 34 pp. 1 fig. Bituminous coals having maximum fluidity values in the 40- to 25,400-dial-divisions-per-minute (ddpm) range were carbonized in a continuous, entrained-bed reactor. Carbonization was conducted in an 8-inch-diameter vertical reactor at temperatures from 955° to 1,345° F and at air-to-coal ratios ranging from 4.63 to 16.12 scf/lb of moisture- and ash-free coal charged. Carbonization rates from about 118 to 360 lb/hr, as-carbonized basis, were examined. It was demonstrated that carbonization temperature and air-to-coal ratio must exceed minimum values for continuous operation. Within the operating conditions discussed, highly fluid bituminous coal was carbonized to produce tar and nonagglomerated char. The yield of tar ranged from 21.3 to 38.9 gallons per ton and the char yield ranged from 1,109 to 1,563 pounds per ton, all units expressed on a moisture- and ash-free basis. It was demonstrated that the maximum fluidity and the average size of the coal along with the air-to-coal ratio and the carbonization temperature act together to influence the carbonization product yields and certain properties of the products. Prediction equations were developed from the data for product yields and selected properties of the char, tar, and gas.

RI 7142. Development of a High-Temperature Interferometric Dilatometer Using a Laser Light Source, by P. M. Johnson, R. L. Lincoln, and E. R. McClure. June 1968. 13 pp. 7 figs. A design for a laser-powered optical interferometer, using a specimen whose thermal expansion is to be measured as part of the optical system, was conceived and applied in a prototype dilatometer. The object of this work was the development of an absolute dilatometer capable of use at elevated temperatures, particularly above 1,000° C. The prototype has been operated at temperatures exceeding 1,500° C. Results obtained with this device agree within 2.5 percent with the published data for the coefficient of expansion of columbium.

RI 7143. An Anisotropic Elastic Solution for Testing Stress Relief Cores, by Robert M. Becker. June 1968. 15 pp. 2 figs. A thick-wall cylinder solution applicable to the evaluation of anisotropic elastic parameters is derived for the interpretation of stress relief data. For a restricted class of problems, a special relationship among certain orthotropic moduli yields stress distributions for the plane orthotropic problem that are identical to the corresponding isotropic case. A ring or hollow cylinder with these specialized anisotropic properties subjected to uniform radial loads is one of the problems in this class. Consequently, known stress solutions are used to develop the strains and displacements for a specialized orthotropic thick-wall cylinder under uniform pressures. The results are consistent with anisotropic equations used in the evaluation of in situ rock stresses.

RI 7144. Laboratory Oil-Recovery Experiments Using Ultrasonic Energy, by C. I. Pierce and C. A. Komar. June 1968. 8 pp. 1 fig. The Bureau of Mines conducted laboratory tests to determine if ultrasonic energy could reduce either the residual water or oil content of petroleum reservoir-rock samples from Appalachian area oilfields. Brine-saturated core samples were flooded with oil to residual brine saturation and subjected to 20 kilocycles per second ultrasonic energy. Then they were flooded with brine to residual oil saturation and again subjected to ultrasonic energy. Additional water displaced as a result of the application of ultrasonic energy to the flow system ranged from 0 to 4.3 percent of the original brine and averaged 1.9 percent. The increase in oil recovery as a result of the ultrasonic energy ranged from 0 to 9.0 percent of the original oil and averaged 3.1 percent. On the basis of the tests, it appears that 20-kcp acoustic waves would not have field application for oil recovery.

RI 7145. High-Purity Vanadium by Metallothermic Reduction of Vanadium Trichloride, by M. J. Ferrante, F. E. Block, and J. L. Schaller. July 1968. 22 pp. 8 figs. The preparation and subsequent reduction of vanadium trichloride was investigated as a process for the production of high-purity vanadium metal. Chlorine was reacted with vanadium oxide in the presence of carbon to form vanadium tetrachloride. The contaminant vanadium oxytrichloride was also formed and later converted to tetrachloride by reaction with chlorine in the presence of activated charcoal. Vanadium tetrachloride was stirred continuously during thermal dissociation to vanadium trichloride powder from which volatile contaminants were removed by distillation. The vanadium trichloride powder was reduced to vanadium sponge by controlled feeding of the trichloride into molten magnesium. Excess reductant and byproduct salt were removed from the vanadium sponge by high-vacuum distillation. Batches as large as 6.5 kilograms of sponge metal were prepared at an average reaction efficiency of 98 percent. Vanadium sponge after consolidation by arc-melting contained 820 to 1,330 ppm of interstitial impurities and had a hardness between Rockwell B 40 and 70. This metal exhibited excellent workability at room temperature. The purification of impure vanadium metal by electron-beam melting resulted in lowering interstitial impurities from 1,890 to 504 ppm and hardness from Rockwell B 87 to 28.

RI 7146. Direct Electrolysis of Rare-Earth Oxides to Metals and Alloys in Fluoride Melts, by E. Morrice, E. S. Shedd, and T. A. Henrie. June 1968. 12 pp. 3 figs. Techniques developed by the Bureau of Mines for the preparation of high-purity rare-earth metals and their alloys by electrolysis of the oxides in fluoride media are summarized. Cerium, lanthanum, neodymium, praseodymium, dysprosium, gadolinium, and yttrium metals, the mixture didymium, and specific alloys of these materials and samarium with iron, nickel, chromium, and cobalt were prepared. Individual metals were electrodeposited in the liquid state on tungsten or molybdenum cathodes. Alloys were prepared by electrodepositing the rare-earth metal on a consumable cathode, at a temperature above the melting point of the eutectic formed between the rare-earth element and the cathode material. Cells were designed for electrowinning metal products in gram and pound quantities, and methods for continuous electrowinning of cerium and lanthanum were developed.

RI 7147. Pressure Pulses Produced by Underground Blasts, by N. E. Hanna and M. G. Zabetakis. June 1968. 16 pp. 12 figs. An investigation was made of pressure pulses produced by unconfined explosive blasts in underground openings. Four tests were made with TNT or modified amatol charges ranging in weight from 60 to 2,000 pounds; each test involved either single or multiple charges. Pressure-time profiles were obtained using mechanical self-recording pressure gages. The cube-root scaling law for peak pressure was found to be valid within about 1 tunnel diameter; at greater distances, the pressures obtained along direct paths were generally higher than this scaling law would indicate.

RI 7148. Beryllium Resources of Idaho, Washington, Montana, and Oregon, by Eldon C. Pattee, Ronald M. Van Noy, and Robert D. Weldin. July 1968. 169 pp. 78 figs. Reconnaisance samples of reported beryllium occurrences in Idaho, Washington, Montana, and Oregon were chemically and spectroscopically tested in a mobile laboratory. The two predominant types of occurrences were green beryl associated with Cretaceous intrusions and disseminated aquamarine associated with Tertiary intrusions. Although the beryllium content of known deposits in the Northwest is too low for economic development at present, total submarginal-grade beryllium resources in pegmatites are estimated to be 570,000 to 1,870,000 tons containing 0.024 to 0.167 percent BeO. A potential source of 500,000 to 700,000 tons of beryllium-bearing tactite in Idaho and Montana averages 0.033 to 0.080 percent BeO. Work on the Idaho section done in cooperation with the State of Idaho Bureau of Mines and Geology.

RI 7149. Development and Evaluation of Nonincendive Detonating Cord, by C. M. Mason, J. L. Uraco, and J. C. Cooper. June 1968. 9 pp. 2 figs. A method for evaluating the relative incendivity of detonating cord in natural gas-air mixtures was developed. The method consisted of firing short lengths of cord in bundles to determine the number of strands per bundle which would ignite natural gas-air mixtures 50 percent of the time in the 45-cubic-foot gallery of the Bureau of Mines. The relative efficiency of a flame quenching agent, potassium acid tartrate (KHT), when incorporated in both the pentaerythritol tetranitrate (PETN) core and the polyethylene sheath, was explored. The effects of sheath thickness, sheath composition, core weight, and core composition were evaluated. The bundle method established a quantitative scale for evaluating the relative incendivity of cords. The relative incendivity determined by the bundle method was then compared with the incendivity of 100-foot lengths of detonating cord when initiated in 8 percent natural gas in the 640-cubic-foot gallery of the Bureau of Mines.

RI 7150. Boron and Boron Carbide by Vapor Deposition, by J. G. Donaldson, James B. Stephenson, and A. A. Cochran. June 1968. 15 pp. 10 figs. The Bureau of Mines investigated the formation of boron and boron carbide coatings by vapor-phase reactions. Optimum parameters were determined for hydrogen reduction of boron trichloride and for the formation of boron carbide coatings on graphite by reaction with the depositing boron. At 1,300° C, about 85 percent of the boron was deposited. Tungsten substrates did not react with the boron deposit; other substrates reacted to various extents. The hydrogen reduction of boron tribromide was briefly investigated. Boron carbide was deposited at 1,300° C by adding methane to the boron trichloride-hydrogen feed gas. The chemical composition of the vapor-deposited boron carbide approximated B_4C. A method of etching B_4C was developed to study its microstructure. When boron was deposited on graphite at 1,500° C, very hard, uniform, strongly adherent coatings of B_4C were formed that might be useful in rocket nozzle applications.

RI 7151. A Model for Molten Pools in Arc Melting, by F. W. Wood. July 1968. 33 pp. 22 figs. The use of consumable-electrode arc melting as a production technology is growing. One advantage of this process is that it avoids ingot contamination by soluble crucible materials by employing a chilled metal crucible. Because the thermal balance under these conditions is rather delicate and does not necessarily provide a favorable environment for solidification, catastrophic imbalances can occur. The effectiveness and mechanistic roles of various factors are mostly unknown, and more intelligent insight into the distribution of temperature and heat is needed.

Experience has provided several pertinent observations, some of which are quite superficial. The most meaningful data have resulted from studies of molten pool shapes and sizes and from measurements of heat flow through crucible walls. Overall experience, intuitively interpreted and supplemented, is sufficient nevertheless as a basis for a boundary-value treatment of the problem. A mathematical analysis based on a separation of variables, using conventional differential equation methods, provides a useful solution. For a cylindrical ingot, the temperature varies as a Bessel function of an argument proportional to the radius and as an exponential function of longitudinal position.

Trial calculations using the problem solution seem to verify the general accuracy of the result compared with experience. The role and nature of solution parameters are also clarified, although not entirely resolved. It is revealed that the barrier to heat flow at the ingot-crucible surface has a prominent influence. The utility of the model embodied in the problem solution is readily demonstrated by considering a variety of contemporary questions about arc melting.

RI 7152. Conversion of Tungsten Oxychloride to Tungsten Hexachloride by Chlorination, by A. W. Henderson, D. H. Yee, and F. E. Block. June 1968. 14 pp. 6 figs. Methods for converting $WOCl_4$ to WCl_6 were investigated in a small-scale laboratory apparatus to devise a method for preparing pure WCl_6 suitable for conversion to tungsten metal. Chlorine, $COCl_2$, and CCl_4, alone and in combination with various forms of carbon, were tested as chlorinating agents at various temperatures. More than 95-percent conversion of $WOCl_4$ to WCl_6 was achieved with all reagents at 800° C in the presence of activated carbon. Only CCl_4 maintained its effectiveness in the absence of carbon at 800° C. The effectiveness of carbon was found to be related directly to its surface area.

RI 7153. Rare-Earth Silicide Additions to an Alloy Steel to Increase Toughness and Ductility, by H. A. Tucker, R. T. Coulehan, and W. G. Wilson. June 1968. 30 pp. 13 figs. This Bureau of Mines investigation was conducted to determine the appropriate quantities of rare-earth metals in the form of silicides to add to an alloy steel for the purpose of increasing toughness and ductility. The work was conducted in a vacuum induction furnace with the rare-earth additions required to deoxidize and desulfurize a simulated basic oxygen furnace vacuum-degassed steel initially containing 0.013 to 0.016 percent sulfur. The product proved to be as good or better than the best basic electric furnace steel of the same composition made by the steel industry.

Twenty-three experimental heats of 5 Ni-Cr-Mo-V steel were made, cast into 50-lb ingots, and hot-worked in a press and a rolling mill to ½-inch plates which were then heat-treated to 130/150 ksi yield strength. Impact and tension tests showed that the addition of 0.025 to 0.100 percent, or ½ to 2 lb per ton, respectively, of rare-earth metals when compounded with silicon were appropriate for increasing toughness and ductility. These quantities resulted in retained cerium contents of 0.014 to 0.025 percent and increased the Charpy V-notch energy absorption and the percent reduction of area significantly as compared with base heats at the same sulfur content levels. All the test heats, including those with rare-earth additions of as much as 4 lb/ton, had greater Charpy V-notch energy absorption values than the base composition could have developed at the starting sulfur range of 0.013 to 0.016 weight-percent. Work done in cooperation with the Molybdenum Corp. of America, N.Y.

RI 7154. Performance Characteristics of Coal-Washing Equipment: Dense-Medium Coarse-Coal Vessels, by J. Hudy, Jr. July 1968. 29 pp. 9 figs. The performance of six dense-medium washers was evaluated in five preparation plants. Three of the plants were making a two-product separation that produced a clean coal and a refuse; one plant employed dense-medium vessels in series to effect a primary and a secondary separation; and one plant was equipped with a two-compartment washer effecting two separations in one vessel. The separate secondary drum-type washer produced a low-ash metallurgical coal and an intermediate-ash product suitable for plant fuel or steam generation. The two-compartment washer produced a premium anthracite product and a middlings product. The sharpness-of-separation values ranged from good to excellent for the five primary separations and for the secondary separation.

RI 7155. Effects of Planes of Weakness on Uniaxial Compressive Strength of Model Mine Pillars, by Frank G. Horino. July 1968. 24 pp. 17 figs. The Bureau of Mines studied the uniaxial compressive strength of model rock pillars as a function of the angle and spacing of noncohesive planes of weakness. The model pillars were prepared from NX 2⅛-inch-diameter drill core of limestone, sandstone, and granite. The planes of weakness were diamond saw cuts ground flat and smooth. The angle of the planes of weakness, measured from the horizontal, varied from zero to 57° in approximately 15° increments. When two planes of weakness were used, the thickness-to-diameter ratios of the wafer were ¼, ½, and 1.

Approximately 400 model pillars were tested in uniaxial compression. The results indicate that the uniaxial compressive strength of model pillars decreases rapidly as the angle of the plane of weakness increases from 30° to 57° and that the spacing of these planes of weakness has only a minor effect on the strength. The effect of the number of horizontal planes of weakness, with a spacing of ¼ and ½ of the diameter, upon the compressive strength of model pillars was also investigated. These results indicate that as the number of planes of weakness increases the compressive strength of the pillar decreases. Normalizing the data provides useful estimates of model pillar strengths for any rock type.

RI 7156. An Evaluation of an Ammonium Sulfate Leaching Process for Recovering Manganese From Minnesota and Maine Resources, by John J. Henn, Frank A. Peters, Paul W. Johnson, and Ralph C. Kirby. July 1968. 68 pp. 21 figs. An evaluation is presented of an ammonium sulfate leaching process designed to extract manganese from Cuyuna, Minn., and Aroostook, Maine, deposits. In this process the manganese and iron in the ore are reduced to MnO and Fe_3O_4 in a shaft furnace; the reduced ore is then leached with ammonium sulfate solution forming soluble manganous sulfate while leaving most of the iron undissolved. After filtration, the manganese and some impurities are precipitated from solution as carbonates which are then pelletized and calcined to form a product composed mainly of Mn_3O_4.

The plants are designed to produce 100 tons per day of manganese contained in a product that is suitable for the production of ferromanganese. A byproduct credit, together with the extra processing cost, is included for the Cuyuna ore processing plants, because Fe_2O_3 may be recovered for use in blast furnaces. The estimated operating costs per ton of manganese, excluding income taxes and return on investment, are as follows:

Ore	Without byproduct recovery	With byproduct recovery
Cuyuna black	$202.20	$184.81
Cuyuna brown	262.22	208.46
Aroostook northern district	321.95	------

The process with or without byproduct recovery, when treating Cuyuna or Aroostook ores, is not economically competitive with ores available at $71.43 per ton of contained manganese.

RI 7157. Hollow-Core Anthracite Briquets as Blast Furnace Fuel, by J. W. Eckerd, R. E. McKeever, P. L. Woolf, and W. S. Sanner. July 1968. 13 pp. 6 figs. Metal production rates of 42 to 45 tons per day were obtained with hollow-core anthracite briquets in an experimental blast furnace. Tuyere pressures were about the same for both coke and briquet operations, but from 150 to 175 pounds more of briquets were required per ton of metal than were needed with coke. Furnace operations were comparatively smooth, furnace hanging occurring less often than in previous tests with anthracite briquets. Dust production was substantially higher than with coke, however, and metal quality could not be controlled by corrective burdening and moisture control.

RI 7158. Analysis of the Northern Great Plains Province Lignites and Their Ash: A Study of Variability, by Everett A. Sondreal, Wayne R. Kube, and James L. Elder. August 1968. 94 pp. 14 figs. Data are presented on the characteristics of lignites with emphasis on the composition and fusion properties of the ash. Differences in the analyses of commercial-grade lignites are related primarily to variations in moisture and ash contents. Lignite ash is generally characterized by high concentrations of alkaline earth oxides and a greater tendency for retention of sulfur in the ash than higher rank coals. Composition of ash varies significantly within and between mines. The differences within mines are significant for short distances and may be eliminated under certain circumstances by normal mixing occurring during mining.

The sulfur in lignite averages 0.6 percent and is found primarily in the organic or pyritic forms with only a trace of the sulfate. During the standard laboratory ashing procedures, from 60 to 100 percent of the original sulfur is retained in the lignite ash. Trace elements, such as uranium and germanium, in the ash from commercial-grade lignites are present in low concentrations, but others, primarily copper and silver, are present in specific samples in concentrations approaching those found in some commercial ores.

RI 7159. Flotation of Mica From Pegmatites of Randolph County, Ala., by Ralph B. Adair and J. S. Browning. July 1968. 11 pp. 2 figs. The Bureau of Mines conducted laboratory and small-scale continuous tests of weathered mica-pegmatite ores from Randolph County, Ala., to determine the feasibility of recovering commercial-grade mica concentrates by flotation. Two flotation methods were used in continuous tests for recovery of mica. One method utilized acid-cationic flotation for the recovery of coarse mica and alkaline-anionic-cationic flotation for the recovery of fine mica. This method yielded mica concentrates containing 98.6 percent mica with a recovery of 85.9 percent. The other method was based on the Bureau-developed alkaline-anionic-cationic method and yielded concentrates containing 97.5 percent mica with a recovery of over 90 percent. In both methods, preconcentration of the ground ore on a Humphreys spiral was employed to reject over half of the feed in a product virtually free of mica. Work done in cooperation with the Black Warrior Petroleum Co., Inc., and the University of Alabama.

RI 7160. Sulfur Retention in Anthracite Ash, by J. J. Demeter and D. Bienstock. July 1968. 12 pp. 5 figs. Anthracite from the four producing regions in Pennsylvania was both ashed in the laboratory and burned on a chain-grate stoker to determine the sulfur-retention properties of its ash. The retention of sulfur in laboratory-prepared anthracite ash was shown to be related to ashing temperature and to the amounts of sulfur and calcium present in the coal. At the usual laboratory ashing temperature of 750° C sulfur retention ranged from 0.8 to 13.2 percent of the total coal sulfur. Sulfur retention in the ash was negligible, 0 to 0.3 percent at 1,200° C, which is the thermal decomposition temperature of calcium sulfate; thus calcium sulfate does not form and cannot serve as a sulfur-retaining agent. In several tests the anthracite was mixed with 6 or 10 percent dolomite prior to firing in the chain-grate stoker. The dolomite did not improve sulfur retention owing to the high temperature in the fuel bed. Sulfur retention was, however, related to the unburned carbon in the ash. The relationship of the percentage of original coal sulfur retained in the ash (Y) to the percentage of the original carbon in the coal remaining in the ash (X) is expressed by $Y = -0.579 + 0.914X$. The percentage of sulfur retained is almost directly proportionate to the percentage of original coal carbon in the ash.

RI 7161. Performance of a Low-Permeability Sandstone Oil Reservoir, West Avant Field, Osage County, Okla., by Kenneth H. Johnston. July 1968. 28 pp. 9 figs. Information and data necessary for research on improving methods of oil recovery from low-permeability reservoirs and for evaluation of performance and comparison of such reservoirs with those producing from more permeable sands were obtained. Core analyses, well logs, production tests, well stimulation techniques, primary and secondary production records, and data on two waterflood projects were examined for wells producing from the Bartlesville sand, West Avant field, Osage County, Okla. Overall recovery from the study area was generally poor with only 9.0 percent of the pore volume recovered to January 1, 1968. Larger fracture treatments (8,000 to 12,000 gal) could have resulted in an increase in primary oil recovery. Secondary recovery by waterflooding accounted for only 1.9 percent of the pore volume because of the inability to control the large volume of injection fluid that escaped from the flood patterns and the excessive volumes of water produced with the oil. Future waterflood development in other low-permeability reservoirs should include the drilling of new input wells, use of injectivity surveys to locate possible natural fracture systems or zones of high permeability, and control of injection fluids by altering flood patterns and/or plugging of the more permeable zones. Work done in cooperation with the State of Oklahoma and on the recommendation of the Oil Recovery Committee of the Independent Petroleum Association of America.

RI 7162. Alumina Extraction by Autoclave Precipitation of Basic Sodium Aluminum Sulfate, by H. G. Iverson and H. Leitch. August 1968. 27 pp. 8 figs. An investigation was conducted on the conditions affecting the precipitation of aluminum by autoclaving synthetic solutions containing Na_2SO_4, $Al_2(SO_4)_3$, H_2SO_4, and H_2O. Virtually all of the alumina could be precipitated as natroalunite ($NaAl_3(SO_4)_2(OH)_6$). This product could be readily filtered and dried. Results are reported in terms of alumina precipitated in this compound and not in terms of alumina itself. Solutions of $\sim$ 0.30, $\sim$ 0.60, and $\sim$ 0.80 mole/liter Al_2O_3 and various concentrations of H_2SO_4 and Na_2SO_4 were investigated. The optimum time and temperature for autoclaving were 20 to 30 minutes at 200° C.

The highest yields of natroalunite were obtained from solutions containing little H_2SO_4 and $\sim$ 2 moles Na_2SO_4 per mole Al_2O_3. Acid in quantities of 0.3 to 0.5 mole/mole of alumina in solution depressed the yield to 90 percent or less.

In differential thermal analysis, at 1,000° C the natroalunite precipitate decomposed without melting to yield SO_3 and SO_2 gases, a solid composed of Na_2SO_4, and gamma and alpha Al_2O_3. Continued heating to 1,200° C produced Na_2SO_4 and alpha Al_2O_3. Water-leaching of this product removed the Na_2SO_4 and left a final residue of alpha Al_2O_3.

RI 7163. Evaluation of the Explosive-Anchored Rock Bolt, by John B. Shutack and Norman E. Hanna. July 1968. 15 pp. 9 figs. In an effort to improve the performance of the explosive-anchored rock bolt, the Bureau of Mines studied the effect of the detonation velocity of the explosive and type of charge (linear or nonlinear) on the fracturing tendency of the anchor tube. Also, different types of tubing were compared to determine the one most suitable for use as an anchor tube. The Bruceton up-and-down method was applied in tests in which steel shooting blocks having boreholes ranging from 1⅜ to 2⅛ inches in diameter were used. Of the four types of tubing evaluated, a welded A-178 tubing that was drawn over a mandrel and renormalized gave the most promising results. The A-179 seamless tubing that is normally used with the explosive bolt was the most inferior. Both types, however, gave significantly better anchorage than the conventional shell when tested in both laboratory and underground experiments. Within the range of velocities studied (5,000 to 7,000 m/sec), the type of explosive showed no significant effect on anchor-tube performance. In general, linear explosive charges provided better anchorage than nonlinear charges.

RI 7164. An Acoustical Bench for an Ultrasonic Pulse System, by R. E. Thill, R. J. McWilliams, and T. H. Bur. July 1968. 22 pp. 12 figs. The ultrasonic pulse measurement system described measures velocities of longitudinal (compressional) and shear waves in rock to give values that can be used with density values to determine the dynamic elastic constants of rock. A special feature of this pulse measurement system is its unique acoustical bench that minimizes the errors in pulse transit times which are commonly associated with coupling, sample alinement, and sample orientation. Some special features of the acoustical bench are its highly versatile transducer cartridges, a pneumatic ram coupling device, an orientation mechanism, and a vacuum chuck sample holder. The lathe-bed-like construction of the acoustical bench assures automatic alinement of samples and versatility in accommodating samples of various shapes and sizes.

RI 7165. Miniature Bilevel Alarm for Oxygen-Deficient Atmospheres, by Robert A. Bradburn and Merle L. Bowser. August 1968. 15 pp. 15 figs. The Bureau of Mines has developed a miniature, portable two-level oxygen-deficiency alarm and produced three prototype models. Each operates from a 4.2-v dc power source, and the highest current drain of any model is 80 ma. An electrochemical cell, which produces an electrical output in proportion to the partial pressure of oxygen to which it is exposed, is used as an oxygen detector. The output of the cell is applied to an electronic circuit that detects two different levels of oxygen percentage below that of normal air and produces distinct audible signals at these levels. The hazard alarm mode is activated when the oxygen percentage first drops below normal and produces a 500-cps beep tone with an intermittency of 1 cps. The danger mode produces a continuous 500-cps audible signal when the oxygen percentage drops still lower.

RI 7166. Purification and Concentration of a Cyclic Manganese Leach Solution by Elevated Pressure-Temperature Methods, by F. E. Brantley, E. K. Landis, and W. R. Cureton. August 1968. 11 pp. 3 figs. Optimum autoclaving conditions were determined for separation of iron and manganese values from pregnant leach liquor produced in extracting manganese from low-grade umber ore. The umber was leached with a synthetic anolyte, similar to a recycle solution used in manganese electrolysis cell operations, that had been renewed with ferrous sulfate and sulfuric acid. The equipment used and the results obtained are presented for the several conditions employed. The kinetics of the separation were studied. Rate equations were derived for the formation of solid ammonium-manganese sulfate, $(NH_4)_2Mn_2(SO_4)_3$. Work done in cooperation with the University of Alabama.

RI 7167. Heats of Formation of Four Anhydrous Sodium Borates, by L. H. Adami and C. J. Joe. August 1968. 9 pp. Heats of formation were obtained for four anhydrous crystalline sodium borates by hydrochloric acid solution calorimetry. The heats of formation at 298.15° K from the elements are $NaBO_2$, —233.2 ± 0.6 kcal/mole; $Na_2B_4O_7$, —786.4 ± 1.0 kcal/mole; NaB_3O_5, −549.9 ± 0.8 kcal/mole; and $Na_2B_8O_{13}$, −1,412.5 ± 2.0 kcal/mole. The heats of formation from the constituent oxides are $NaBO_2$, −31.5 ± 0.8 kcal/mole; $Na_2B_4O_7$, −78.8 ± 1.3 kcal/mole; NaB_3O_5, −44.1 ± 0.8 kcal/mole; and $Na_2B_8O_{13}$, −96.7 ± 1.5 kcal/mole.

RI 7168. Investigation of Operating Variables in the Attrition Grinding Process, by Martin H. Stanczyk and I. L. Feld. August 1968. 28 pp. 4 figs. Bench-scale, laboratory batch attrition grinding tests were made of a coarse commercial kaolin in a stainless steel, 5-inch-diameter attrition grinding machine to study the effect of a number of basic operating variables on particle size reduction and electric energy consumption. The results of the investigation showed that the more important operating variables influencing the efficiency of kaolin comminution and energy consumption requirements were type, size, and shape of grinding media, grinding media to clay weight ratio, peripheral rotor speed, clay slip pulp density, degree of pulp dispersion, and the angular arrangement of the rotor and stator bars. The tests also indicated that variables having less influence on grinding efficiency and energy consumption were pulp temperature, design of rotor cage, rotor clearance, rotor-stator bar interval, addition agents, pulp level, degree of pulp aeration, and chamber liners. The research showed that grinding media had the greatest influence on abrasion of machine parts and that spherical-shaped grinding media were superior to sharp angular or long bladed media with respect to media degradation, machine abrasion as well as grinding efficiency. Work done in cooperation with the University of Alabama.

RI 7169. Corrosion Properties of the TZM and Molybdenum-30 Tungsten Alloys, by W. L. Acherman, J. P. Carter, and David Schlain. August 1968. 23 pp. 4 figs. The Bureau of Mines found the chemical and galvanic corrosion behavior of the TZM and molybdenum-30 tungsten alloys to be generally equal or superior to that of unalloyed molybdenum in many aqueous solutions of acids, bases, and salts. Notable exceptions occurred in 1 *N* nitric acid, where both alloys corroded appreciably faster than molybdenum. In mercuric chloride solutions, the TZM alloy was susceptible to a type of crevice corrosion which was not due to differential aeration. The alloys were usually not adversely affected by contact with dissimilar metals in galvanic couple experiments, but the dissimilar metals sometimes corroded galvanically. Both alloys were resistant to substitute ocean water spray at 60° C.

RI 7170. Ultrafine Grinding of Anthracite, by W. S. Sanner. August 1968. 17 pp. 7 figs. Grinding experiments were conducted to determine the finest anthracite particles that could be produced in a ball mill. Continuous and batch tests were run in a dry-grinding ball mill. Batch grinding produced the finest coal particles. They averaged 2.2 microns in diameter and were 99.0 percent smaller than 37 microns. Continuous grinding yielded a product 6.1 microns in diameter, with 96 percent smaller than 37 microns.

RI 7171. Effect of End Conditions on Determining Compressive Strength on Rock Samples, by John R. Hoskins and Frank G. Horino. August 1968. 22 pp. 10 figs. The Bureau of Mines conducted an investigation to more exactly define the influence of some end conditions on the laboratory-determined uniaxial compressive strength of rock samples. Limestone, marble, sandstone, and granite were used to provide a range of specimen modulus of elasticity from 2.7×10^6 psi to 10×10^6 psi. Four variables were studied: Nonparallelism and surface texture of specimen ends were the specimen variables investigated; the end platen size and the adjustable or spherical head friction were the machine variables studied. It was concluded that the loading ends of small laboratory models and samples should be prepared with surface irregularities that do not vary from a plane surface by more than 0.001 inch. It was also concluded that nonparallelism of the specimen ends should not exceed 8 minutes for a rigid head load or 15 minutes for an adjusting head load. The measured compressive strength of specimens prepared with these tolerances will be statistically the same with any diameter or thickness of platen and any degree of head friction if initial alinement of the specimen is assured.

RI 7172. Characteristics of Green River Formation Oil Shales at Bureau of Mines Wyoming Corehole No. 1, by John Ward Smith, Laurence G. Trudell, and Kenneth E. Stanfield. September 1968. 92 pp. 6 figs. The Bureau of Mines drilled Wyoming Corehole No. 1 in Sweetwater County, Wyo., to sample Green River Formation oil shale. Core obtained was assayed for oil yield to determine richness and stratigraphic distribution of oil shale in the deposit. Oil shale in place at Wyoming No. 1 site represents over 200 million barrels of oil per square mile. Additional data useful in evaluating the deposit, including generalized stratigraphy and mineralogy, detailed lithologic descriptions of the core, rock specific gravity, and bore-hole logs, are presented with the oil-yield data. The sampled Wyoming oil shale resembles Mahogany-zone oil shale in rock properties and gross mineralogy. A statistically derived equation relating shale density to oil yield for the Wyoming deposit compares with a similar relationship valid for the better known Mahogany-zone oil shales in Colorado and Utah. A density log from Wyoming Corehole No. 1 is calibrated for direct oil-yield logging. The alternating rich and lean beds of shale at this site may permit creating the permeability necessary for direct production of shale oil from the shale in place. Work done in cooperation with the University of Wyoming.

RI 7173. A Petrofabric Study of Tectonic and Mining-Induced Deformations in a Deep Mine, by Elbridge W. Gresseth and Rolland R. Reid. September 1968. 64 pp. 35 figs. Rock deformational structures in a deep mine were analyzed by petrofabric techniques to learn (1) the relative magnitude and direction of the principal stresses involved in tectonic deformations prior to mining, (2) the preferred orientation of rock planar discontinuities which define rock anisotropy prior to mining, and (3) the relationship of mining-induced rock failure to inherent rock stresses and inherent rock anisotropy. Rock fabric elements used for petrofabric analysis consisted of bedding planes, faults, joints, fractures, foliation, sericite plane (001), quartz axis [0001], quartz deformation lamellae, and microfractures. Structures and structural symmetries from different areas within the mine and from different scales of observation were compared to learn the nature of rock anisotropy and the orientation of the principal stresses defined by rock deformations.

Analysis of such fabric as regional and macroscopic faults, b-c joints, quartz [0001], sericite (001), and microfractures indicates that during the epochs of tectonic deformation, the maximum and minimum principal stresses were horizontally oriented and acted along northwest and northeast axes, respectively. This condition of regional stress appears to have continued during folding and the associated period of faulting. The most recent tectonic deformation represents a rotation of the minimum principal stresses into a vertical position, as shown by the development of a tensile joint system, quartz deformation lamellae, and microfractures. Good interscale correlation and statistical homogeneity of tectonic fabric indicate a stress field homogeneity in this area during tectonic deformation. Rock physical anisotropy is genetically associated with tectonic fabric and consists of preferentially oriented planar discontinuities intersecting along a nearly vertical axis.

The mining-induced deformations were correlated with the inherent rock anisotropy which either directly controls or greatly affects their development. This phase of rock deformation shows a greater degree of stress field heterogeneity than was the case with tectonic deformations. This is explained as a result of nonconfinement afforded by underground openings and the increase in ground stresses due to mining activity.

RI 7174. Preparation Characteristics of Coal From Clarion County, Pa., by J. E. Zeilinger and A. W. Deurbrouck. September 1968. 34 pp. 3 figs. This Bureau of Mines report describes the preparation characteristics of the significant coalbeds of Clarion County, Pa. Of the 15 samples collected, one was of metallurgical quality as received, four could be sufficiently upgraded to provide acceptable products, and the remaining 10 samples could not be upgraded to metallurgical quality because their sulfur contents could not be lowered to meet the standard. For steam or power generation, one sample was of low sulfur content as received, one sample could be upgraded to low sulfur content, and 10 samples could be upgraded to medium sulfur content. The original sulfur content of the remaining three samples can be appreciably reduced by removal of the sink 1.58 specific gravity material; however, these coals would be classified as medium sulfur coals both before and after removal of the sink material.

RI 7175. Amino Acids as Retaining Agents for Separation of Rare-Earth Elements on Ion-Exchange Resin, by J. O. Winget and R. E. Lindstrom. September 1968. 8 pp. 3 figs. Amino acids were investigated in conjunction with rare-earth separation by ion exchange to determine whether they can be utilized effectively as retaining agents for metals separation using ethylenediaminetetraacetic acid (EDTA) eluant at 85° to 90° C. Hydroxyethylethylenediaminetriacetic acid (HEDTA) and diethylenetriamine pentaacetic acid (DTPA) were the most effective amino acids investigated. Elements of atomic numbers 39 and 57 through 68 were effectively retained, whereas elements of atomic numbers 69 through 71 passed through the retaining-agent band. Utilization of HEDTA or DTPA retaining agents allows an increase of 75 percent in the EDTA eluant concentration over that possible wtih hydrogen- or copper-retaining ions without precipitation occurring. Eighty-five percent recovery of the EDTA eluant collected before rare-earth breakthrough and during elution of lutetium, ytterbium, and thulium, and essentially complete recovery of the HEDTA or DTPA retaining agents, are possible without extensive processing.

RI 7176. Changes in Ash Composition of North Dakota Lignite Treated by Ion Exchange, by Leland E. Paulson and Walter W. Fowkes. September 1968. 18 pp. 15 figs. This investigation examined the feasibility of altering the inorganic component of North Dakota lignite by ion exchange. Lignite of specific size consist was washed with various ionic solutions and examined for evidence of exchange. Ions of higher valance substituted preferentially at equivalent concentrations. Results indicate that a major portion of the inorganic material associated with lignite is combined in exchangeable form with the organic component. Particle size of the treated coal is a critical factor in determining the rate of exchange. The data indicate that monovalent ions are easily replaced by divalent and trivalent ions, and the presence of ionic material in slurries containing finely divided lignite significantly increases filtration rates.

RI 7177. A Multistage Probability Model of Sample Reduction in the Mineral Industries, by Robert M. Becker. December 1968. 121 pp. 2 figs. A multistage probability model for assessing the reliability of mineral samples following any number of stages of sample reduction is presented. Sample reduction is the process of alternately crushing or grinding and sampling mineral particles prior to assaying. The final multistage model developed accurately describes the ideal sample reduction practice. This model is based on previously developed and experimentally tested models for a single stage of sampling.

The problem is approached through the probability distributions for the various stages of sampling. The probability distribution, moments, and moment relationships for a single stage of sampling are first reviewed, and the useful concept of unit moments is defined. In presenting the models for two stages of sampling, emphasis is placed on the physical description of the sample reduction process which leads quite naturally to its mathematical representation. In this representation, crushing or particle-size reduction between the stages of sampling is viewed as a random process with respect to the number and proportion of particles of the various kinds produced. The physical and mathematical description is extended to more than two stages of sample reduction, and the first three moments for any number of stages are developed.

In common sample reduction practice the effects of a finite population (finite amount of material) at each stage of sampling appear to be important in describing the variance contribution of each stage. This is also true for the third moment about the mean. An example is cited in which the skewness increases by more than an order of magnitude when several stages of sampling are considered. This is largely due to the dependence of the multistage third moment about the mean on the variance. In general the model and results should be useful in helping to understand, control, and reduce the random errors that arise in the sample reduction process.

RI 7178. Chlorine Dissolution of Several Ferroalloys, by D. H. Chambers, P. M. Sullivan, and L. L. Kupper. September 1968. 14 pp. 1 fig. Digestion studies were undertaken to develop a method for the rapid dissolution of high-temperature ferroalloy scrap. Laboratory tests showed (1) dissolution of alloy scrap with ferric ion as the leaching agent was a moderately rapid method of digestion; (2) the dissolution process can be considered as a typical reaction of a metal with chlorine gas, although evidence was obtained to show dissolution as a two-step process, one step as the reduction of ferric ion by the soluble alloy constituents and the other as the oxidation of ferrous ion with chlorine gas; and (3) the attack of ferric ion on the alloy was a function of alloy composition, ferric to ferrous ion ratio, and area of contact between leach solution and alloy.

The exceedingly complex nature of alloy compositions and dissolution products generally precluded satisfactory analytical determinations. Results of moderate accuracy were obtained using complex modifications of standard analytical and spectrographic techniques.

RI 7179. A Comparison of Infrared and Gas Chromatographic Methods for Determination of Methane in Mine Air, by R. W. Freedman and H. W. Lang. September 1968. 4 pp. The gas chromatographic method, devised by the Bureau of Mines for analyzing routine mine air samples, was compared with the infrared method used for confirmatory determination of methane in mine air. While maintaining the specificity of the infrared method for methane determination, the gas chromatographic method is more precise, much more rapidly performed, and more convenient.

RI 7180. Gas Chromatographic Analyses of the Principal Constituents of Mine Atmospheres, by R. W. Freedman, H. W. Lang, and M. Jacobson. September 1968. 13 pp. 1 fig. The Bureau of Mines has developed a gas chromatographic method for the rapid and accurate determination of oxygen, nitrogen, carbon dioxide, methane, and, if present, carbon monoxide in mine air. This method replaces such presently used gas-reaction types as the Haldane or Orsat analysis, offering advantages in terms of precision, accuracy, speed, and convenience.

RI 7181. Magnetic Separation of Pyrite From Coals, by Sabri Ergun and Ernest H. Bean. September 1968. 25 pp. 2 figs. Previous studies of magnetic separation of pyrite from coals have been reviewed critically. Magnetic susceptibilities of United States coals of differing rank have been measured. The effects of crushing, magnetic mixing, drying, weathering, and heat treatment on the enhancement of the magnetism of pyrite have been analyzed. The importance of size distribution of pyrite in the coal and the necessity of crushing to liberate the pyrite have been discussed.

It has been found that the inherent susceptibilities of the carbonaceous, mineral-free portions of coals ($\simeq -0.5 \times 10^{-6}$ in cgs units) and of relatively pure pyrite isolated from coals ($\simeq -0.3 \times 10^{-6}$) do not permit efficient separation of pyrite from coal; the average susceptibility of the magnetic fraction of coal must be raised to 3×10^{-6}. Friction forces encountered in crushing sedimentary pyrite embedded in coal do not increase its susceptibility. Subsequent weathering or heat treatment below 400° C leads to the formation of iron sulfate and hence increases the effective paramagnetism of pyrite. Ferromagnetic compounds of iron are not formed in significant quantities at temperatures below 400° C. The degree of liberation and apparent susceptibility of pyrite are the most important parameters in its separation. It is concluded that effective beneficiation of coals can be achieved by magnetic separation.

A sufficient increase in the susceptibility can be achieved by converting less than 0.1 percent of pyrite into ferromagnetic compounds of iron. Such conversions occur only at temperatures >500° C. An investigation of the dielectric properties of coals and pyrite in the frequency range 0.1 to 60 Mhz indicates that the imaginary dielectric constant of the pyrite is about 100 times larger than that of coal. Exploratory experiments indicate that pyrite can be selectively heated to temperatures above 500° C without appreciable rise in the temperature of coal. It appears that dielectric heating of coals in the Ghz frequency range is the most feasible method of enhancing the paramagnetism of pyrite.

RI 7182. Copper Cementation Using Automobile Scrap in a Rotating Drum, by Karl C. Dean, Rees D. Groves, and Sherman L. May. September 1968. 12 pp. 1 fig. The Bureau of Mines studied the precipitation of copper from dilute acidic sulfate solutions using shredded automobile scrap in a rotary drum. The tests established that the scrap in the rotary drum precipitated copper faster and more completely than shredded, detinned, tinplate scrap in a launder, with comparable iron consumption. Although power is required to rotate the drum, the faster precipitation and continuous recovery of cement copper are advantages of the tumbler method. Cost evaluation indicates that the rotary drum method, which uses relatively inexpensive and readily available shredded automobile scrap, is competitive with the launder method, which uses relatively high-cost shredded tinplate scrap or detinned shredded cans.

RI 7183. Processing Characteristics of Crude Oils From the Williston Basin in Montana, North Dakota, and South Dakota, by W. J. Wenger and J. C. Morris. 1968. 95 pp. 4 figs. Results of the analyses of 151 crude oils from 123 oilfields in the Williston basin are presented. Production statistics are compiled by geographical areas within the basin, by geological age of the producing zones, by States, and by field for the nine fields with the greatest production. Characteristics of the oils are tabulated, and correlations are included to show relationships between properties of the oils and some factors in the environment. Properties of the oils in some instances imply that there has been migration and mixing of the oils between productive formations of different geological time periods.

RI 7184. Colorimetric Method for Arsenic in Coal, by R. F. Abernethy and F. H. Gibson. October 1968. 10 pp. 1 fig. A chemical method of determining microgram quantities of arsenic in coal was investigated by the Bureau of Mines to supplement a semiquantitative spectrographic method of determining arsenic in coal ash. In accordance with a method recommended by the International Organization for Standardization, 1-gram samples of coal are decomposed by wet oxidation with boiling sulfuric acid (H_2SO_4) and nitric acid (HNO_3) to remove the organic matter. After heating to fumes of SO_3 to remove HNO_3, the arsenic is separated as arsine by the action of zinc in H_2SO_4 solution. The arsine is absorbed in dilute iodine solution in which the arsenic is determined colorimetrically by the molybdenum-blue reaction. Two modifications of the method for obtaining the arsenic in solution, in addition to the wet oxidation method, give satisfactory results. The modifications are (1) furnace ashing with MgO added to the coal, followed by treatment with H_2SO_4, and (2) extraction of arsenic from the coal by dilute HNO_3 without ashing. Float and sink tests show that arsenic is associated mainly with mineral matter in the three coals examined. High-temperature ashing tests show that very little arsenic is volatilized from coal ash below 1,000° C, but it is virtually all removed from the ash at 1,300° C.

RI 7185. Recovery of Sulfur From Molybdenite, by F. P. Haver, K. Uchida, and M. M. Wong. October 1968. 15 pp. 4 figs. The Bureau of Mines developed a process to extract about 90 percent of the sulfur from molybdenite flotation concentrate by compacting the concentrate with one-quarter of its weight of aluminum powder, heating it at 800° C for 30 minutes, and then allowing the product to react with water. This thermite reduction yields an impure molybdenum alloy plus aluminum sulfide. The latter readily hydrolizes, to yield pure hydrogen sulfide which can be converted to elemental sulfur by the Claus process. At least 95 percent of the molybdenum can be subsequently recovered as 99.95-percent-pure molybdic oxide.

RI 7186. Field Freezing of a Cerium-Iron Alloy, by J. E. Murphy, E. Morrice, and T. A. Henrie. October 1968. 14 pp. 8 figs. Field freezings was used by the Bureau of Mines to effect the redistribution of the components in a cerium-12.5-atomic-percent-iron alloy. The application of the electric field caused the iron to migrate toward the anode. A field intensity of 0.04 v/cm and a current density of 240 amp/cm^2 were used. The conditions that yielded the greatest redistribution of alloy components were a small thermal gradient along the specimen (from 5° C/cm to 10° C/cm) and a very slow freezing rate (0.15 cm/hr). Under these conditions it was possible to process specimens of ½-inch diameter as compared with the capillary-size specimens used by most previous investigators.

RI 7187. The Reactivity of Ammonium Nitrate-Fuel Oil With Pyrite-Bearing Ores, by D. R. Forshey, T. C. Ruhe, and C. M. Mason. October 1968. 10 pp. The recent occurrences of fatal accidents in copper mines, presumably due to premature ignition of loaded holes by the heat from reacting ammonium nitrate-fuel oil (AN-FO) and pyrite-bearing ores, has led to an examination of this reaction. The reactivity of prilled AN-FO mixtures with pyrite-bearing ores and the effects of water, dilute sulfuric acid, and potential inhibitors on reactivity of the mixtures were evaluated. Initiation of an exothermic reaction was observed as low as 150° F with acid in the absence of inhibitors. Low concentrations of urea, calcium carbonate, zinc oxide, and magnesium oxide were effective in inhibiting the reactivity of the mixtures. The temperatures produced during the reaction of mixtures of AN-FO and pyrite-bearing ores, in the absence of inhibitors, always exceeded the temperature at which electric blasting caps are thermally initiated.

RI 7188. Flotation Characteristics of Some Beryllium Minerals and Associated Gangue Minerals, by Andrew J. Fergus, Gerald V. Sullivan, and Garry F. Workentine. October 1968. 22 pp. 8 figs. The purpose of this study was to provide basic information to aid further research on beryllium mineral flotation. Contact-angle and microflotation (Hallimond tube) methods were used to study collector action and flotation response of beryllium minerals and associated gangue minerals with representative commercial surfactants. Chrysoberyl received prime attention. Results indicated that selective flotation of beryl and chrysoberyl from fluorite and quartz is possible with sodium isooctyl phosphate below pH 2, and fluorite and topaz are readily collected by both anionic and cationic surfactants. Several modifying reagents were studied at 1 pH and one level of collector concentration. Aluminum sulfate, starch, and sodium silicate proved to be depressants in chrysoberyl flotation.

RI 7189. Microflotation Studies of Some Columbium-Tantalum Minerals, by Andrew J. Fergus and Gerald V. Sullivan. October 1968. 29 pp. 13 figs. A study of the flotation characteristics of columbium-tantalum minerals was made by contact-angle and microflotation methods, and the findings were confirmed by flotation of two natural ores. In the contact-angle study conditions for collection of columbite, pyrochlore, and tantalite were determined for (1) sodium oleate with a sulfonate; (2) sodium isooctyl phosphate; (3) a short-chain primary amine; (4) a long-chain primary amine; and (5) a quaternary amine. These conditions were confirmed in microflotation tests. Information about collector action on common gangue minerals was also obtained by these two methods.

In batch flotation tests on a pyrochlore ore and a columbite ore, it was demonstrated that collectors selected on the basis of contact-angle and microflotation studies would float columbium minerals from a complex natural ore. However, multiple cleaner and scavenger flotation steps will be necessary to produce commercial concentrates. From a pyrochlore ore containing 0.54 percent Cb_2O_5, a 44.4 percent Cb_2O_5 concentrate was made containing 36.4 percent of the total Cb_2O_5. For a columbite ore the corresponding values were 4.35, 54.6, and 67.1 percent. During the batch flotation study, wetting agents were found to aid in the gangue-ore mineral separations.

RI 7190. Thermodynamic Properties of Helium, Nitrogen, and Helium-Nitrogen Mixtures From 240° to 950° R for Pressures Between 14.696 and 3,000 PSIA, by Robert E. Wood. October 1968. 361 pp. 15 figs. The Leiden form of the virial equation of state was used in thermodynamic equations to compute specific volume, enthalpy, entropy, internal energy, Joule-Thomson effect, fugacity-pressure ratio, isobaric specific heat, and excess enthalpy and entropy of mixing values for the helium-nitrogen system. Tabular values for these properties for helium, nitrogen, and nine helium-nitrogen mixtures, at 10.00 percent helium increments, are presented for 46 temperatures in the range 240° to 950° R, and for 26 pressures in the range 14.696 to 3,000 psia.

The equation of state relates pressure, volume, temperature, and gas composition by virial and interaction virial coefficients through fifth virial coefficients. It is suitable for computing the variations in the isothermal thermodynamic properties of all possible helium-nitrogen mixtures within the temperature and pressure domain of the equation of state given herein. Accurate analytical expressions are given for the zero pressure of ideal-gas properties so that variations in the thermodynamic properties along isobars or isometrics are tractable.

The computed thermodynamic properties are compared with experimental Cp and J-T data and properties derived from other equations of state. The agreement between the derived thermodynamic properties and experimental data is, in general, within the inherent accuracy with which properties have been obtained by direct experimental measurements. For example, gas phase Cp values derived from the equation of state are within 1 to 2 percent of like quantities obtained from flow calorimetry. However, the difference in computed and experimental values may rise to 10 percent as critical conditions are approached.

RI 7191. Mine Water Research, The Limestone Neutralization Process, by E. A. Mihok, Maurice Deul, C. E. Chamberlain, and J. G. Selmeczi. September 1968. 20 pp. 14 figs. A pilot plant for treating mine drainage by neutralization with limestone was designed, fabricated, and operated by the Bureau of Mines. The process consists of (1) producing a very fine (minus 400-mesh) limestone slurry, (2) mixing the slurry with the mine water, (3) aerating the resulting mixture to remove carbon dioxide and precipitate iron, and (4) separating the solids from the liquid by sedimentation.

A mine discharge of pH 2.8, containing 1,700 ppm total acidity, 36 ppm ferrous iron, and 360 ppm total iron was treated at rates from 300 to 400 gpm. The treated water ultimately reached a pH of 7.4 and contained no detectable iron. The resulting sludge compacted to approximately one-third the volume of sludge from mine water neutralized with lime.

The advantages of the limestone process, compared with the conventional lime process are as follows: Widespread distribution and lower cost of run-of-mine, indigenous limestone; simplicity of plant design; reduced hazards and plant operating and maintenance costs accruing from the use of a less reactive chemical agent; higher solids concentration of the precipitated sludge; and no deleterious effect caused by accidental overtreatment.

RI 7192. Low-Temperature Performance of Compressed Oxygen Closed-Circuit Breathing Apparatus, by E. J. Kloos, A. J. Beckert, and R. H. Schutz. October 1968. 12 pp. 6 figs. Two self-contained breathing apparatus of the closed-circuit compressed-oxygen type were evaluated for performance at 32° to −25° F. Low-temperature effects of oxygen and carbon dioxide concentration, visual properties of the facepiece, and mechanical operation of the apparatus were studied. Although operation varied with the wearer, his breathing rate, the apparatus precooling time, and the temperature, results suggest that general use of currently approved compressed-oxygen closed-circuit breathing apparatus be limited to temperatures above 32° F.

RI 7193. Determination of Incombustible Content of Mine Dust by Nuclear Method, by Joseph W. Martin and Robert F. Stewart. October 1968. 12 pp. 7 figs. The Bureau of Mines investigated the backscattering of low-energy gamma rays as a method for rapidly determining the incombustible content of coal mine dust. In this method, 60-kev gamma rays from americium-241 penetrate the dust and are reflected by elements in the dust to a thin crystal scintillation detector. The number of backscattered gamma rays is proportional to the incombustible content. Tests of 40 dry, mine-dust samples containing 50 to 100 percent inert material show an average error of 2 percent. Calibration of the apparatus is necessary for each rock dust to account for variable composition. Results for samples containing more than 6 percent moisture are subject to error, but the values are lower than values obtained by chemical analysis and thus fall on the safe side. Development of a small meter based on the backscatter principle appears feasible. Such a meter would find application within coal mines to check the effectiveness of rock dusting procedures.

RI 7194. Preparation of Anhydrous Chromous Chloride, by Robert L. de Beauchamp and Thomas A. Sullivan. October 1968. 7 pp. 3 figs. The Bureau of Mines designed a chlorination apparatus to prepare $CrCl_2$ free of $CrCl_3$ by the direct reaction of chlorine and chromium. Equipment and procedures were developed for routine preparation of 25-pound batch quantities of anhydrous $CrCl_2$. Calcium, iron, nickel, and silicon impurities were in the 0.01 to 0.05 percent range, and all other impurities were below 0.01 percent.

RI 7195. Development of Slurry Explosives for Use in Potentially Flammable Gas Atmosphere, by R. W. Van Dolah, C. M. Mason, and D. R. Forshey. October 1968. 9 pp. 2 figs. The feasibility of formulating cap-sensitive slurry explosives for use in underground mines with potentially flammable gas atmospheres was examined. Formulations containing aluminum metal as sensitizer and sodium chloride to reduce incendivity were prepared; some were cap-sensitive and had adequate air gap. Flaked aluminum metal rather than the atomized type proved to be the more effective sensitizing agent. Of the formulations tested for incendivity in the large gallery of the Bureau of Mines, some were found to be suitably nonincendive.

RI 7196. Large-Scale Studies of Gas Detonations, by D. S. Burgess, J. N. Murphy, N. E. Hanna, and R. W. Van Dolah. November 1968. 53 pp. 27 figs. The characteristics of gas-phase detonations were observed in 20 instrumented firings within earthen tunnels, in 100 such detonations in a 24-in-diam by 163-ft-long steel pipe, and in about 200 smaller scale firings. Most of the fuels studied were representative hydrocarbons—acetylene, propane, gasoline, and a roughly equimolar mixture of methylacetylene, propadiene, and propane.

In a pipe with two closed ends, the detonable limits were demonstrated to be very nearly the same as reported limits of flammability. The side-on impulses (pressures integrated over 200-msec intervals) were shown to be the same function of concentration regardless of whether deflagration or detonation had occurred.

In a pipe with only the initiation end closed, the impulses of all fuel-air systems tended toward the same level when averaged over comparable ranges of fuel concentration; the lower pressures with saturated hydrocarbons were nearly compensated by longer durations of pressure transient. In all fuel-air systems, unexpectedly high impulses were obtained with slightly lean mixtures.

In earthen confining structures, the impulse of the explosion was efficiently converted into momentum of the failing wall. In the configurations studied, an earth velocity of about 20 fps was critical to overcome the soil's resistance to shear. The destructive effect was determined by gas pressure rather than by total energy release.

The assignment of a "TNT equivalent" to an explosive gas mixture is discussed in terms of the confinement of the mixture.

RI 7197. Storage Stability of Gasoline: Oven Test for Prediction of Gasoline Storage Stability, by Frank G. Schwartz, Charles S. Allbright, and Cecil C. Ward. December 1968. 28 pp. 13 figs. The Bureau of Mines developed a rapid test method for predicting the stability of motor gasoline during long-term storage. The amounts of gum and inorganic residue formed in 13 gasolines during a 16-hour oven test at 200° F were compared with the amounts formed in the same gasolines stored at 110° F and analyzed following 8-, 16-, 32-, 44-, and 52-week storage periods. Satisfactoriy methods were developed for predicting gum and inorganic residue formation during fuel storage periods as long as 32 weeks at 110° F, the approximate equivalent of 5.7 years at 80° F. The only data required to apply the methods are the amount of gum and inorganic residue formed, and the amount of oxygen that reacted, during a 16-hour oven test. A direct relationship existed between inorganic residue formed during the oven test and during 110° F storage. Statistical treatment of the data showed predicted values were as reliable as determined values.

By use of a modified Arrhenius equation, the 110° F storage time can be extrapolated to equivalent time at any temperature below 110° F. Thus by combining the stability prediction method with the mathematical extrapolation, the storage performance of motor gasoline for extended periods can be estimated at any temperature up to 110° F.

RI 7198. Earth Pressure at Rest and One-Dimensional Compression in Mine Hydraulic Backfills, by David E. Nicholson and Richard A. Busch. October 1968. 40 pp. 27 figs. The Bureau of Mines has constructed a special compression chamber for developing stress-strain relationships of mine backfill and simulating the high compressive ground pressures encountered in underground mines. A one-dimensional or earth-pressure-at-rest model is proposed for backfills subjected to these pressures. Results of the compression tests performed in the chamber indicate that reliable stress-strain relationships can be developed from these tests.

The primary objective of the test series was to evaluate the effectiveness of compaction of common backfills in retarding ground closure. Analysis of the stress-strain data shows an eightfold reduction in relative strain in optimum well-graded, compacted backfills over poorly graded, loose backfill material.

Analysis of the one-dimensional compression test data also indicates a significant retardation of transmitted stress in dense compacted samples of backfill and natural sands. Although not fully understood, a deformation mechanism is thought to occur at the intergranular contacts in cyclic fashion causing frictional heat loss and a reduction in transmitted stresses in the densely packed materials. The experimental values of transmitted stress are compared with theoretical values of effective stress calculated from the one-dimensional compression relationships developed by Hendron. These experimental values of transmitted stress compare very closely with the theoretical values of effective stress.

RI 7199. Laboratory Studies on the Use of Sodium Sulfate for Removing Copper From Molten Iron, by H. V. Makar, B. W. Dunning, Jr., and H. S. Caldwell, Jr. November 1968. 14 pp. 2 figs. Laboratory tests were performed to obtain a quantitative description of the effectiveness of sodium sulfate (Na_2SO_4) for removing copper from molten iron and to determine the effectiveness of Na_2SO_4 on actual auto scrap. The tests were conducted on induction melted heats of iron averaging 0.58 and 1.50 perment initial copper and on cupola-melted auto scrap containing 0.45 percent initial copper. The Na_2SO_4 was added in powder form in amounts ranging from 2.9 to 43.8 percent of the weight of iron being treated.

The data showed that copper removal for the various Na_2SO_4 treatments followed a similar trend, regardless of the iron composition that was tested. The equation $Y = 1 - e^{-3.23x}$ approximately reflects the relationship between copper removal and amount of Na_2SO_4 added, where Y is the fraction of copper removed and x is the ratio of the weight of Na_2SO_4 added to the weight of metal treated. Copper removals ranged from 3.3 to 74.5 percent and reductions down to less than 0.10 percent final copper were achieved in the auto scrap. Copper removals were generally accompanied by sulfur removal, and intial sulfur contents ranging from 0.10 to 0.20 percent were reduced to as low as 0.02 percent. High temperatures and long slag reaction times tended to induce copper and sulfur reversion from the slag, but, generally, the Na_2SO_4 treatments were effective up to approximately 2,820° F with reaction times not exceeding 7 minutes.

RI 7200. Stresses and Displacements Induced in Rock by Tunnel Boring Machine Props, by Wilbur I. Duvall and Wilson Blake. November 1968. 29 pp. 5 figs. The Bureau of Mines presents a theoretical solution for the stresses and displacements in an infinite elastic plate containing a circular hole whose boundary is subjected to applied shear loads over four separated arcs. The results for the applied shear loads can be superimposed on the results for applied radial loads, given in a previous publication, to obtain a complete two-dimensional approximation of the stresses and displacements induced in the rock by tunnel boring machines anchored in a circular tunnel by means of four props. Analysis of the various solutions shows that the tangential tensile stresses induced on the boundary of the circular tunnel by applied radial loads can be minimized in the roof and floor of the tunnel by the application of appropriate shear loads to each of the four props. Thus, when planning tunnel boring operations, consideration should be given to the in situ stress field in the rock and the induced stresses in the rock resulting from the applied radial and shear loads produced by the props of the boring machine.

RI 7201. High-Temperature Heat Contents and Entropies of Four Crystalline Sodium-Calcium Silicates, by L. B. Pankratz. November 1968. 8 pp. 1 fig. Heat contents were measured for Na_2CaSiO_4 and $Na_2Ca_2Si_2O_7$ between 298° and 1,300° K, for $Na_2Ca_2Si_3O_9$ between 298° and 1,500° K, and for $Na_4CaSi_3O_9$ between 298° and 1,350° K. Copper-block drop calorimetry was employed. Reversible, first-order transitions were found for Na_2CaSiO_4 and $Na_2Ca_2Si_3O_9$. The transition for Na_2CaSiO_4 is at 830° K with a heat absorption of 160 cal/mole; that for $Na_2Ca_2Si_3O_9$ occurs at 750° K with a heat absorption of 1,550 cal/mole. Results for the other two silicates showed no irregularities. A table of heat content and entropy increments above 298.15° K and heat content equations are included for use in thermydynamic calculations.

RI 7202. Comparison of Trip Lights and Reflectors, by R. H. Oitto, D. W. Mitchell, R. A. Hood, and J. H. Stears. November 1968. 17 pp. 3 figs. To determine whether reflectors could substitute for the trip lights referred to in the Federal Mine Safety Code, the Bureau of Mines studied trip safety devices under simulated haulageway conditions. The noticeability of reflectors compared with trip lights and fluorescent panels was evaluated from distances of up to 850 feet with light source intensities of up to 1.6 foot-candles. Reflectors tested consisted of a reflective lens in a holder secured to a frame that can be attached to a trip.

Reflectors were found to be suitable for use as a trip safety device. In fact, for the conditions in many underground haulageways some reflectors would be more effective than a permissible trip light.

RI 7203. Coal-Derived Humus: Plant Growth Effects, by Philip G. Freeman and Walter W. Fowkes. November 1968. 16 pp. 8 figs. The growth-promoting properties of coal-derived humus were tested by a variety of bioassay methods. Humate materials used included leonardite, a form of naturally oxidized lignite, and humic acids extracted from leonardite. It was found that the greatest effects were evident when water-soluble humic acid was applied to excised root tips. No significant short-term effect was noted when water-soluble humic acid was applied to stem or coleoptile sections. Root initiation was promoted in bean stems when high concentrations of coal-derived humate were applied. Gross weight of tomato plants was increased by up to 40 percent when coal-derived humates were added in concentrations of 10^1 to 10^4 ppm to the nutrient in a hydroponic growth test of 6 weeks' duration. It is concluded that coal-derived humate promotes the uptake of minerals, specifically iron, by serving as a metal chelate.

RI 7204. Composition and Characteristics of Municipal Incinerator Residues, by C. B. Kenahan, P. M. Sullivan, J. A. Ruppert, and E. F. Spano. December 1968. 20 pp. 8 figs. The Bureau of Mines is developing methods for reclaiming the metal and mineral values contained in municipal incinerator residues. This report describes the first phase of the research, in which reliable methods for sampling and analyzing municipal residues were established and the composition and characteristics of the residues were determined. Samples were obtained from a variety of grate-type furnaces and also from a rotary kiln furnace. The samples were processed on a batch basis and separated into their natural categories by a variety of methods including screening, magnetic separation, air separation techniques, and handpicking. The main components of the residues were determined to be metal and metal oxides, glass, and ash.

RI 7205. Evaluation of Phosphate Fines From Southeastern Idaho, by J. W. Town and P. E. Sanker. December 1968. 9 pp. 5 figs. The Bureau of Mines determined the physical properties of southeastern Idaho phosphate fines as related to mineral composition, particle size, and liberation, beneficiation, and potential use in structural clay products. The phosphate mineral in the fines was identified by unit-cell dimensions to be essentially the same as the phosphate mineral fluorapatite identified in the coarser sizes. The mean particle frequency as determined by electron microscopy and pipet analyses was between 0.5 and 0.2 micron. Liberation of the phosphate could not be definitely determined because of the weathered condition of the minerals and their extreme finenesss. No beneficiation scheme was developed that would concentrate the phosphate into a marketable fertilizer product; therefore, forming and firing tests were made to demonstrate that the fines can be used to manufacture structural clay products.

RI 7206. Field Investigation and Testing of a Minnesota Clay Resource for Iron Ore Pellet Bonding, by James H. Aase and George E. Leonard. December 1968. 17 pp. 8 figs. Selected glacial lake clay deposits in Minnesota were sampled, tested, and evaluated to determine their suitability for use as a bonding agent in iron ore pellet manufacturing. Preliminary tests conducted on clay samples obtained from five ancient glacial lake basins identified the clays in the Lake Agassiz glacial lake basin near Cook, Minn., as having the greatest bonding potential. An auger drilling program was conducted to obtain substantial quantities of representative material for detailed testing. The drilling indicated the presence of large clay reserves in excess of 500 million tons within the 12-square-mile area investigated.

Bench-scale tests indicated that the bonding properties of Cook area clays, when activated with relatively small quantities of sodium carbonate monohydrate ($Na_2Co_3 \cdot H_2O$), imparted excellent strength characteristics to iron ore pellets. Larger scale continuous pelletizing tests were made to confirm the bench-scale results. These tests indicated that use of 1 percent activated clay alone as binder gave the iron ore pellets an overall strength slightly lower than with 0.75 percent bentonite, considered the industry standard. Use of 0.5 percent activated clay plus 0.5 percent bentonite produced better pellet strength qualities than use of 0.75 percent bentonite alone, without increasing the silica plus alumina content.

The data from both bench-scale and larger scale continuous tests suggest that the Cook, Minn., clays can be utilized after activation either alone or in combination with bentonite at an economic advantage over present pelleting practice with bentonite.

RI 7207. Effect of Physical Parameters on the Reaction of Graphite With Silica in Vacuum, by L. A. Haas and S. E. Khalafalla. December 1968. 21 pp. 12 figs. The degree of reduction of various silica-graphite mixtures was studied in a batch reactor to determine optimum physical conditions for maximizing the carbothermic reduction of silica. The extent of interaction was determined for reactant mixtures in loose powder and briquet forms at pressures less than 0.01 torr and temperatures up to 1,445° C. Molar ratios were varied from 0.05 to 6.5 with maximum reaction at a ratio of about 1.5. The solid-solid reaction did not appear to involve gaseous intermediates. The extent of reaction better correlated with the number of interparticle contacts than with the true surface area of the reactants. Carbonized dextrose was a better reductant than graphite. Work done under an agreement with the National Aeronautics and Space Administration.

RI 7208. Explosibility of Miscellaneous Dusts, by John Nagy, Austin R. Cooper, and Henry G. Dorsett, Jr. December 1968. 31 pp. 1 fig. Dust explosion data obtained in laboratory tests by the Bureau of Mines are presented for 181 miscellaneous materials that present an explosion hazard. Data are given also for 50 dusts that present primarily a fire hazard and for 88 dusts that did not present an explosion hazard.

RI 7209. Reaction of Coal With Steam at High Pressures, by Sam Friedman, Paul S. Lewis, Richard D. Graves, and Raymond W. Hiteshue. December 1968. 25 pp. 10 figs. The Bureau of Mines conducted experiments using bench-scale apparatus to explore the effect of large changes in process variables on the yield and composition of the gases produced by passing 800° C steam through a fixed bed of Pittsburgh seam (hvab) coal. The total yield of combustible gases increased throughout the given range for the following variables: Superficial steam velocity increasing from 0.02 to 0.12 fps, pressure increasing from 1,000 to 6,000 psig, residence time increasing from 0 to 60 minutes, and temperature increasing from 800° to 900° C; however, a greater increase in the yield of hydrogen in comparison with the increase in yield of methane reduced the gross heating value of the gas to around 470 Btu per scf at conditions giving the maximum yield.

Pressures of 1,000, 3,000, and 6,000 psig at 0.09 fps steam velocity, 800° C, and 60 minutes residence time, respectively, produced methane yields of 20, 24, and 22 percent, based on maf coal, with the gross heating value of the CO_2-free gas decreasing from 552 to 520 and to 470 Btu per scf. Methane concentrations in the CO_2-free gas were 26, 22, and 14 percent, respectively. Based on the gross heating value of the coal, the percentage of the heating value recovered in the gas was 60, 71, and 87 percent, respectively.

The use of tungsten sulfide as a catalyst for converting carbon oxides, and hydrogen into methane was explored briefly using both a sulfur-free gas rich in methane and a sulfur-bearing synthesis gas ($3H_2$:1CO).

RI 7210. Removal of Nonferrous Metals From Synthetic Automobile Scrap on Heating in a Rotary Kiln, by Gerald W. Elger, Willard L. Hunter, and C. E. Armantrout. December 1968. 17 pp. 7 figs. To determine the feasibility of removing nonferrous metal impurities from automobile scrap by thermal treatment in a rotary kiln, the Bureau of Mines conducted four series of tests with synthetic scrap mixtures heated at various temperatures under oxidizing and reducing conditions. The treated scrap mixtures were melted in an electric-arc furnace and cast into small ingots for impurity evaluation. Analyses showed that the ingots were essentially free of residual metal impurities except for copper. Test data indicated that in an oxidizing atmosphere the percentage of copper removed increased with treatment temperature. Percent of copper removed in a reducing atmosphere was found not to be temperature dependent. A significant finding was that copper was embrittled under some of the operating conditions and was mechanically removed by fragmentation.

RI 7211. Columbium and Tantalum Alloy Development, by Herbert R. Babitzke, Laurence L. Oden, and Hal J. Kelly. December 1968. 12 pp. 2 figs. As part of a project to develop refractory metal alloys suitable for high-temperature structural applications, the Bureau of Mines applied solid solution and precipitation-hardening techniques to columbium and tantalum alloys. Thirty-three alloys were evaluated to determine their formability, strength, and oxidation resistance.

Three alloys had tensile strengths near 40,000 psi at 1,200° C: Cb-1N-5W-5V-10Hf, Cb-15Hf-5W-0.5B, and Cb-15Hf-5W-1B. Oxidation resistance of the high-strength alloys was good. The first alloy gained only 34 mg/cm² at 1,200° C, and 21 mg/cm² at 1,000° C in 2 hours. Hot forming was done without any protection from oxidation.

RI 7212. Electrowinning Aluminum From Aluminum Chloride, Operation of a Two-Compartment Cell, by E. L. Singleton, D. E. Kirby, and T. A. Sullivan. December 1968. 15 pp. 8 figs. The electrochemical reduction of aluminum chloride to aluminum was investigated in a closed, two-compartment cell utilizing a molten chloride electrolyte. The externally heated cell was divided into a reduction compartment and a combination $AlCl_3$ feed and metal removal compartment. Aluminum was deposited at 700° C on a molten aluminum cathode from a KCl-NaCl-$AlCl_3$ electrolyte. The $AlCl_3$ content of the electrolyte was replenished by either vapor or solid additions. The chlorine evolved was collected and measured to give a quantitative evaluation of $AlCl_3$ reduction. The effects of anode and cathode current densities and $AlCl_3$ concentration on anode current efficiencies were studied. A range of 64 to 84 percent anode current efficiency was obtained with the 25-pound electrolyte capacity cell and related auxiliary equipment.

RI 7213. Recovery of Hydrofluoric Acid From Waste Fluosilicic Acid, Preliminary Studies, by Philip C. Good and Jack E. Tress. December 1968. 14 pp. 4 figs. Preliminary studies showed that direct hydrolysis of H_2SiF_6 to SiO_2 and HF at elevated temperatures was subject to many mechanical difficulties and that corrosion of construction materials was a serious problem. Elimination of SiO_2 from the HF product was generally poor. An alternative procedure, hydrolysis of lime-neutralized H_2SiF_6 by steam at 950° to 1,100° C, yielded a product very low in SiO_2. Condensates containing up to 300 g/l HF were prepared.

RI 7214. Use of Fly Ash for Remote Filling of Underground Cavities and Passageways, by Edwin M. Murphy, Malcolm O. Magnuson, Pete Suder, Jr., and John Nagy. December 1968. 27 pp. 15 figs. Methods are described for filling underground cavities remotely with dry material pneumatically injected through a borehole to seal openings, prevent air movement, and reduce subsidence; this often brings underground fires under control by limiting the access of air. Large-scale tests were made in the Bureau of Mines Experimental Coal Mine, Bruceton, Pa., in an operating mine, and in an abandoned Pennsylvania mine. Supplemental trials were made aboveground in galleries and in the laboratory. The parameters studied include horizontal and inclined passageways, obstructions in the entry, water leakage into the borehole, dry material, and grout and slurry mixes. The materials studied were fly ash, crushed and pulverized limestone, and sand. Best results were obtained with dry fly ash, though satisfactory seals were obtained with the other materials. When a borehole is dry and ends at an open void, casing is not necessary. If more than 5 gpm of water flows in the borehole, if the void contains loose debris, or if coarse material is injected, a material feedpipe should be inserted through the borehole. Fly ash was most suitable for remote filling because of its low angle of repose (8°) and its good flow characteristics. The depth of borehole through which the fly ash is injected has no appreciable effect on the filling operation.

RI 7215. Horizontal Zinc Retorts, by M. E. Tyrell and K. J. Liles, with appendix on statistical sampling plan for zinc retort research by F. Reid Creech. January 1969. 41 figs. 88 pp. Research objectives were to determine the reasons for erratic behavior of semisilica horizontal zinc retorts in service; to investigate potential corrective measures including the possible utilization of more refractory materials in the retort body; and to delineate laboratory tests suitable for process control in the manufacture of retorts.

Correlation of laboratory test results and data supplied by the cooperating smelters indicated that structural failures due to thermal shock and laminations in the retort body are largely responsible for the erratic behavior of horizontal zinc retorts in service.

The most promising modifications made in the retort body and evaluated on a laboratory scale included finer grinding of the plastic clay fraction, substitution of mullite grog for calcined fire clay and grain alumina for silica, plus the use of an organic binder. Lamination-free extrusions having excellent thermal shock resistance were prepared from a mixture composed of 50 percent low-silica Missouri plastic clay through 100 mesh, 25 percent mullite grog through 6 mesh, and 25 percent alumina through 100 mesh. The mix was pugged under 28-inch vacuum with 1 percent ligno sulfonate binder in 12 percent tempering water.

Laboratory tests suitable for process control in the manufacture of retorts are described.

RI 7216. Preparation Characteristics of Coal From Clay, Gilmer, and Lewis Counties, W. Va., by J. E. Zeilinger. January 1969. 40 pp. 3 figs. This Bureau of Mines report describes the preparation characteristics of the significant coalbeds of Clay, Gilmer, and Lewis Counties, W. Va. In 1966, almost

1.3 million tons of coal was mined in these counties, of which more than one-half was from the Pittsburgh coalbed. Washability analyses were made of 16 coalbed samples. Of these, only 11 samples could be upgraded to metallurgical quality. For steam or power generation five of the coals were of low sulfur content as received. The remaining samples were generally of medium sulfur content even after upgrading.

RI 7217. Heats of Formation of Chromium Carbides, by Alla D. Mah. January 1969. 9 pp. The heats of combustion of three chromium carbides, $Cr_{23}C_6$, Cr_7C_3, and Cr_3C_2, were determined by combustion calorimetry. Heats of formation calculated from the results follow:

$$\Delta Hf^{\circ}_{298}\,(Cr_{23}C_6) = -94.7 \pm 5.0 \text{ kcal/mole},$$
$$\Delta Hf^{\circ}_{298}\,(Cr_7C_3) = -43.3 \pm 1.7 \text{ kcal/mole},$$
$$\Delta Hf^{\circ}_{298}\,(Cr_3C_2) = -22.5 \pm 0.8 \text{ kcal/mole}.$$

RI 7218. Copper Removal From Steel Scrap by Thermal Treatment. Feasibility Study, by R. R. Brown and F. E. Block. December 1968. 15 pp. 2 figs. The Bureau of Mines undertook a limited feasibility study to determine the practicality of removing copper from automobile scrap by thermal treatment. Test specimens, prepared by wrapping bare and insulated copper wire around small steel coupons, were heated at 600° to 1,150° C in various atmospheres for different lengths of time under both static and dynamic conditions. The tests indicated that adequate removal of copper cannot be effected by thermal treatment of scrap above the melting point of copper. Tests showed that copper present in scrap as insulated wire is embrittled by thermal treatment at 800° to 900° C if the insulation contains lead and that the embrittled copper is almost completely removed by a mechanical action such as tumbling. Also chemical pretreatment of specimens to effect embrittlement of copper and the magnetic separation of oxide scale were studied. Tests showed that bare copper can be embrittled by depositing waterglass ($Na_2\,Si_4O_9$) on copper prior to thermal treatment.

RI 7219. Analyses of Tipple and Delivered Samples of Coal Collected During Fiscal Year 1968, by S. J. Aresco and J. B. Janus. 1969. 31 pp. The Bureau of Mines has been active in promoting the purchase of coal for Government use under specifications that define the requirements in terms of heating value of the coal, expressed in British thermal units, and the composition as shown by proximate analyses. To these, when required, are added the ash-softening temperature, the free-swelling index, and the Hardgrove grindability index. Under most of these specification contracts the bidders guarantee the quality of the coal, and that guaranteed by the successful bidder becomes the standard of his contract. The deliveries are sampled in accordance with instructions issued by the Bureau of Mines; the samples are analyzed in the Bureau laboratory to determine whether the coal is of the quality guaranteed by the contractor; if it is not, a price adjustment is made.

Analyses of the delivered coal and tipple samples (samples collected at mine tipples as coal is being loaded into railroad cars or trucks) provide valuable data for use in evaluating future bids. In addition, the continuous sampling of coal as delivered is a check on the practical results obtained in burning the coal.

The Government, with the exception of the Tennessee Valley Authority, purchased approximately 6.1 million tons of coal in fiscal year 1968. In connection with these purchases, the Bureau analyzed 6,077 samples. These have been tabulated by States for the use of Government officials and the public. 40 cents.

RI 7220. Load Loss From Rock-Bolt Anchor Creep, by Edward W. Parsons and Lars Osen. January 1969. 26 pp. 15 figs. To determine in what part and to what extent creep or movement exists in an installed rock-bolt anchor and the effect of the creep or bleedoff on the tension load on a rock bolt, as well as the effect of normal mining activity on the rock-bolt load and anchor, the Bureau of Mines conducted tests in the laboratory and in two mines using four types of expansion-shell anchors, the wedge bolt, and in one mine, explosive-anchored rock bolts.

Specially mounted heavy-duty springs, calibrated to obtain load readings from spring movement, were installed on the test bolts to prevent a drastic reduction in tension load caused by slipping or seating of the anchor. A dial gage, reading to 0.0001 inch, measured movement of the anchor shell against the rock and seating of the anchor wedge plug in the shell. While all bolts had electrical resistance strain gages for load reading, only readings from the laboratory tests were used because those from the field tests were erratic.

The tests revealed that most load loss resulting from static loading is due to the slippage and seating of the serrations on the anchor shell into the drill-hole wall. Dynamic loading, primarily from sudden shocks from nearby blasting, and possibly from ground movement or mining activity, will cause the anchor wedge plug to seat in the anchor shell.

RI 7221. Beneficiation of Titanium Chlorination Residues. Preliminary Study, by C. C. Merrill, M. M. Wong, and D. D. Blue. February 1969. 7 pp. 1 fig. The Bureau of Mines beneficiated the wastes generated by commercial titanium chlorination operations to reclaim metal values and reduce the problem of disposing of solid wastes. A water leach solubilized about 40 percent of the dry weight and over 75 percent of the metallic impurities. The residue from the water leach was rich in titanium dioxide and carbon; it was combined with rutile and recycled to a laboratory chlorinator. The contained carbon was used in lieu of part of the coke requirement.

RI 7222. Some Strain-Aging Effects in Electrorefined Vanadium, by G. H. Keith and H. G. Iverson. February 1969. 26 pp. 15 figs. Oxygen and nitrogen cause strain aging in electrorefined vanadium, as evidenced by maxima in yield and tensile strengths and by Snoek internal friction peaks. Alloys containing up to 0.22 percent oxygen and 0.11 percent nitrogen were investigated. Tensile strengths of oxygen- and nitrogen-containing alloys were 66,000 and 68,000 psi at 300° to 400° C, compared with 53,000 and 62,000 psi, respectively, at room temperature. Total elongation decreases to about 7 percent at the temperature of maximum strength. At 600° C strain aging is not evident.

Based on interstitial contents calculated from internal friction measurement, the increases in strength caused by nitrogen and oxygen were 440,000 psi per weight-percent nitrogen and 260,000 psi per weight-percent oxygen. Application of the Schoeck and Seeger treatment to the Snoek effect in these systems results in a calculated lattice distortion of 0.24 and 0.15 caused by the presence of an interstitial nitrogen or oxygen atom, respectively.

Alloys containing boron or carbon were also investigated. Both elements refine the grain size but have no other effect because of their low solubility in vanadium.

RI 7223. Face Ventilation in Underground Bituminous Coal Mines. Airflow and Methane Distribution Patterns in Immediate Face Area-Line Brattice, by James V. Luxner. February 1969. 16 pp. 10 figs. The airflow and methane distribution patterns developed in an equipment-free entry 6.5 feet high and 12 feet wide, ventilated by line brattice operated blowing to or exhausting from the face, were determined by the Bureau of Mines for varying conditions. Results of these studies show that blowing line brattice systems of face ventilation are more effective than comparable exhaust systems. The face ventilating efficiency of any line brattice system is dependent upon the method of ventilation, the face distance, the tight rib distance, the volume of air delivered to the end of the line brattice, and the volume of methane released at the face. Experimental results indicate that maximum face ventilation efficiency is achieved when the inby terminus of the line brattice is installed 5 feet from the face and at a distance less than one-third of the entry width from the nearest rib. Analyses of data are based upon the ability of a face ventilation system to dilute methane in the immediate face area.

RI 7224. Near-Surface Horizontal Stresses Including the Effects of Rock Anisotropy, by Verne E. Hooker and Charles F. Johnson. February 1969. 29 pp. 4 figs. In situ stresses, based on isotropic and anisotropic relations, were evaluated using computer techniques from overcoring data obtained in dimension stone quarries along the Appalachian Piedmont, the Ozark uplift, and the Ouachita tectonic belt. Stresses in the horizontal plane near the surface are compressive and range from 100 to 4,500 psi. The direction of maximum compressive stress seems to be alined with the general tectonic structure for most of the determinations. The ratio of the maximum to minimum elastic parameters in the horizontal plane ranges from 1.05 to 2.46 for these competent rocks. Isotropic versus anisotropic stress determinations show differences only as great as 25 percent in stress magnitude and 25° in orientation.

RI 7225. Joining Refractory Metal Compounds by Hot Pressing, by John E. Kelley, Donald H. Sumner, and Hal J. Kelly. February 1969. 26 pp. 11 figs. The Bureau of Mines conducted a study to determine the feasibility of joining refractory metal compounds to each other and to oxide ceramics by a vacuum hot press-diffusion bonding method. Very satisfactory joins were made of ZrC to ZrB_2, ZrN to ZrB_2, ZrC to ZrN, and ZrC, ZrN, and ZrB_2 to Al_2O_3. Each of these join assemblies contained a mixture layer comprising 50 weight-percent each of the two end compounds. The mixture layer, sandwiched between each end compound, enhanced bonding and smoothed out the thermal expansion gradient between the two end members.

Strength and thermal shock tests showed that the join areas of the ZrC, ZrN, and ZrB_2 joins were stronger and more shock resistant than the parent materials. Also included in the joining tests was one each of TiC to TiB_2, TiC to TiN, TiB_2 to TiN, and TiC to ZrB_2 joins. Each of these was well bonded, showing that the vacuum-hot-press method can be used for a variety of systems.

RI 7226. Beneficiation of Ferrochromium by Molten Salt Electrolysis, by F. R. Cattoir and T. A. Sullivan. February 1969. 26 pp. 9 figs. This Bureau of Mines study investigated molten salt electrorefining for beneficiating low-grade, high-carbon ferrochromium products which can be readily produced from domestic chromite concentrates. A second objective was to refine commercial ferrochromium into low-iron chromium products. Electrorefining of both types of ferrochromium in molten $CaCl_2$-NaCl-$CrCl_2$, $CaCl_2$-$MgCl_2$-$CrCl_2$, or KCl-LiCl-$CrCl_2$ electrolytes produced chromium-iron products with virtual elimination of other impurity elements and some lowering of the iron content. Over 90 percent of the chromium present in the feed materials was recovered. The electrodeposited products were upgraded further by magnetic separation techniques into chromium containing less than 5 percent iron. The technical feasibility of preparing a premium chromium product from a low-grade, high-carbon ferrochromium made from domestic chromite was demonstrated. Chromium virtually free of carbon, oxygen, and silicon from high-carbon ferrochromiums was produced. In addition, the amenability of three commercial grades of ferrochromium to electrorefining and magnetic separation for preparing chromium metal containing less than 5 percent iron was determined.

RI 7227. Improved Eluex Process for Eluting Uranium From Ion Exchange Resins, by D'Arcy R. George and J. Richard Ross. February 1969. 10 pp. 6 figs. The Bureau of Mines has developed, on a laboratory scale, a superior Eluex-type circuit for eluting and recovering uranium from ion exchange resins. The improved circuit differs from conventional Eluex practice in that a stage of uranium solvent extraction is coupled with each stage of resin elution rather than the elution and solvent extraction operations being conducted separately. The new system reduces the number of stages, retention time, and resin inventory in the elution circuit to one-fourth or one-fifth that in existing circuits. The system is applicable to both resin-in-pulp and moving-bed-type ion exchange uranium recovery circuits.

RI 7228. Dispersion-Strengthened Copper. Its Preparation and Properties, by D. H. Desy. March 1969. 24 pp. 15 figs. The Bureau of Mines studied the properties of copper that had been oxide dispersion strengthened with 2 volume-percent of either yttria or alumina. Compounds of copper and aluminum or yttrium, coprecipitated from aqueous solution, were converted to oxides; the copper was reduced, compacted, sintered, and extruded. For the resulting copper-dispersoid composites, room temperature tensile properties after annealing in hydrogen, elevated temperature tensile and stress-rupture properties, and electrical conductivity were determined. Compared with oxygen-free copper, copper-2 volume-percent alumina or yttria had improved strength after annealing between 400° and 1,000° C, and improved elevated temperature strength, with little loss in electrical conductivity.

RI 7229. Effect of Varied Extrusion Temperature on the Properties of a Zinc-Copper-Titanium Alloy, by L. A. Neumeier and J. S. Risbeck. February 1969. 22 pp. 16 figs. The Bureau of Mines evaluated the properties of a Zn-0.75 percent Cu-0.12 percent Ti alloy extruded at temperatures between 400° and 720° F. The extrusions were made with a reduction ratio of 28 to 1 and at relatively slow speed. Rod was also extruded at 560° and 640° F with a reduction of 255 to 1. With increased extrusion temperature, extrusion pressures decreased substantially and creep resistance of the rod improved significantly. Coefficients of thermal expansion were low in the long rod dimension. Microstructures, hardness, and tensile properties were also evaluated, and a limited evaluation was made of bend ductility at 32° F for the rod extruded with the 255-to-1 reduction.

RI 7230. Improving Returns From Mine Products Through Use of Operations Research Techniques, by Thys B. Johnson. March 1969. 78 pp. 9 figs. Operations research techniques for determining optimal shipping schedules and production and product allocation are discussed. A hypothetical mining operation model is formulated by the Bureau of Mines, and optimal production and product allocation are determined. The technique of sensitivity analysis is discussed and is used to illustrate the effect of the variability in a mining operation on the optimal production and product market plan.

RI 7231. Pyrite Size Distribution and Coal-Pyrite Particle Association in Steam Coals: Correlation With Pyrite Removal by Float-Sink Methods, by J. T. McCartney, H. J. O'Donnell, and Sabri Ergun. February 1969. 18 pp. 5 figs. In an effort to correlate the size of pyrite particles in coal and coal-particle association with the removal of pyrite before burning, the Bureau of Mines conducted a study of 61 coals presently being used for electric power production. The results were obtained by visual microscopic studies of polished briquets of minus 14-mesh samples. Mean pyrite particle sizes ranged from 20 to 400 microns and proportions of pyrite contained in coal particles to an extent greater than 50 percent by volume (estimated) ranged from 20 to 95 percent. These parameters were correlated with reductions in pyrite accomplished by float-sink tests at 1.60 specific gravity on 14-mesh, ⅜-inch, and 1½-inch samples. The correlation coefficients between pyrite removal and mean pyrite particle size were 0.89, 0.84, and 0.79, respectively, for these samples. Correlation coefficients between pyrite removal and coal-pyrite association parameter were 0.92, 0.90, and 0.85, respectively. It is apparent that extent of pyrite removal can be fairly well predicted from microscopic analysis.

RI 7232. Liquidus Temperatures of Titaniferous Slags (in Three Parts). 3. Production of Nominal Slag Compositions, by Wesley T. Holmes II and William A. Stickney. February 1969. 21 pp. 3 figs. In this final stage of a three-part investigation of the smelting of titania-bearing iron materials, the Bureau of Mines conducted semicontinuous smelting tests in a laboratory electric arc furnace on four concentrates and one ore. The objective was to substantiate the significance of liquidus temperature measurements in predicting satisfactory slag compositions in electric furnace smelting of titaniferous magnetites to produce pig iron. Previously obtained liquidus temperature data were used in determining flux requirements. Self-fluxing pellets of either ore or concentrate plus fluxes and reductants were made to produce pig iron and slags containing 0.2 to 0.6 percent titanium. Individual constituents of the slags generally agreed within 5 percent with the value of the corresponding constituent of target composition. Liquidus temperature of furnace slags generally agreed within 50° C of the value obtained from corresponding nominal synthetic slag.

The results of the three phases of the investigation may serve as guidelines for determining flux requirements in smelting a wide variety of titaniferous magnetites and other titania and iron-bearing materials.

RI 7233. Compressibility Factors for Helium and Carbon Dioxide Mixtures at 0°, 10°, 20°, 23°, and 35° C and to 900 PSIA, by G. W. Weems and N. L. Miller. March 1969. 41 pp. 8 figs. The Bureau of Mines used the Burnett method and apparatus to determine the compressibility factors for helium and carbon dioxide mixtures at 0°, 10°, 20°, 23°, and 35° C and to pressures of 900 psia. Tables of compressibility factors and approximations of the virtual coefficients are presented for seven binary mixtures as well as for helium and carbon dioxide. The results compare favorably with existing data.

RI 7234. Influence of Spherical Head Size and Specimen Diameters on the Uniaxial Compressive Strength of Rocks, by John R. Hoskins and Frank G. Horino. January 1969. 16 pp. 8 figs. Uniaxial compressive strength of rock is usually determined in the laboratory from cylindrical samples that vary in diameter from ⅝ to 8 inches, using a spherically seated compression head of unspecified size. The Bureau of Mines conducted a series of tests on limestone, marble, sandstone, granite, and plaster of paris to determine the influence of the spherical head sizes and the specimen diameters themselves on the uniaxial compressive strength. Cylindrical samples of several different diameters of each rock type, all having a length of twice their diameter, were prepared and broken using at least three different diameter spherical heads.

Analysis of the data shows that spherical head size does not significantly affect the uniaxial compressive strength of cylindrical rock samples. However, the diameter of the rock specimens does significantly affect the uniaxial compressive strength. Within the range of specimen diameters tested, a coefficient of variation of 6.4 percent for plaster of paris can be attributed to the selection of specimen diameter alone. Similarly, a maximum coefficient of variation of 4.7 percent for the rock types tested can be attributed to the specimen diameter alone.

RI 7235. Use of Antifissurants in Making Better Coke From Sunnyside Coal From Utah, by M. J. Kovalik, D. E. Wolfson, F. Fischler, and L. Mafrica. February 1969. 15 pp. 3 figs. Lower Sunnyside seam coal from Utah was blended with various proportions of char and high-temperature coke to improve the quality of the coke obtained from carbonizing this coal. The Hanson 5-pound carbonizer was used as a "screening test" for the larger scale Bureau of Mines-American Gas Association (BM-AGA) tests, which were correlated with industrial production. Eighteen carbonization tests were made in the BM-AGA 13-inch retort, with a coal charge of about 90 pounds; the cokes were evaluated by the standard ASTM tumbler test. Carbonization of blends containing char and coke breeze yielded less fissured and blockier cokes of significantly higher ASTM 1-inch tumbler indices as compared with the value for the straight Sunnyside coal. It was found that the simultaneous addition of char and coke breeze yielded stronger cokes than that obtained by the addition of either one of these additives. Addition of a small proportion of Pocahontas No. 3 or Sewell coal to an optimum blend improved the resulting coke strength further.

RI 7236. Carbonizing Properties of Coals From Nicholas, Randolph, and Webster Counties, W. Va., by D. E. Wolfson and C. Ortuglio. March 1969. 17 pp. 1 fig. This report presents 900° C BM-AGA carbonization and related data for coals from the principal beds of Nicholas, Randolph, and Webster Counties, W. Va. Thirty-three samples from nine coal beds in three counties were carbonized at 900° C in the 18-inch-diameter BM-AGA retort, data from which have been correlated with industrial production. Most of the samples were chemically suitable for metallurgical use, and their coking properties were satisfactory. Except for four of the Lower Kittanning samples, the ranges of constituents in the coal seams were 1.8 to 9.0 percent ash and 0.4 to 1.1 percent sulfur, values within the range of acceptability for metallurgical coals. Coke strength indexes were normal for Appalachian coals of similar rank, and the tumbler stability indexes of the coke ranged from 35 to 57.

RI 7237. Application of Statistical Response Surface Fitting in Predicting Lignite Properties, by Manuel Gomez and William L. Meyer. March 1969. 64 pp. 13 figs. The Bureau of Mines used data from 31 core samples to develop prediction equations for evaluating chemical and carbonization properties of six seam units in a lignite deposit approximately 2 miles wide and 8 miles long in the Wilcox Formation of central Texas. Statistical response surfaces, based on core analyses, were computed for 14 parameters indicative of lignite quality. These computed surfaces, and their mathematical equations, can be used to predict values of the selected properties of the lignite seams at any desired surface coordinate position between core hole locations. The wide range of application shown by this study indicates that the methods of statistical regression analysis may be used to evaluate large deposits of lignite or higher rank coal. Work done in cooperation with the Texas Power and Light Co.

RI 7238. Rotary Coring of Appalachian Area Oil-Producing Formations With Mud or Air, by R. L. Rough. March 1969. 32 pp. 12 figs. The Bureau of Mines analyzed rotary-coring-operations data to compare mud and air as coring mediums, and to compare core recoveries, penetration rates, and cost data for the respective mediums as part of an investigation of the susceptibility to secondary-recovery techniques of petroleum reservoirs in Ohio, Pennsylvania, and West Virginia. This report describes the rotary-diamond coring equipment and operations employed while coring 20 wells—10 cored using mud and 10 cored using air. Data relevant to the draw works, rotary-table power, drill pipe, drill collars, core barrel, core head, mud pumps, or air compressors are tabulated. Average bit weight and rotary speed, core recovery, and penetration rates are listed for each formation cored. In general, core recoveries were better from the mud-cored wells, whereas penetration rates were faster for the air-cored wells. Coring costs were about the same for single-formation wells cored with either mud or air; however, costs increased considerably when multiple-formation wells were cored with air.

RI 7239. Pulverized-Coal Flames. Flame Propagation in the Absence of Recirculation, by C. R. McCann and A. A. Orning. March 1969. 22 pp. 12 figs. The Bureau of Mines conducted an experimental study of conditions needed to produce flames of pulverized coal when the heat needed for ignition is supplied only from the flame and hot furnace refractory. An electrically heated furnace which burned about 1 pound of coal per hour was designed and fabricated. A sheath of air, surrounding the primary coal and air stream, was used to prevent entry of hot gases from recirculating combustion products. Furnace temperatures needed for ignition ranged from about 1,830° F for an Illinois coal to 2,250° F for a Beckley seam coal. Apparent flame velocities were about 2 to 5 feet per second, increasing with volatile content of the coal and with distance from the burner mouth to the flame. The time required for ignition, approximately 0.02 to 0.07 sec, was a better measure of flame behavior than was velocity.

RI 7240. Major Ash Constituents in U.S. Coals, by R. F. Abernethy, M. J. Peterson, and F. H. Gibson. 1969. 9 pp. Analytical results, including ash fusibility data, are presented by the Bureau of Mines for 10 major constituents in coal ash from 373 samples of commercial U.S. coals. Determinations of SiO_2, Al_2O_3, Fe_2O_3, and P_2O_5 were made by colorimetric methods, Na_2O and K_2O by flame photometry, TiO_2, CaO, and MgO by a spectrochemical method, and SO_3 by a gravimetric method. In bituminous coal ashes the silicon, aluminum, and iron calculated as oxides often make up about 90 percent of the ash. 25 cents.

RI 7241. Continuous Monitoring of Diesel Exhaust Gas for Carbon Dioxide, Carbon Monoxide, Oxygen, Methane, and Nitrogen Oxides, by Helen W. Lang, W. E. O'Neill, B. A. Coulehan, and R. W. Freedman. March 1969. 14 pp. 3 figs. This report describes a monitoring system applied by the Bureau of Mines to provide rapid, continuous determination of the main constituents of exhaust gas during the Bureau's approval schedule testing of diesel engines for underground use. Commercially available continuous analyzers with strip chart readout are employed for nitric oxide (mass spectrometric), carbon dioxide (nondispersive infrared), methane (NDIR), carbon monoxide (NDIR) and oxygen (polarographic). Good correlation is obtained between the continuous instrumental results and those obtained by batch chemical and gas chromatographic methods.

RI 7242. Reduction Roasting of Steep Rock Iron-Bearing Materials, by Charles Prasky and Willard S. Swanson. March 1969. 21 pp. 7 figs. The Bureau of Mines investigated the conversion of nonmagnetic iron minerals to magnetic form through reduction roasting operations. The primary objective was to obtain a concentrate that could be used as a direct shipping material for blast furnace consumption. Crude iron materials from the Steep Rock Lakes, Ontario, area were prepared into a blend of 8 parts siliceous ore, 3 parts pyritic ore, and 1 part tailings. Experimental work included laboratory reduction roasting tests, two continuous 10-day campaigns, and one 12-hour test, all in a 34-inch by 36-foot rotary kiln. The objective of the project was achieved in producing an iron concentrate containing about 66 percent iron with over 90 percent iron recovery. Desirable operating conditions were developed in the kiln, but optimum process variables were not completely established. Work done in cooperation with the Dravo Corp.

RI 7243. Transformations of the Elastic Constants for Anisotropic Media by Successive Simple Rotations, by Thomas R. Bur. March 1969. 15 pp. 1 fig. This method of performing general transformations by use of Eulerian angles greatly reduces the time required for the determination of values for the elastic compliance constants (s_{ij}), elastic stiffness constants (c_{ij}), Young's modulus, shear modulus, or Poisson's ratio for any orientation of the cartesian coordinate system in an anisotropic material.

RI 7244. Raw Materials for Lightweight Aggregate in Appalachian Region, Alabama and Georgia, by Ronald P. Hollenbeck and M. E. Tyrrell. March 1969. 21 pp. 5 figs. Samples of clays, shales, and slates from 29 locations in the Appalachian region of Alabama and Georgia were tested and evaluated to determine their suitability as raw material for the manufacture of lightweight aggregate by the rotary-kiln method. Samples from 11 locations in Alabama (one each in Etowah, Lawrence, and Morgan Counties and two each in Colbert, Cullman, Tuscaloosa, and Walker Counties) and one location in Walker County, Ga., produced satisfactory lightweight aggregate.

RI 7245. Separation of Feldspar, Quartz, and Mica From Granite, by T. E. Hill, Jr., H. Kenworthy, R. A. Ritchey, and J. A. Gerard. March 1969. 25 pp. 2 figs. The Bureau of Mines investigated the possibility of physically separating Missouri and Minnesota granites into commercially usable fractions of feldspar, quartz, and mica by mineral dressing techniques. The probability of recovering a feldspar fraction from raw granite suitable for commercial uses was developed through correlation of the iron oxide content by extensive petrographic studies. This probability evaluation also included Wisconsin granites and a high-feldspar iron ore concentration tailing from Missouri. Laboratory recoveries of feldspar and quartz were on the order of 80 percent. Mineral content of each fraction was generally over 95 percent, indicating excellent response to separatory techniques. Acid leaching of feldspar and quartz concentrates to remove iron oxide improved the grades chemically; however, occluded iron oxide particles in the leached products prevented attaining top grades of feldspar. Mica was removed as scrap grade at low recoveries. Each concentrate conformed to some category of commercial feldspar, quartz, or mica.

RI 7246. Phase Diagram for the $KF\text{-}YF_3$ System, by Bernard Porter, R. E. Meaker, and P. R. Bremner. March 1969. 8 pp. 2 figs. Differential thermal analysis measurements were used to characterize a phase diagram for the $KF\text{-}YF_3$ system at compositions between 0 and 60 mole-percent YF_3. A congruent melting point compound was observed at $3KF \cdot YF_3$, which melts at 965° ± 5° C and undergoes solid-state decomposition at 725° ± 2° C. One peritectic and two eutectic compositions are also defined.

RI 7247. Preparation of Tungsten Carbide by Electrodeposition, by John M. Gomes and M. M. Wong. April 1969. 13 pp. 2 figs. The preparation of tungsten carbide by molten-salt electrolysis was investigated. Sodium tungstate in the electrolyte and carbon from the graphite anode were the source materials. Optimum results were obtained with an electrolyte consisting of 83 mole-percent sodium chloride and 5.7 mole-percent each of sodium tungstate, sodium metaborate, and sodium hydroxide; a temperature of 1,000° to 1,025° C; an anode current density of 37 amp/dm^2 or less; and an initial cathode current density of 150 amp/dm^2. The yield was approximately 0.45 g/amp hr. The electrolytic tungsten carbide product contained approximately 5.4 weight-percent combined carbon as compared to 6.1 weight-percent for pure tungsten carbide. Microhardness of the electrolytic tungsten carbide, determined with a 50-gram load, varied from 3,480 to 3,970 dph. The material was friable and could be ground in a laboratory ball mill to less than 400-mesh particle size.

RI 7248. Theoretical Relationship Between Density and Oil Yield for Oil Shales, by John Ward Smith. April 1969. 14 pp. 2 figs. The Bureau of Mines derived equations expressing the theoretical relationship between density of oil-shale rock and its organic content. Effects on theoretical shale density produced by variations in mineral composition and organic matter properties were evaluated. The theoretical relationship was extended to relate oil-shale density to oil yield in both oil weight and volume units by considering the fraction of organic matter converted to oil and the specific gravity of the oil produced. Corollary equations relating organic content by volume to organic content by weight and to oil yield were developed. The general relationships apply to an oil-shale deposit uniform in character. Application of the theoretical relationships to Green River Formation oil shales was demonstrated. Work done in cooperation with the University of Wyoming.

RI 7249. Five-Piece Concrete Sets for Small Mine Openings: A Progress Report, by K. R. Dorman. April 1969. 45 pp. 26 figs. To further investigate the potential of precast concrete sets as a support medium for underground mines, the Bureau of Mines designed a five-piece precast concrete drift set for a small opening and tested it to destruction in a straining frame. Twenty-seven tests were made with three sizes of members using three loading conditions. In addition, six tests were made with sets in a distorted configuration. Test results and typical failure patterns are presented. A comparison of results with those previously reported for the three-piece set shows the five-piece set supports considerably larger total loads than does the three-piece set of equivalent cross section designed for the same size of opening. Recommendations are made for improvements in design.

RI 7250. Experimental Leaching of Gold From Mine Waste, by H. J. Heinen and Bernard Porter. April 1969. 5 pp. Excellent gold recovery was demonstrated in a laboratory-scale leaching test on waste material from an open-pit mine in northeastern Nevada. An injection system of leaching was applied in which the sodium cyanide solution was introduced into the interior of the dump at selected points. Dissolution of gold from the waste material, which assayed 0.06 ounce gold per ton, was readily achieved because the gold occurred as submicroscopic particles in a porous host rock. Gold recovery of 80 percent was obtained in 11 days from material crushed to 1 inch in size, and recovery was 90 percent after 21 days.

RI 7251. Recovering Gold From a Graphitic Schist From Tallapoosa County, Ala., by G. V. Sullivan, James S. Browning, and S. J. Saunders. April 1969. 11 pp. 3 figs. The Bureau of Mines conducted preliminary beneficiation studies of a gold-bearing graphitic schist from Blue Hill, Tallapoosa County, Ala. The average analysis of the material was 0.08 oz/ton gold. Tabling of minus 35-mesh material recovered 83 to 94 percent of the gold at grades of 6.925 to 2.165 oz/ton, respectively. A combination of jigging and tabling resulted in a concentrate assaying 24.3 oz/ton gold and contained 87 percent of the total gold. Treatment of the material by jigging, tabling, and amalgamation recovered 86.5 percent of the gold. Work done in cooperation with the University of Alabama.

RI 7252. Some Aspects of the Aerodynamics of Formation of Float Coal Dust Clouds, by J. M. Singer, N. B. Greninger, and J. Grumer. April 1969. 26 pp. 8 figs. The Bureau of Mines investigated the threshold of dispersal of monolayers and piles of rock dust, anthracite, and Pittsburgh seam coal dust in a small wind tunnel that simulated a coal mine gallery, with the objective of preventing or limiting the formation of flammable dust clouds. The effect of selected variables on entrainment velocity was examined. Mode of entrainment flow and processes in the wake region of dust configurations were investigated by means of high-speed motion pictures. Significant results were as follows:

1. Local minimum air velocities required for dispersal were only slightly higher for shallow dust ridges than for dust particles.

2. Minimum velocities for entrainment of dust particles from smooth glass and coal surfaces increased in the order rock dust, anthracite, Pittsburgh seam coal.

3. The mechanism for dispersal of dust piles depended significantly on dust pile geometry, cohesiveness of dust, bulk density and compaction of dust, adhesive surface, and vibrations perturbing the supporting surface.

RI 7253. Energetics of Percussive Drills, by William E. Bruce and James Paone. April 1969. 31 pp. 20 figs. The Bureau of Mines performed drill calibration tests on two industrial percussive drills of 2⅝- and 2½-inch piston diameters to determine operating characteristics for their use in conjunction with penetration rate data in developing drillability equations and furthering the knowledge of percussive drills. The use of a linear velocity transducer for measuring piston velocities and application of its instrumentation are described. Data presented include relationships between maximum piston velocity and feed air pressure. Other results confirm the theory or data of previous investigators, and some comparisons are made with the performance prediction formulas of other investigators.

RI 7254. Recovery of Rhenium From Tungsten-Rhenium Alloy, by M. J. Ferrante, F. E. Block, A. D. Fugate, and F. A. Skirvin. April 1969. 11 pp. 3 figs. The Bureau of Mines recovered rhenium powder from scrap tungsten alloy containing approximately 25 percent rhenium. Oxidation of the scrap at 950° C separated voaltile rhenium heptoxide from tungsten trioxide. Minor amounts of tungsten, iron, and nickel were removed by selective precipitation from a rhenium solution from which was recovered crystalline ammonium perrhenate. Experimentation showed that hydrogen reduction of minus 325-mesh ammonium perrhenate at 1,000° C produced rhenium powder averaging 2.1 microns in size (Fisher Sub-Sieve method). The powder contained <50 ppm of total metallic impurities and 1,070 ppm of total interstitial impurities. Sintered compacts had a density of 95 percent of theoretical. Approximately 96 percent of the rhenium contained in the scrap alloy was recovered.

RI 7255. Turbine Blade Wear by Coal Ash in Working Fluid at 1,200° F, by J. P. McGee, Arthur J. Liberatore, Donald C. Strimbeck, and Gerald B. Goff. April 1969. 15 pp. 13 figs. A 1,000-hour test with a gas turbine at 1,200° F showed a working fluid of 1 gr of ash per 100 scf of powder gas (79 percent of the ash 7 to 35 microns in diameter) to be excessive for acceptable blade wear for commercial practicability. Blades in the turbine consisted of about 20 percent each of chromium, cobalt, and nickel; 3 percent molybdenum; 2.5 percent tungsten; and smaller amounts of manganese, columbium and tantalum. Erosion of both the fronts and backs of the turbine nozzles was particularly heavy, the trailing edges being worn to a featheredge. Erosion of the buckets was less marked, although the leading edges were somewhat pitted. A refractory-lined combustor performed efficiently and with little abrasion of the lining by the ash-laden gas.

RI 7256. A Microscope System Using Automated Reflectance Scanning To Study Coal Components. Application to Analysis of Pyrite Distribution, by J. T. McCartney and S. Ergun. May 1969. 15 pp. 3 figs. The Bureau of Mines has developed an automated reflectance scanning microscope system, primarily for determination of volume proportions, size distribution, and mode of association of the physical (petrographic) components of coals. The process, which is potentially more rapid and objective and less tedious than a visual microscopic procedure, involves magnetic tape recording of several millions of reflectance readings on micro-meter sized areas of polished coal surface and computer analysis and interpretation of some characteristics of the coal components. The system was tested in a study of pyrite distribution in steam coals. The application was essentially successful, but defects in polished pyrite surface characteristics and problems in adequate sampling prevented completely satisfactory results. Pyrite content and coal-pyrite particle association could be determined nearly as well as by visual microscopy, but size distribution data were less acceptable.

RI 7257. Calculating Equilibrium Compositions of Multiconstituent, Multiphase, Chemical Reacting Systems, by H. F. Feldmann, W. H. Simons, and D. Bienstock. May 1969. 22 pp. 2 figs. This Bureau of Mines report presents a method for the computer solution of the equilibrium compositions of any complex, multiphase, chemical system for which appropriate thermodynamic data are available. The method describes in detail the computation of systems in which solid or liquid species can form by heterogeneous chemical reactions where these species do not occur in any equilibrium equations. Also described are the calculation of phases formed by condensation (pure or solutions) and the inclusion of other system restrictions such as electroneutrality. The method is being used to compute the equilibrium composition of mixtures of an electrically conductive plasma and a liquid slag phase arising from the high-temperature combustion of coal for magnetohydrodynamic power generation. These mixtures can contain up to 65 species including gases, liquids, free electrons, and ions.

RI 7258. Effect of Microstructure on Superconductivity in the Columbium-Hafnium System, by R. E. Siemens, L. L. Oden, and D. K. Deardorff. May 1969. 22 pp. 21 figs. The Bureau of Mines sought to correlate the variation of structure-sensitive superconducting properties with microstructure in selected Cb-Hf alloys and to compare the experimental results with those predicted by the GLAG theory. Alloys in wire and rod form were evaluated by critical temperature, critical current, magnetization, resistivity measurements, and optical and electron microscopy. In the absence of an external magnetic field, the current carrying capacity of columbium was greatly reduced with addition of up to 85 wt pct Hf, but a large increase in I_c occurred for Cb-90 wt pct Hf. Favorable I_c-H behavior was observed in cold-drawn alloys containing 25 and 57 wt pct Hf. Correspondingly, a maximum in T_c occurred at 10-25 and 90 wt pct Hf. Four- or five-hour treatments at 600° C resulted in maximum I_c values and maximum hysteresis in magnetization. Dislocation pileup, polygonization, and fine precipitates, responsible for flux pinning, are listed in order of their effectiveness as pinning sites. Sites having an average separation of 1,500 to 3,000 A and a diameter of 1,000 A or less were most effective in influencing I_c-H and M-H behavior. The resistive critical fields increased smoothly to a maximum of 80 kOe between 60 and 65 wt pct Hf. High-field, mixed state, reversible paramagnetism was observed in some alloys; however, the GLAG theory was in good agreement with experimental results for the majority of the composition range studied.

RI 7259. Experiments on the Flow of Mercury in Porous Media in a Transverse Magnetic Field, by W. E. Wallace, C. I. Pierce, and W. K. Sawyer. May 1969. 13 pp. 3 figs. Volume-rate-of-flow measurements were made of the flow of mercury through porous samples under conditions of no field, magnetic field transverse to the direction of flow, and transverse magnetic field and electric current to determine if a magnetic method might be potentially useful in the study of pore-size distribution. No change was observed in the flow rate from the application of a magnetic field alone. The application of both field and current produced an electromagnetic pumping action with or against the direction of flow, depending upon the direction of the electric current. This pumping effect was observed to be greater in a rectangular porcelain sample than the calculated value for an equal-sized open channel.

RI 7260. Chlorine in Coal Combustion, by T. L. Iapalucci, R. J. Demski, and D. Bienstock. May 1969. 12 pp. 5 figs. To determine the behavior of chlorine in coal combustion, the Bureau of Mines burned 10 chlorine-containing coals, high-, medium-, and low-volatile, in a laboratory-scale pulverized-coal combustor. At carbon-combustion efficiencies of 94 to 98 percent, 1.6 to 7.1 percent of the chlorine or an average of 4 percent of the chlorine in the coal was retained in the ash; the balance, predominantly hydrogen chloride, was evolved in the combustion gas. Sulfur retention in the ash ranged from 2.3 to 10.7 percent or an average of 6.3 percent. Addition of alkali and alkaline earth carbonates to a medium-volatile coal containing 0.27 percent chlorine by preferentially reacting with the chlorine increased the Cl-S atom ratio in the ash. Lithium carbonate addition at 0.43 percent and K_2CO_3 at 1.59 percent increased the Cl-S ratio in the ash from 0.2 to 0.6.

RI 7261. Chemical and Vegetative Stabilization of a Nevada Copper Porphyry Mill Tailing, by Karl C. Dean, Richard Havens, and Kimball T. Harper. May 1969. 14 pp. 3 figs. The Bureau of Mines stabilized 10 acres of windblown copper mill tailings at McGill, Nev., by a combination chemical-vegetative procedure. Legumes, winter wheat, wheatgrasses, and wild rye were seeded, and the area was subsequently sprayed with a resinous adhesive chemical to stabilize the sands until the vegetation could grow. During the year since treatment, the area has been well stabilized against wind erosion. The established vegetation appears to be capable of self-perpetuation and renewal without irrigation. The cost of stabilizing the area was $135.50 per acre.

RI 7262. Interactions of Titanium and Molybdenum Additions With Interstitial Impurities in Vanadium, by G. H. Keith. May 1969. 22 pp. 10 figs. The Bureau of Mines determined the mechanism(s) involved in observed anomalous changes in mechanical properties of vanadium-base alloys. Tensile properties of electrorefined and commercial-purity vanadium-base alloys containing up to 5 atomic percent molybdenum or titanium were measured between 77° and 673° K. Snoek oxygen and nitrogen peak heights were measured to determine the changes in dissolved interstitial content caused by increasing quantities of solute. In addition, changes in lattice parameter were followed with precision X-ray techniques.

Softening, observed in alloys containing titanium, is explained by the formation of a second-phase titanium compound with oxygen or nitrogen. However, because of partitioning of titanium between compound formation and solid solution formation, about five times the stoichiometric amount was required for complete reaction. Addition of 1 percent titanium drastically lowered the strengthening due to strain aging at 673° K, and 2 percent titanium essentially eliminated it. All alloys were ductile at 77° K. Variations in the tensile properties of the molybdenum-containing alloys are explained by variations in the amounts of interstitial impurities present. The molybdenum did not react with these impurities and had no effect on strengthening due to strain aging. Commercial-purity vanadium alloys containing more than 2 percent molybdenum were brittle at 77° K.

RI 7263. Flotation of Muscovite From Alabama Graphitic-Mica Schist Ore, by Ralph B. Adair and James S. Browning. June 1969. 7 pp. 1 fig. The Bureau of Mines conducted laboratory and continuous pilot plant flotation tests to determine the feasibility of recovering commercial-grade mica from an Alabama graphite-mica schist. Preconcentration of the ground ore on a Humphreys spiral was employed to reject the heavy minerals and part of the quartz in a product virtually free of mica. The acid-cationic mica flotation process recovered over 89 percent of the mica in a product containing 98.7 percent mica. Grinding of the mica concentrate in a fluid energy mill produced a product with a bulk density of 12 lb per cubic foot. Work done in cooperation with the University of Alabama.

RI 7264. Extraction of Aluminum and Fluorine From Leached Potlining Residues, by P. C. Good and W. G. Gruzensky. June 1969. 9 pp. The Bureau of Mines conducted a laboratory investigation of a sinter-leach method to recover aluminum and fluorine from waste carbon potlining residues from secondary cryolite recovery operations in aluminum reduction plants. After removal of carbon by burning, the residue was sintered at 900° to 1,100° C with silica and Na_2CO_3, then crushed and leached with dilute NaOH solution, dilute Na_2CO_3 solution, water, or water containing residual Na_2O which remained in the sinter after reaction and decomposition of Na_2CO_3. Over 90 percent of the contained aluminum and up to 87 percent of the contained fluorine were extracted from this waste product in the form of a mixed alkaline solution. Treatment of the alkaline solution with CO_2 yielded a white precipitate containing 89 percent of the original aluminum and 61 percent of the original fluorine as a mixture of synthetic cryolite and alumina, together with a variable excess of soda.

RI 7265. Preparation of Thorium Metal by Vacuum Distillation of Electrodeposited Thorium-Chromium and Thorium-Manganese Alloys, by J. E. Murphy, E. Morrice, and M. M. Wong. June 1969. 9 pp. 1 fig. High-purity thorium metal was prepared by the Bureau of Mines from electrolytically produced thorium alloys. The thorium-chromium and thorium-manganese alloys were separated into the component elements by vacuum distillation. Chromium and manganese impurities remaining in the thorium metal after distillation at 1,850° C were <0.005 weight-percent. Removal of volatile impurities such as aluminum, calcium, magnesium, and lead was also accomplished.

RI 7266. Dispersion-Strengthening in Copper-Alumina and Copper-Yttria Alloys, by R. L. Crosby and D. H. Desy. June 1969. 17 pp. 8 figs. The Bureau of Mines investigated alloys of copper with 2, 3, and 4 vol pct alumina and with 2 vol pct yttria. Alloys were prepared by a coprecipitation process and were fabricated by pressing and sintering of powders, extrusion, and swaging. Tensile properties at room and elevated temperatures, stress-rupture strength, electrical conductivity, and density were measured. The superiority in elevated temperature strength of dispersion-strengthened copper to OFHC copper was confirmed. Increasing the oxide content from 2 to 4 vol pct produced only a small improvement in strength properties and decreased the electrical conductivity. The 3 vol pct alumina alloy had the best overall combination of properties.

RI 7267. Oxygen Consumption and Hydrogen Production by Shrink-Resistant Grouts in Confined Places, by Mary A. Barrett. June 1969. 8 pp. 5 figs. The Bureau of Mines conducted a laboratory-scale investigation of grouting mixtures containing iron or aluminum to determine the existence of health or explosion hazards, due respectively to oxygen depletion or hydrogen emission. Mixtures containing iron created an oxygen deficiency in less than 24 hours and released small amounts of hydrogen; a health hazard could occur but only under extremely unfavorable conditions. Mixtures containing aluminum released little hydrogen and consumed little oxygen; however, if improper on-site mixing yielded high local metallic aluminum concentrations, enough hydrogen might be released to produce an explosive atmosphere in a confined space.

RI 7268. Inductoslag Melting of Titanium, by P. G. Clites and R. A. Beall. June 1969. 20 pp. 12 figs. The Bureau of Mines developed techniques for induction melting of titanium in a split, water-cooled copper crucible. Calcium fluoride, which was used as an inert slag cover during melting, formed an insulating layer of solid slag between the ingot and the crucible wall. This thin layer of slag effectively insulated the ingot from the crucible and prevented the molten metal from shorting across the slits between adjacent segments of the crucible. The technique provides a means of melting loose titanium sponge and scrap and eliminates the need for fabricating a consumable electrode. This report describes the equipment developed and compares ingots produced from two varieties of titanium sponge, from titanium scrap, and from previously melted titanium with ingots prepared by vacuum-arc melting and electroslag melting. A melting scheme was also proposed and evaluated whereby loose titanium sponge was consolidated into a first-melt ingot for vacuum-arc melting.

RI 7269. Elastic Moduli of Rock at Elevated Temperatures, by Carl F. Wingquist. June 1969. 8 pp. 8 figs. In support of Bureau of Mines studies of thermal fragmentation of rock, the elastic moduli of four types of rock were measured at temperatures ranging from room temperature up to 1,500° F (1,089° K). The sonic method was employed to determine the resonant frequencies of the rock specimens and from these frequencies, the elastic moduli were calculated. Data for Young's modulus, shear modulus, and Poisson's ratio are given as a function of temperature for Dresser basalt, Reserve taconite, Jasper quartzite, and Charcoal granite. Young's modulus and the shear modulus decreased with increasing temperature up to about 1,200° F and then became relatively insensitive to temperatures from 1,200° to 1,500° F.

RI 7270. Bureau of Mines Portable Recording Methanometer, by Merle L. Bowser and William E. Thomas. July 1969. 6 pp. 3 figs. The Bureau of Mines has developed a portable recording methanometer that utilizes the Bureau's methane sensor. The methanometer can operate continuously for at least 30 hours on small, sealed, rechargeable lead-acid batteries.

RI 7271. Vapor Pressures of Liquid Titanium (2,008° to 2,379° K) and Liquid Platinum (2,045° to 2,442° K), by R. K. Koch, E. D. Calvert, C. R. Thomas, and R. A. Beall. July 1969. 14 pp. 4 figs. The vapor pressures of liquid titanium and liquid platinum were studied under the Bureau of Mines program for the determination of thermochemical data on the transition elements. Heating was done in a 2-kw electron-beam furnace with a water-cooled copper crucible to contain the melt. Temperature was measured with a disappearing-filament brightness pyrometer. The vapor pressure data for liquid titanium in the range 2,008° to 2,379° K are represented by the least-squares derived equation

$$\log p \text{ (atm)} = 6.268 - \frac{22{,}330}{T}.$$

Two series of determinations were made on liquid platinum. Results of the first series are expressed by the least-squares derived equation

$$\log p \text{ (atm)} = 8.240 - \frac{30{,}460}{T}$$

for the range 2,086° to 2,420° K. Results of the second series are expressed by the least-squares derived equation

$$\log p \text{ (atm)} = 7.795 - \frac{29{,}580}{T}$$

in the range 2,045° to 2,442° K.

Third-law evaluations of each series gave mean standard heats of sublimation of 112.4 kcal/mole, 133.3 kcal/mole, and 133.8 kcal/mole for titanium, first series on platinum, and second series on platinum, respectively. Second-law heats of sublimation and equations for heats, free energies, and entropies of vaporization were obtained from sigma plots of each data set.

RI 7272. Gasflood Performance Prediction for the Cooper Sand of the Fork Run Pool, Warren and McKean Counties, Pa., by K-H. Frohne, L. A. Schrider, and M. K. Romeo. July 1969. 49 pp. 15 figs. This report presents a study of the Cooper sand of the Fork Run pool of Warren and McKean Counties, Pa., and a prediction of the secondary oil recovery by gasflooding the reservoir. A computer program employing a modification of the Craig, Geffen, and Morse secondary calculation was used to make the gasflood performance forecast and is presented in the appendix.

The Cooper sand reservoir in the Fork Run pool lies at a depth of about 1,900 feet and covers an area ½ mile wide by 2¼ miles long. Original oil in place is estimated to have been 8,266,000 stb. The primary recovery mechanism is solution gas drive, and ultimate primary recovery may reach 20 percent over a well life of 90 years.

Two computer predictions were made for gasflooding the Cooper reservoir. The first was for a

25-acre pilot five-spot utilizing existing wells, but project economics were poor since only 25 percent of injection gas is utilized for pilot oil recovery. Recovery was 71,000 stb, or 22 percent of oil in place at flood initiation, but required 25,700 scf gas injected per stb of oil recovered.

In the second prediction, pilot area performance was projected for the entire Fork Run pool, and economics became good. Recovery was 1,753,000 stb from 25 five-spots after the injection of only 6,400 scf per stb of oil recovered.

RI 7273. Separation and Characterization of Metallo-Organic Materials in Petroleum, by C. W. Dwiggins, Jr., K. W. Willcox, D. A. Doughty, and R. J. Heemstra. July 1969. 41 pp. 16 figs. The Bureau of Mines characterized the chemical and physical properties of metallo-organic materials in petroleum to determine their effect on petroleum production and refining. The structures and physical properties of porphyrins and materials that normally contain metalloporphyrins such as crude oil and asphaltenes were investigated using elemental analysis, NMR analysis, absorption spectrometry, and small-angle X-ray scattering. Petroleum fractions greatly enriched in metalloporphyrins were obtained using asphaltene precipitation, liquid extraction, and large-scale liquid-solid chromatography. Selected fractions containing porphyrins were further purified by chromatographic methods, crystallization, and demetalation followed by chromatography. Nonporphyrin metals could not be appreciably concentrated from the bulk of the asphaltene.

RI 7274. Eight-Piece Concrete Sets for Small Mine Openings: A Progress Report, by M. O. Serbousek and K. R. Dorman. July 1969. 35 pp. 17 figs. To further investigate the potential of precast concrete sets as a support medium for underground mines, the Bureau of Mines designed an eight-piece precast reinforced concrete drift set for a small opening. Twenty-two sets of three different member sizes were tested to destruction under two loading conditions. A discussion of the test results and typical failure patterns is presented.

RI 7275. Alkalized-Alumina Attritioning and SO_2 Sorption Rates, by Joseph W. Town, Philip E. Sanker, and Hal J. Kelly. July 1969. 29 pp. 18 figs. The Bureau of Mines conducted studies related to SO_2 air pollution to determine attritioning rates, SO_2 sorption rates, and sulfur loads that could be obtained on commercial alkalized alumina sorbent pellets. Fluidized-bed attritioning rates ranged from 0.025 pct/hr for alkalized alumina with a crushing strength of 4 kg to 0.075 pct/hr for 0.5 kg crushing strength material. Airlift attritioning rates ranged from 0.50 pct/hr for 3 kg crushing strength alkalized alumina to about 3 pct/hr for 0.5 kg material. Attritioning rates for the commercial alkalized alumina were comparable to those obtained for sorbent pellets prepared in the Bureau of Mines laboratory. Sorption rates were related to SO_2 concentration in flue gas, temperature, and presence of nitrogen oxides in the gas stream. Sorption rates at 300° C were 0.35×10^{-5} gS/gp/sec (grams sulfur per gram pellet per second) in 0.045 percent SO_2 gas, 5.1×10^{-5} gS/gp/sec in 0.34 percent SO_2 gas, and 65×10^{-5} gS/gp/sec in 10 percent SO_2 gas. For the 0.34 percent SO_2 gas, sulfur loads of 0.10 gS/gp (the projected load for regeneration) were obtained in 47 minutes at 130° C and in 116 minutes at 300° C. The presence of either NO or NO_2 in the 0.34 percent SO_2 gas increased the SO_2 sorption rates 2 to 3 times at 300° C but had no effect at 130° C.

RI 7276. Operating Characteristics of a High-Temperature Electrostatic Precipitator, by C. C. Shale and G. E. Fasching. July 1969. 19 pp. 7 figs. A semicommercial, high-temperature electrostatic precipitator and adjunct equipment are described; operating characteristics at 1,470° F and 80 psig are presented for both positive and negative polarity. Removal efficiency for negative corona was about 91 to 96 percent while that for positive corona was only about 75 to 77 percent. Results are compared with those from bench-scale invesigations, and equipment limitations are discussed. Theoretical aspects of the precipitation process are related to the operating characteristics.

RI 7277. Factors Affecting Detonation Velocities of Desensitized Nitroglycerin in Simulated Underground Fractures, by J. S. Miller, W. D. Howell, J. L. Eakin, and E. R. Inman. July 1969. 19 pp. 9 figs. The Bureau of Mines conducted surface tests to determine the feasibility of using liquid explosives for underground rock fracturing. The effects of configuration, confinement, length, critical layer thickness, and fracture-propping sand on detonation and explosive propagation velocity of desensitized nitroglycerin were studied, using polymethyl methacrylate and glass-plate reservoirs through lengths from 3 to 12 ft, with explosive-layer thicknesses from 0.1875 to 0.0312 inch and in aluminum tubes 8 feet long with diameters from 2.000 to 0.125 inch. Interval and continuous detonation velocity data were obtained.

Under the test conditions detonation velocity was dependent upon explosive confinement and fracture-propping sand. The detonation velocity of a confined nitroglycerin explosion in aluminum tubes can be reduced by as much as 85 percent, when the tube contains fracture-propping sand. The shape of the reservoir, whether triangular or rectangular, has little effect on the detonation velocity or explosive propagation. The critical or minimum explosive-layer thickness between glass plates, capable of supporting propagation, was 0.0312 inch. The presence of a fracture-propping sand in the sheetlike layers increased the critical explosive layer thickness to 0.0625 inch. In nitroglycerin-filled and nitroglycerin-sand filled tubes, the minimum tube diameters successfully tested were 0.125 inch and 0.375 inch, respectively.

RI 7278. Effects of Pressure, Temperature, and Type of Oil on Vaporization of Oil During Gas Cycling, by Alton B. Cook, F. Sam Johnson, George B. Spencer, Abdo M. Bayazeed, and C. J. Walker. July 1969. 26 pp. 9 figs. Data are presented to show oil vaporization resulting from the passage of natural gas through a sand-packed tube saturated with synthetic reservoir oils. The Bureau of Mines performed 13 experiments, using reservoir oils synthesized with base crude oils of approximately 22°, 35°, and 45° API, at 100°, 175°, or 250° F and 1,100, 2,600, or 4,100 psia. It has been determined that the amount of vaporization is significant if proper conditions exist. These experiments show that oil vaporization depends on pressure, temperature, volatility of the oil, and amount of gas cycled. Increases in each of these conditions increase the volume of oil vaporized.

RI 7279. Explosion Development in a Spherical Vessel, by John Nagy, John W. Conn, and Harry C. Verakis. August 1969. 22 pp. 12 figs. The Bureau of Mines examined explosion development in a closed spherical vessel, mathematically correlating flame travel, pressure, and time with parameters defining the reaction. The model assumes that burnt and unburnt zones are separated by a thin, radially moving flame front. Isothermal and adiabatic systems are considered. Correlation with gas and dust explosion data is better for the adiabatic system, but the isothermal development is simpler and in reasonably good agreement.

Interpretation of the explosion phenomena is facilitated by expressing the rate of mole change in the flame front in terms of elementary parameters. This expression is developed by examining the components of spatial-flame velocity.

RI 7280. Thermodynamic Data for Ferric Sulfate and Indium Sulfate, by L. B. Pankratz and W. W. Weller. July 1969. 8 pp. 2 figs. The Bureau of Mines determined low- and high-temperature thermodynamic properties for anhydrous ferric sulfate and anhydrous indium sulfate. Low-temperature heat capacities were measured between 50° and 298° K, and enthalpy increments above 298° K were determined. The high-temperature measurements of $Fe_2(SO_4)_3$ extended to 900° K and those of $In_2(SO_4)_3$ to about 1,000° K. A minor transition was found for $Fe_2(SO_4)_3$ at 800° K, with a heat of transition of 540 cal/mole. Tabulations were made of the low-temperature heat capacities and the high-temperature enthalpy and entropy increments. The 298° K entropies derived from the low-temperature measurements were 67.6 $\pm$ 0.5 cal/deg mole for ferric sulfate and 72.2 $\pm$ 0.5 cal/deg mole for indium sulfate. High-temperature enthalpy increments were also given in equation form.

RI 7281. Spectrochemical Analyses of Coal Ash for Trace Elements, by R. F. Abernethy, M. J. Peterson, and F. H. Gibson. July 1969. 20 pp. 2 figs. The Bureau of Mines made spectrochemical analyses of ash from 827 U.S. commercial coals for barium, beryllium, boron, chromium, cobalt, copper, gallium, germanium, lanthanum, lead, lithium, manganese, molybdenum, nickel, scandium, strontium, tin, vanadium, ytterbium, yttrium, zinc, and zirconium. These 22 elements were detected in almost all of the ash samples examined. In addition, arsenic, bismuth, cerium, neodymium, niobium (columbium), rubidium, and thallium were detected in many samples.

RI 7282. Entrainment Drying and Carbonization of Wood Waste, by Charles C. Boley and W. S. Landers. August 1969. 15 pp. 1 fig. The Bureau of Mines dried and carbonized two wood wastes, one softwood (redwood) and one hardwood (oak), using continuous, vertical entrainment techniques previously developed for use with coal. It was demonstrated that these techniques are readily applicable to wood waste and that appreciable changes in the yields of carbonization products can be obtained by varying operating conditions.

A limited amount of experimental work was done on briquetting the charcoals. Firm briquets were formed with oak charcoal, although greater quantities of starch binder than used commercially for kiln-produced charcoal were required. Redwood charcoal did not briquet successfully under the test conditions employed. Work done in cooperation with the Silver Corporation (Silver Engineering Works Division), Denver, Colo.

RI 7283. Materials Handling Research: Hydraulic Transportation of Coarse Solids, by R. S. Fowkes and G. A. Wancheck. August 1969. 36 pp. 16 figs. The Bureau of Mines constructed a fully automated pilot plant facility to study the hydraulic transportation of solids through a lock hopper feeder system. An equation for the energy requirements to transport coarse solids hydraulically proved applicable to this system. Optimum velocities were obtained for limestone, mine refuse, and bituminous coal. The experimental data, calculations, and graphs show the effect of velocity, specific gravity, and solids concentration on head loss and power requirements. Other data were obtained and evaluated to determine the effect of particle size on head loss. Results also are given for (a) tests using friction reducing polymers; (b) tests using seven test sections of steel alloy pipe to determine their wear characteristics; (c) tests to determine spatial segregation of moving particles; and (d) tests to determine the effect of shape, size, and specific gravity on particle velocity in a horizontal pipeline. The lock hopper feeder system was found practical for continuous hydraulic transportation of the material types and size ranges tested.

RI 7284. Influence of Residence Time, Temperature, and Steam Concentration on Coal-Steam Gasification Reactions, by J. L. Konchesky and R. F. Stewart. August 1969. 19 pp. 16 figs. The Bureau of Mines investigated the main reactions of coal gasification by steam. Coal (minus 70 mesh)-water slurry was fed into a laboratory-scale tube-coil gasifier to show the effects of residence time (0.6 to 1.1 sec), steam-coal ratio (2 to 11 lb/lb), and temperature (1,600° to 1,900° F), at about 1½ atm. Devolatilization was very rapid: about 70 percent of the coal's volatile matter evolved within 0.6 sec at about 1,600° F; temperature increase released more volatile matter until about 95 percent was driven off at 1,900° F. Devolatilization was not increased by raising steam concentrations and was only slightly increased by extending residence time. Below 1,600° F, there was no evidence of the steam-carbon reaction, but at 1,900° F more than 80 percent of the coal's fixed carbon was converted to gas; the conversion was increased significantly by increased residence time and steam concentration. The water-gas shift reaction occurred simultaneously with devolatilization and the steam-carbon reaction, approaching equilibrium with increased residence time and temperature and decreased steam concentration.

RI 7285. Tensile and Stress-Rupture Properties of Rolled Pb-Cd-Sb Alloys, by M. M. Tilman. August 1969. 11 pp. 8 figs. In a Bureau of Mines investigation to develop lead alloys with improved tensile strength and creep resistance, lead-base alloys containing cadmium and antimony in norminal 1-to-1 atomic ratios were melted in air, cast, and rolled into sheet to 90 percent reduction at temperatures varying from room temperature to 175° C. Tensile testing at room temperature and stress-rupture testing at 90° $\pm$ 3° F were conducted on the as-rolled alloys. The best tensile properties were observed in an alloy of Pb-4.2 wt pct Cd-4.5 wt pct Sb which exhibited an average tensile strength of 7,270 psi with 36 percent elongation in 2 inches. An alloy of Pb-5.5 wt pct Cd-6.0 wt pct Sb had 100-hour stress-rupture values of approximately 2,100 psi and 1,000-hour values of approximately 1,700 psi.

RI 7286. Determination of Dawsonite and Nahcolite in Green River Formation Oil Shales, by John Ward Smith and Neil B. Young. August 1969. 20 pp. 3 figs. An analytical method developed by the Bureau of Mines to determine dawsonite, nahcolite, and nondawsonite alumina (called excess alumina) extractable from Green River Formation oil shales is presented. The method requires water extraction of nahcolite followed by HCl-extraction of dawsonite and an unidentified mineral yielding excess alumina from the water-leached residue. Instrumental determination of sodium in the water extract and sodium and aluminum in the HCl extract measures the sample's content of the minerals. Detailed evaluation shows the method to be adequately specific, precise, and reproducible and free from uncorrectable interferences. The method's results define precisely the production of sodium carbonates and alumina possible from a sample of oil shale and the interval it represents. Shale-oil yields, nahcolite contents, and yields of extractable alumina determined on 83 samples representing an 821-foot section of dawsonite-nahcolite-bearing shale from Colorado Corehole No. 3, drilled in the north part of Colorado's Piceance Creek basin, are presented. These samples resulted in nahcolite contents to 53.3 percent, oil yields to 48.3 gallons per ton, and alumina yields to 5.80 percent. Use of these data to evaluate the production potential of a section of the formation are suggested.

RI 7287. Compressibility Data for Helium at 0° C and Pressures to 800 Atmospheres, by Ted C. Briggs, B. J. Dalton, and Robert E. Barieau. August 1969. 54 pp. 5 figs. The Bureau of Mines is evaluating the thermodynamic properties of helium and helium-containing mixtures. Twenty-two compressibility runs were made with helium at 0° C and pressures to 800 atmospheres using a Burnett-type apparatus. Data from the 22 runs were treated simultaneously and as separate runs while different functional forms and weighting factors were used.

A fourth-degree-polynomial equation in the pressure gives a statistically satisfactory representation of the compressibility factor when the data are treated simultaneously and a weighting factor of $P_r^{-3/4}$ is used.

The second viral coefficient of helium at 0° C from this investigation is 11.997 ± 0.015 cm^3 $mole^{-1}$. The stated uncertainty is the random error standard deviation. Compressibility factors determined by this investigation are precise to better than 0.01 percent and are believed to be accurate to better than 0.02 percent.

RI 7288. Chemical Stabilization of the Uranium Tailings at Tuba City, Ariz., by Richard Havens and Karl C. Dean. August 1969. 12 pp. 4 figs. Acidic and basic uranium leach plant residues located on the Navajo Indian Reservation, Tuba City, Ariz., were successfully stabilized against wind erosion using a relatively low-cost chemical method. An elastomeric polymer chemical was applied to the dike areas and a calcium magnesium lignosulfonate to the beach areas of three tailings ponds. The water-soluble chemicals were applied with an automated sprinkling system. The stabilization cost was $335 per acre for the 34.5-acre tract.

RI 7289. Electrical Resistivity of Hyperstoichiometric Columbium and Zirconium Carbide Materials at Elevated Temperatures, by Danton L. Paulson and Gene Asai. August 1969. 30 pp. 21 figs. Elevated temperature electrical resistivity measurements were made by the Bureau of Mines on arc-melted, spin-cast, and hot-pressed columbium carbide-carbon (CbC-C) and zirconium carbide-carbon (ZrC-C) materials up to 2,000° C. The CbC-C materials displayed electrical resistivity values ranging from 35.20 microhm cm at 23° C for hot-pressed material containing 12 wt pct carbon to 242.64 microhm cm at 1,622° C for arc-cast material containing 17.0 wt pct carbon. Electrical resistivity values ranged from 29 microhm cm at 20° C for arc-cast ZrC-C containing 16 wt pct carbon to 279 microhm at 1,951° C for hot-pressed ZrC-C containing 21 wt pct carbon. Data from a previous report were included to establish comparison between the electrical resistivities of the CbC-C, ZrC-C, and HfC-C systems.

RI 7290. Metallization of Iron Ores With Solid Reductants, by M. M. Fine and R. B. Schluter. September 1969. 19 pp. 7 figs. Research on the solid-fuel reduction of Knob Lake iron ores was conducted to upgrade lean and high-grade ores and recover metallized products suitable for ironmaking or steelmaking. The program included bench-scale tests plus a number of continuous campaigns in a 34-inch by 30-foot rotary kiln. In the laboratory, metallizations in excess of 90 percent were achieved by reduction of crushed ore with lignite at 950° C. Subsequent grinding (to minus 20 mesh) and wet magnetic separation yielded concentrates analyzing less than 3.0 percent SiO_2 and more than 90 percent Fe. Virtually complete recovery of the iron occurred. During early continuous tests the crushed ore created a serious ringing in the kiln which was solved by balling the fines with bentonite. Unfortunately, at this temperature (950° C) the bentonite militates against the concentratability of the metallized product. For example, a run on direct-shipping ore produced concentrates of 89.5 percent Fe and 4.5 percent SiO_2. At 900° C the adverse effect of bentonite disappeared and concentrates of 88.4 percent Fe and only 2.5 percent SiO_2 resulted. However, with comparable feed rates, the metallization dropped to 73 percent.

RI 7292. Magnetic Separation of Minerals of Low Susceptibility and Small Particle Size, by Foster Fraas. September 1969. 14 pp. 7 figs. This Bureau of Mines report describes a method for separating minerals at magnetic susceptibilities within the diamagnetic susceptibility range. The maximum feed rate varies directly with the square root of the lower limit of permissible susceptibility, while the lower limit of permissible susceptibility varies inversely as the square of the magnetic field strength. Minerals may be separated at particle sizes smaller than those possible on conventional dry-type magnetic separators.

RI 7293. Mass Spectrometry. Residual Gas Analysis During Vacuum Melting, by W. E. Anable and E. D. Calvert. September 1969. 11 pp. A 180° magnetic deflection residual gas analyzer mass spectrometer with a mass range of 2 to 200 amu was used to study the nature of gases evolved during arc and electron-beam melting of certain reactive and refractory metals. The partial pressure of residual gases over molten molybdenum, hafnium, titanium, and iron was found to be similar: Water and hydrogen were evolved from the samples and from the furnace components, carbon dioxide and carbon monoxide resulted from deoxidation of some of the melts. Argon and acetone were residuals in the system, and methane was a decomposed organic compound from the oil diffusion pump.

RI 7294. Preparing Alkalized Alumina, by Laurance L. Oden and Paul E. Francoeur. September 1969. 16 pp. 5 figs. The Bureau of Mines studied three processes for preparing $NaAl(OH)_2CO_3$, the intermediate compound which is calcined to produce alkalized alumina: (1) Mixing of Na_2CO_3 and of $Al_2(SO_4)_3$ solutions, (2) digestion of aluminum hydroxide in solutions of Na_2CO_3 and $NaHCO_3$ at 90° C, and (3) addition of CO_2 at 25° C to caustic solutions of aluminum to precipitate aluminum hydroxide followed by digestion at 90° C. The first process had the highest raw material consumption and washing requirements, and successful application of process 2 dependent upon the availability of active aluminum hydroxide. Process 3 was the most effective, considering both process technology and raw material requirements. Procedures were also investigated for washing, filtering, drying, and calcining precipitates. Analytical methods included X-ray diffraction, atomic absorption spectroscopy, differential thermal analysis, and thermogravimetric analysis.

RI 7295. Bureau of Mines Coal-Fired Gas Turbine Research Project. Test of Combustor and Ash Separators for Open-Cycle Plant, by Donald C. Strimbeck, Arthur J. Liberatore, Gerald B. Goff, and James P. McGee. September 1969. 12 pp. 9 figs. The Bureau of Mines designed a down-fired refractory-lined combustor that efficiently burned pulverized coal to produce a gas suitable as working fluid for an open-cycle gas turbine. The gas contained relatively little carbon, so the load on the ash-separation equipment was significantly reduced. Moreover, reduction in carbon content of the gas increased the average density of the solid particles making them more amenable to removal by centrifugation. Centrifugal-type separators failed to remove sufficient ash, however, to limit blade wear enough to achieve operating periods generally deemed necessary for commercial practicability.

RI 7296. Laboratory Oil-Recovery Tests With Ultrasonically Formed Emulsions, by C. A. Komar and H. A. W. Moore. September 1969. 14 pp. 3 figs. The Bureau of Mines conducted oil-displacement tests in the laboratory with three water-in-oil and five oil-in-water emulsions that were created with ultrasonic energy at a frequency of 20 kHz and an acoustic intensity of approximately 100 watts per cm^2. Emulsions of either crude oil or kerosine, brine, and 0.5 to 2 percent emulsifier were formed during 30 seconds of acoustic irradiation.

Results indicate that ultrasonic energy induces greater and more uniform dispersion of one liquid in another in the presence of small amounts of chemical emulsifiers. When the emulsions were injected as a buffer slug before waterflooding, recovery of the oil-in-place was 8 to 22 percent greater than with conventional waterflooding in the test specimens, regardles of the continuous phase (oil or brine). The emulsions do not appear to be applicable to the Appalachian area, however, because the oilfields are too "tight," the clays in the formation remove the emulsifier from the displacing fluid, and not enough additional oil is produced, compared with recovery using conventional waterflooding, to warrant the increased operating costs.

RI 7297. Structural Design Data For Unreinforced Concrete Tunnel Linings, by J. D. Dixon. October 1969. 43 pp. 7 figs. The Bureau of Mines has developed structural design data for unreinforced concrete tunnel linings in the form of stress and deflection coefficients from which bending, axial, shear, and boundary stresses, moments, thrusts, and shear forces, and structural deflections can be determined at any point on the lining. Results were obtained by structural analyses of nine concrete-lined tunnel configurations subjected to 22 biaxial load conditions. The tunnel configurations include three basic shapes, circular, rectangular, and horseshoe, with dimensions based on designs evolved by the mining industry. These analyses were made by the direct stiffness matrix method, a computer-oriented procedure. Numerical results agree closely with those obtained experimentally.

RI 7298. Effect of Increasing End Constraint on the Compressive Strength of Model Rock Pillars, by Clarence O. Babcock. September 1969. 18 pp. 7 figs. Model pillars of limestone, marble, sandstone, and granite with length-to-diameter (L/D) ratios of 3, 2, 1, 0.5, and 0.25 (0.286 for granite) were tested to failure in axial compression to determine to what extent an increase in end constraint increased compressive strength. Adjustable steel rings, mechanically tightened about the ends of test specimens to create a radial prestress of 3,000 or 5,000 psi prior to the application of axial load, increased end constraint more than was possible in previous tests using solid steel rings. (Solid rings, epoxy-bonded to the ends of dogbone specimens, increased compressive strength compared with that of straight specimens without ring constraint.) During the loading cycle, additional end constraint was produced by lateral expansion of the specimens against the rings. The effect of the end constraint was to increase the compressive strength 55 to 58 percent for the shorter pillars of dogbone shape compared with the compressive strength of straight pillars with the same L/D ratios without ring constraint. Most pillars with L/D ratios of less than 2 were made stronger by end constraint. Pillars with an L/D ratio of 3 did not benefit significantly from end constraint.

When the results from compression testing of straight specimens of rock in the laboratory are used to design mine pillars in situ, the pillars will be larger than necessary if the horizontal compressive stress is several thousand pounds per square inch greater than that resulting from the weight of the overlying rock alone. The L/D ratio can be increased by a factor of 1.76 for ratios in the range 0.25 to 3 and still provide the same compressive strength. The safety factor applied with straight specimen test results should also be acceptable for use with constrained pillar test results.

RI 7299. Methods for Producing Alumina From Clay. An Evaluation of Two Lime Sinter Processes, by John J. Henn, Paul W. Johnson, Earle B. Amey III, and Frank A. Peters. September 1969. 43 pp. 17 figs. Two lime sinter processes for recovering alumina from clay, the double-leach process and the single-leach process, are evaluated in this Bureau of Mines report. In both processes, clay and limestone are mixed and sintered to form calcium aluminate from which alumina is extracted as sodium aluminate by leaching with a dilute solution of sodium carbonate. The pregnant liquor is desilicated, then carbonated to precipitate alumina trihydrate which is recovered and calcined to α-alumina.

The fixed capital costs for plants producing 1,000 tons per day of alumina are $85 million for the double-leach process and $86 million for the single-leach process based on a Marshall and Stevens chemical equipment index of 240.0. Because plant locations are variable with respect to the proximity of clay and limestone deposits, a nomograph is included to determine operating costs at various delivered costs of clay and limestone. For plants at which the delivered cost of clay containing 30 percent Al_2O_3 is $2 per ton and the delivered cost of limestone is $1 per ton, the operating costs are $81.04 and $89.87 per ton of alumina for the double-leach process and single-leach process, respectively.

RI 7300. Drillability Studies—Laboratory Percussive Drilling, by James Paone, Dick Madson, and William E. Bruce. September 1969. 22 pp. 17 figs. The Bureau of Mines conducted laboratory drillability studies on nine rock types using two mining-type percussive drills. Percussive-bit action was simulated by dropping a known weight on a rock sample to obtain a coefficient of rock strength for each rock drilled. While no single physical property of a rock is completely satisfactory as a predictor of penetration rate, coefficient of rock strength showed a better correlation with penetration rate than did other physical properties. Results also indicate that over the range of energies investigated, energy per unit volume in a given rock is independent of blow energy. A drillability index for the percussive system is proposed that utilizes the coefficient of rock strength test to determine energy per volume for a given rock which, along with the rate of a given drill and the bit diameter, is used to predict the penetration rate as shown in the following equation:

$$R = \frac{4P}{\pi D^2 Ev},$$

where R = penetration rate, in/min, P = work rate, in lb/min, D = bit diameter, in, and Ev = energy required to produce a given volume of rock, in lb/in^3. Laboratory tests indicate this method's potential as a simple and reasonably accurate method of predicting penetration rates with any percussive drill and bit combination.

RI 7301. Extraction of Copper From Oxides Using Iron and Steel Scrap. Principles and Application to Pure Systems, by S. E. Khalafalla, H. W. Kilau, and L. A. Haas. October 1969. 13 pp. 5 figs. The Bureau of Mines investigated the metallothermic reduction of copper oxide as a function of temperature, reactant proportions, form of reductant, and gaseous environment, using iron and steel scrap reductants. The reactions proceeded rapidly with powdered iron at temperatures above 560° C, attaining over 95 percent copper metallization within 3 hours. The importance of interreactant contacts on the extent of the reaction was evident from the variable, but usually lesser, degree of metallization obtained with iron from tin cans and automobile scrap. Reduction decreased as the molar ratio of copper to iron increased between 1 and 3. The most favorable gaseous environment for the reaction was a static helium atmosphere containing about 0.6 percent water vapor. Ferrothermic extraction of copper from its oxides appears to be essentially a "solid-state cementation" process. While ordinary cementation processes must be preceded by leaching, the ferrothermic method avoids this generally slow step and also water pollution caused by the leaching agents. Sulfidic copper concentrates could likewise be reduced with metallic iron following their complete oxidative roasting.

RI 7302. Destructive Distillation of Scrap Tires, by D. E. Wolfson, J. A. Beckman, J. G. Walters, and D. J. Bennett. September 1969. 19 pp. 4 figs. Destructive distillation (carbonization) was shown to be a feasible method of disposing of scrap tires. The Bureau of Mines conducted tests under a variety of conditions. Solid, liquid, and gaseous products were produced, recovered, and analyzed. The quantities of the various products were shown to be quite dependent on the test temperature. Variability in composition of the liquid and gaseous products with changes in test temperature was also significant. Work done in cooperation with The Firestone Tire and Rubber Co.

RI 7303. Gas Combustion Retorting of Oil Shale Under Anvil Points Lease Agreement: Stage I, by J. R. Ruark, H. W. Sohns, and H. C. Carpenter. November 1969. 109 pp. 13 figs. This report presents results of mining operations and of research and development work done during stage I of the gas combustion retorting research program conducted by the Colorado School of Mines Research Foundation and six major oil companies at the Bureau of Mines Anvil Points Oil Shale Facilities. A brief description of the gas combustion process is given and the experimental program is discussed. Included in this discussion are (1) air-gas distributor development, (2) results of gas and shale distribution studies, and (3) effects of other process variable studies. The report concludes with a statistical evaluation of experimental results. Two appendixes present a chronological account of the experimental work and tabulations of data for all retorting runs conducted during stage I. Work done in cooperation with the University of Wyoming.

RI 7304. Radiotracer Procedures for Mechanistic Studies in Air Pollution Research, by M. L. Whisman and Basil Dimitriades. October 1969. 36 pp. 3 figs. Radiotracer techniques were developed for stoichiometric studies of photochemical reactions associated with atmospheric smog formation. Stock blends of separate hydrocarbon and oxygenated compounds were prepared and calibrated. C^{14}-labeled reactants and products in reaction systems involving hydrocarbons and nitrogen oxides at the ppm level were analyzed for qualitative and quantitative data. Precision and accuracy of these methods developed by the Bureau were determined by replication and statistical treatment of data, and these methods are described.

RI 7305. A Systems Approach to Recovering Gold Resources in Jefferson County, Mont. Introductory Review, by Robert W. Ageton, George T. Krempasky, and William L. Rice. October 1969. 16 pp. 5 figs. The Bureau of Mines is currently conducting a comprehensive study to evaluate all aspects of recovering gold from large, low-grade deposits in the Golden Sunlight area, Whitehall mining district, Jefferson County, Mont. Prior to World War II this area produced significant quantities of gold. The study includes geologic mapping, diamond drilling, assaying, computer analysis of assay data, metallurgical research and ore testing, mine and mill planning, and an economic evaluation of all factors bearing on the establishment of a producing gold mine. Preliminary evaluation of the deposit indicates about 31 million tons of submarginal gold resources. This report presents the geology and mining history of the area, together with a summary of Bureau work in progress.

RI 7306. Infrared Evaluation of Starch Products Used in Iron Ore Flotation, by A. F. Colombo and A. R. Rule. October 1969. 16 pp. 7 figs. Infrared spectroscopy employing attenuated total reflectance (ATR) techniques on thin films of dried gelatinized starch solution was used during Bureau of Mines research to determine the structural and impurity differences in starch products and to correlate these characteristics wtih the flotation response of a nonmagnetic taconite. All of the starch products evaluated gave spectrograms which were characteristic of the anhydroglucose monomer and its polymerization product. Distinct infrared absorption peaks caused by the protein molecule were observed and were used to classify the starches.

Correlation of laboratory flotation of calcium-activated gangue from a Mesabi range nonmagnetic taconite and infrared spectra produced from gelatinized starches showed that protein impurities and linear chain structure limited the effectiveness of starches as iron mineral depressants. Starch products having spectrograms similar to pure amylopectin were generally good depressants for iron oxides; they were effective at about one-half the addition that was required for starches that gave infrared responses similar to pure amylose and yielded acceptable iron concentrates containing 61.5 percent iron and 6.5 percent silica.

RI 7307. Vapor Pressures of Metal Halides. The $CdCl_2$-$SnCl_2$, $CdCl_2$-$ZnCl_2$, $PbCl_2$-$SnCl_2$, and $PbCl_2$-$ZnCl_2$ Binary Systems, by L. C. George, A. Visnapuu, Barbara C. Marek, and Robert M. Doerr. October 1969. 15 pp. 12 figs. The Bureau of Mines measured the vapor pressures of selected mixtures in the binary systems $CdCl_2$-$SnCl_2$, $CdCl_2$-$ZnCl_2$, $PbCl_2$-$SnCl_2$, and $PbCl_2$-$ZnCl_2$ by the static pressure method. These data were evaluated by the second-law (sigma-plot) method. Equations expressing the vapor pressures and the heats and free energies of vaporization as functions of temperature are given.

RI 7308. Preparation of Rare-Earth and Yttrium Metals by Electrodeposition and Vacuum Distillation of Alloys, by E. Morrice, J. E. Murphy, and M. M. Wong. October 1969. 11 pp. 2 figs. Gadolinium, dysprosium, and yttrium are difficult to electrowin as high-purity liquid metals because of their high melting points (>1,300° C). Samarium metal is difficult to prepare directly by electrolysis because the metal reacts with the electrolyte. In this Bureau of Mines study, the rare-earth metal was electrodeposited on a solid manganese, chromium, or iron cathode to form a low-melting alloy. The alloy was then vacuum distilled to separate the rare-earth metal from the ferrous metal. A typical samarium metal product, obtained as the distillate from vacuum distillation of a samarium-iron alloy, contained 150 ppm oxygen, 80 ppm carbon, and 50 ppm iron as impurities. Gadolinium metal obtained as a residue from the distillation of a gadolinium-chromium alloy contained 300 ppm oxygen, 200 ppm carbon, and 100 ppm chromium.

RI 7309. Gamma and Beta Distribution Functions Applied to Size Distribution of Mineral Products, by Hillary W. St. Clair. November 1969. 33 pp. 3 figs. This report describes a mathematical procedure for analyzing size distribution data by the method of moments. The method was applied to Andreasen's data on a variety of grinding mill products. It was found that the observed size distributions could be represented by gamma and beta distribution functions over a wide range of sizes. A computer program, written in BASIC, is described for calculating moments, distribution parameters, and the weight fraction in any size range.

RI 7310. Effect of Cetane Improvers in the Fuel on Nitrogen Oxides Concentration in Diesel Exhaust Gas, by H. W. Lang, A. J. Sippel III, and R. W. Freedman. October 1969. 5 pp. 2 figs. The Bureau of Mines conducted an investigation to observe the effect of cetane improvers upon nitrogen oxides concentration in diesel exhaust gas. Amyl nitrite and amyl nitrate were used as additives to the fuel used in a four-cycle, single cylinder type test engine. It was concluded that nitrogen oxide concentrations were not enhanced at fuel-air ratios above 0.03 pound of fuel per pound of air.

RI 7311. Relative Effects of Grouped Physical Variables on the Revenue-Cost System of a Lead-Zinc Mining Operation, by Richard E. Dawes. November 1969. 26 pp. 5 figs. Physical variables, a principal factor in the economies of mineral production, affect both capital and direct operating costs. By using a revenue-cost system for the framework, the analyses of revenue and cost categories demonstrate the relative importance of groups of physical variables, whether explicitly defined or not, to a lead-zinc mining operation.

Physical variables affecting the producer represent about 60 percent of the total system influence as expressed by cost ranking. Other physical variables affect the remaining costs as controlled by the smelter, the transporter, and the landowner. Such resource conservation aspects as mineral losses due to mining method and mineral processing constitute a portion of the total revenue effects of physical variables. The physical variable revenue-cost system presented in this report offers a framework for cost-benefit analysis of mineral related research.

RI 7312. Thermodynamic Properties of a Redlich-Kwong Fluid in the Two-Phase Region, by B. J. Dalton and Robert E. Barieau. December 1969. 181 pp. 114 figs. The Bureau of Mines Helium Research Center has as a long-range objective the development of an equation of state for helium that will allow all of the thermodynamic properties to be calculated within the accuracy with which they are known. If this objective is to be realized, a method of calculation must be known. This report gives the principles of the method used in such problems.

A computer program was developed for predicting these properties, including those at the critical point, that is perfectly general and applicable to any equation of state. To demonstrate the efficacy of the method, this computer program was used to evaluate thermodynamic properties of a Redlich-Kwong fluid in the two-phase region. Expressions for calculating various thermodynamic functions specific for this particular equation of state are derived. Numerical values are tabulated and graphs are presented for all functions calculated. It is shown that for a Redlich-Kwong fluid there are finite discontinuities in (1) the second temperature derivative of the Gibbs free energy or chemical potential at the critical point, (2) the second derivative of the vapor pressure curve with regard to the temperature on passing through the critical point, and (3) the measured heat capacity at constant volume on passing through the critical temperature when the calorimeter is filled to the critical density. It is also shown that the heat of vaporization is infinite for a Redlich-Kwong fluid at absolute zero.

RI 7313. High-Purity Zinc and Tin by Amalgam Electrorefining, by D. H. Chambers and A. W. Maynard. November 1969. 10 pp. 3 figs. The Bureau of Mines developed a process for producing high-purity zinc and tin by electrorefining from liquid amalgams. Commercial-grade metals were dissolved in mercury to produce saturated amalgams at room temperature. Amalgams were also prepared by electrolytic transfer from soluble anodes of the metals to a mercury cathode. Amalgams formed by both methods were used as anodes in electrorefining cells to produce high-purity cathodes. Metal impurities, excluding mercury, were at levels of less than 5 ppm in zinc and 9 ppm in tin. Mercury content was about 2 to 10 ppm in zinc products, and this was effectively removed by heating the cathodes in a vacuum. Mercury was excluded from tin cathodes by pumping the tin electrolyte through tin turnings and controlling the cell temperature.

RI 7314. Production of Metallic Concentrates From High-Silica Iron Ores, by H. D. Jacobs and R. B. Schluter. November 1969. 17 pp. 8 figs. The Bureau of Mines developed a concentration method to upgrade and utilize marginal natural or direct-shipping iron ores and fine-grained lean iron ores. Presently these ores receive little beneficiation and accordingly have low iron-silica ($Fe-SiO_2$) ratios. Ore samples were roasted with equal weights of solid reductant at 1,100° C for 1 hour to metallize the iron and for an additional hour at 1,200° C to promote grain growth. Concentration was effected by crushing and screening techniques and/or wet magnetic separation. Sized concentrates (minus 4 plus 35 mesh) derived from crushing-screening processes contained from 80 to 85 percent iron that was 90 percent metallized. Iron-silica ratios as high as 12:1 and iron recoveries from 75 to 94 percent were obtained. The sized concentrates were judged suitable for use as blast furnace feed. Minus 200-mesh metallized concentrates derived from roasted minus 1-inch plus 8-mesh ore fractions and magnetically concentrated contained 90 percent Fe and 4 percent or less SiO_2, chemically qualifying them as feed for electric furnaces. Roasting minus 8-mesh ore with hydrogen, then magnetically concentrating it, produced iron concentrates containing 57 to 67 percent Fe and 3.6 to 8.4 percent SiO_2. The concentrates having $Fe-SiO_2$ ratios ranging from 8:1 to 12:1 were considered adequate for use as blast furnace feed. Overall iron recoveries for the 12 ores tested ranged from 56 to 94 percent with an average iron recovery of 86 percent.

RI 7315. Refining Zinc-Base Die-Cast Scrap Using Low-Cost Fluxes, by D. Montagna and J. A. Ruppert. October 1969. 10 pp. 2 figs. Large quantities of zinc-base die-cast scrap containing 3 to 4 percent aluminum are presently refined by mixing with other secondary zinc products, such as galvanizer dross, and distilling in a retort. The Bureau of Mines investigated alternate aluminum removal processes utilizing low-cost fluxes. Basing the investigation on the metallurgical principle that a reactive impurity can be removed from a less reactive matrix metal by melting under a flux consisting of a salt or oxide of a metal less reactive than the impurity, three separate flux mixtures were studied. In the first flux system, $FeCl_3 + NaCl$, part of the aluminum is eliminated by the formation of volatile aluminum chloride and the rest by the creation of a high melting point iron-aluminum intermetallic compound that can be separated from the remaining molten zinc by filtration. Aluminum removal in the second system, $Fe_2O_3 + CaCl_2 + NaCl$, is effected by the formation of the iron-aluminum compound and possibly aluminum oxide. The third system, spent sal skimmings—essentially a mixture of $ZnCl_2$, NH_4Cl, and ZnO—depends solely on aluminum chloride formation. Of the three flux systems investigated, the best results obtained were with system 3. Aluminum was reduced in the molten die-cast alloy from 4.10 percent to 0.01 percent when depleted sal skimmings were used.

RI 7316. Chemical Reclaiming of Superalloy Scrap, by P. T. Brooks, G. M. Potter, and D. A. Martin. November 1969. 28 pp. 15 figs. This Bureau of Mines study describes a process for recovering nickel, cobalt, molybdenum, and chromium contained in complex waste superalloy grindings that, for lack of an economical domestic recovery process, are being largely marketed abroad. The process, devised by laboratory-scale operations, includes scrap preparation, dissolution of metalics in hot chlorinated acidic liquor, carbon adsorption, three successive solvent extraction separations, and selective chemical precipitations. Nearly 90 percent of the nickel, cobalt, molybdenum, and chromium were separated and recovered as oxides, carbonates, and basic sulfate products.

RI 7317. The Electrohydraulic Effect: Potential Application in Rock Fragmentation, by H. K. Kutter. December 1969. 36 pp. 21 figs. The pressure pulse generated by an underwater spark was investigated in relation to its potential use for rock fragmentation. The study established (1) the relation between the peak discharge current and the peak wave pressure; (2) the relationships among the peak wave pressure, the discharge voltage, and the spark gap width; (3) the type and pulse duration of the generated wave; (4) the percentage of energy transmitted in the spark as a function of spark gap width and discharge voltage; and (5) the percentage of energy converted into the pressure wave as a function of gap width and discharge voltage. Spark-generated fractures were studied in two- and three-dimensional rock and plastic specimens. The laboratory results indicated that the pressure pulse generated by an underwater spark is a potential practical tool for rock fragmentation. The paper contains an appendix describing the capacitive pressure gage specially developed for the laboratory tests.

RI 7318. Effect of Sodium Nitrate on the Incendivity of Explosives in Coal Dust-Gas-Air Mixtures, by C. M. Mason and P. A. Richardson. November 1969. 7 pp. 1 fig. A series of gelatinous permissible explosives was prepared with increasing sodium nitrate content and subjected to an improved technique for evaluating incendivity in coal dust-air and coal dust-gas-air mixtures. Those explosives containing an appreciable amount of sodium nitrate were found to be very hazardous in coal dust-air and coal dust-gas-air mixtures.

RI 7319. Selective Flotation of Minerals From North Carolina Mica Trailing, by W. H. Eddy, James S. Browning, and James E. Hardemon. November 1969. 10 pp. 1 fig. Laboratory batch and small-scale continuous flotation tests were conducted by the Bureau of Mines on a mica waste tailing from Kings Mountain, N.C., to determine the feasibility of producing high-quality mica, feldspar, and glass sand. Mica was recovered by two methods; one was by flotation in an alkaline circuit, which produced a mica concentrate assaying 92.0 percent mica with a recovery of 87.1 percent, and the other by flotation in an acid circuit, which produced a mica concentrate assaying 91.0 percent mica with a recovery of 79.4 percent. Continuous flotation processing yielded a feldspar concentrate assaying 1.10 percent Na_2O and 13.50 percent K_2O, with recoveries of 66.4 and 80.6 percent, respectively. The feldspar tailing was high-quality quartz glass sand analyzing 98.6 percent SiO_2 and 0.02 percent Fe_2O_3. Work done in cooperation with the University of Alabama.

RI 7320. The System Al_4C_3-AlN-Al_2O_3. Powder Forming and Sintering Behavior, Phase Identification, and Refractory Composition Properties, by Jack L. Henry, James H. Russell, and Hal J. Kelly. November 1969. 24 pp. 7 figs. The ternary system Al_4C_3-AlN-Al_2O_3 has been examined to determine compositions which may display desirable high-temperature refractory properties. Powder methods were employed in the synthesis of all test compositions. Forming and sintering behavior was examined and hot-pressing parameters were measured. Several properties were studied for each composition of interest in the system. The properties included hydrolysis rate in moist air, elevated temperature oxidation rate, density, softening point, tensile strength, and rupture strength. In most cases equilibrium was not achieved, and the data are representative of a nonequilibrium system. Approximately 16 separate phases have been observed in the system.

Forming behavior and selected properties of five compositions of interest were compared with those of aluminum oxide and aluminum nitride. None of the compositions compared favorably. Oxidation and vaporization appear to be serious drawbacks to the use of these compositions at elevated temperatures.

RI 7321. Sampling and Coking Studies of Several Coalbeds in the Kokolik River, Kukpowruk River, and Cape Beaufort Areas of Arctic Northwestern Alaska, by R. S. Warfield and Charles C. Boley. December 1969. 58 pp. 12 figs. Several reconnaissance-type surface and drill core samples of Arctic Northwestern Alaska coals were taken during the summer field seasons of 1964 and 1966 for coking studies. Surface samples were taken from the Kokolik River and the Cape Beaufort areas; core samples were obtained from the Kukpowruk River and the Cape Beaufort areas. Only one Kokolik River surface sample possessed coking properties. This sample, representing an 11.6-ft coal seam, made coke approaching metallurgical quality when a 30-percent portion of selected blending coals was added. Four Kukpowruk River core samples, each representing the same 19- to 20-ft coal seam, were all of about the same coking quality. No differences of coke quality attributable to depth of permanently frozen overburden were found, but the data confirm previously reported information that the 19- to 20-ft coalbed is a potentially satisfactory base coking coal. In the Cape Beaufort area, a core sample with appreciable coking properties was taken at depth from a coalbed determined to be noncoking from a surface sample.

RI 7322. Fluidized-Bed Low-Temperature Carbonization of Bituminous Coal and Thermal Cracking of the Tar Vapors, by W. S. Sanner, B. W. Naugle, and D. E. Wolfson. November 1969. 19 pp. 7 figs. A High Splint coal was carbonized in a low-temperature, fluidized-bed system to study the effects of thermal cracking on the products of decomposition. The coal was fluidized in recycle gas at 485° to 600° C, and the products were cracked at 600°, 700°, and 800° C in a bed of fluidized coke. Yields of tar, pitch, paraffins, and olefins decreased as carbonization temperature increased. Thermal cracking of the tar vapors produced the highest tar yields at 600° C, and light oil yield increased at cracking temperatures up to 700° C. At an 800° C cracking temperature, the yield of light oil decreased.

RI 7323. Heats of Formation of Three Oxides of Rhenium, by E. G. King, D. W. Richardson, and R. V. Mrazek. November 1969. 13 pp. Heats of formation of three crystalline oxides of rhenium (ReO_2, ReO_3, and Re_2O_7) have been determined by the method of solution calorimetry, using an aqueous perchloric acid—ceric perchlorate solvent. Copper metal and cupric oxide were utilized as auxiliary substances. Heats were determined at 298° K for the reactions $Re + 2CuO = ReO_2 + 2Cu$, $Re + 3CuO = ReO_3 + 3Cu$, and $2Re + 7CuO = Re_2O_7 + 7Cu$. Standard heats of formation were derived using the value of -37.23 ± 0.15 kcal/mole as the heat of formation of CuO.

The standard molal heats of formation of the rhenium oxides were determined: ReO_2, -107.3 ± 0.8 kcal; ReO_3, -140.8 ± 0.9 kcal; and Re_2O_7, -301.9 ± 1.8 kcal.

RI 7324. Preparation Characteristics of Coal From Beaver and Lawrence Counties, Pa., by J. E. Zeilinger. December 1969. 23 pp. 3 figs. This Bureau of Mines report describes the preparation characteristics of the significant coalbeds of Beaver and Lawrence Counties, Pa. Washability analyses were made on seven coalbed samples, none of which were of metallurgical quality as received. Five of the samples could be sufficiently upgraded to produce acceptable products, and the remaining two samples could not be upgraded to metallurgical quality because their sulfur contents could not be lowered to meet the standard. For steam or power generation, one sample was of low sulfur content as received, one sample could be upgraded to low sulfur content, and three samples could be upgraded to medium sulfur content. The original sulfur content of the remaining two samples can be appreciably reduced by removal of the sink 1.58 specific gravity material; however, these coals would be classified as medium sulfur coals both before and after removal of the sink material.

RI 7325. Storage Stability of Aviation Turbine Fuels. A Radiotracer Technique for Estimating Component Contribution to Thermally Induced Deposits, by Marvin L. Whisman, John W. Goetzinger, and Cecil C. Ward. December 1969. 23 pp. 13 figs. A radiotracer technique developed by the Bureau of Mines extends to the parts-per-billion range the sensitivity for determining contributors of deposits formed in stored and thermally stressed jet fuels. The method depends upon measuring radioactivity associated with thermally induced deposits from fuels containing one labeled compound. The technique was applied to 88 test blends, representing 12 fuels and nine carbon-14 labeled fuel constituents or fuel additives, or both. Data from results of these tests are included in this report. With this radiotracer technique, the contribution of fuel components and additives to thermally induced deposits in a variety of fuel environments was estimated before and after storage. Work done under an agreement with the Aero Propulsion Laboratory, Research and Technology Division of the Air Force, Wright-Patterson Air Force Base, Ohio.

RI 7329. Energetics of Percussive Drills—Longitudinal Strain Energy, by Robert G. Lundquist and Carl F. Anderson. December 1969. 23 pp. 11 figs. The Bureau of Mines compared longitudinal strain energy output of a percussive drill to energy determined by measuring maximum piston velocity. Strain gages were used to determine the strain-time waveform and its amplitude at seven levels of operating pressure and eight levels of thrust. The longitudinal strain energy was found to be approximately 14 ft lb less than the maximum piston energy at comparable operating conditions.

RI 7333. An Ultrasonic Method for Determining the Elastic Symmetry of Materials, by Thomas R. Bur, Richard E. Thill, and Kenneth E. Hjelmstad. December 1969. 23 pp. 10 figs. Symmetry theory, based on groundwork established in the study of single crystals and experimental procedures utilizing ultrasonic pulse velocities of spherical specimens plotted on equal area polar projections, enables the direct identification of a material's elastic symmetry system and the determination of its orientation, as well as the position of the elastic coordinate axes. The method is especially useful for elasticity studies of polycrystalline and amorphous materials for which this knowledge of symmetry is a prerequisite in determining the independent elastic constants. Projections based on theoretically derived velocities are given for a single crystal from each of the major crystallographic symmetry systems except the triclinic. Projections based on experimentally derived velocities are given for one brass and several rock spheres.

RI 7334. Suggested Orientation Conventions for Elastically Anisotropic Polycrystalline and Amorphous Materials, by Thomas R. Bur. December 1969. 9 pp. 1 fig. The order of identification and in some cases the magnitude of the elastic constants of an anisotropic material depend on the orientation of the cartesian coordinate axes with respect to a set of reference coordinate axes within the material; thus confusion will result unless standard orientations are used. In this paper the relationship between the cause (the internal fabric) and the effect (the elastic properties in this case) is discussed for single crystals and for polycrystalline and amorphous materials. While reference axes based on the cause are used in the IRE (Institute of Radio Engineers) standard for piezoelectric crystals, it is shown that a reference coordinate system that would be suitable and practicable for all anisotropic polycrystalline and amorphous materials must be based directly on a three-dimensional expression of the effect. The conventions offered are similar to the IRE standards for piezoelectric crystals but use the elastic coordinates of the wave surface which can be quite readily established experimentally as the reference coordinates.

RI 7335. An Ultrasonic Method for Determining the Attenuation Symmetry of Materials, by Thomas R. Bur, Kenneth E. Hjelmstad, and Richard E. Thill. December 1969. 8 pp. 2 figs. The amplitude of the first peak of an ultrasonic pulse which has traversed the diameter of a sphere is obtained for many directions in the sphere. This amplitude is relative to an input which is held constant for all measurements on a given sphere. Since the boundary conditions, distance of travel, and the controllable experimental factors are constant for all measurements, variations in this amplitude reflect variations in the attenuation or absorption with direction. The data are plotted and contoured as an equal area projection. The attenuation symmetry is the symmetry expressed by the contour pattern. Analysis of the data from several rock types indicates that the amplitude expresses a higher percentage of anisotropy than the velocity. In most cases the attenuation symmetry appears to be of the same system as the elastic symmetry expressed by the velocity. Results are shown for three rock spheres.

RI 7337. Mine Water Research. Catalytic Oxidation of Ferrous Iron in Acid Mine Water By Activated Carbon, by Edward A. Mihok. December 1969. 7 pp. 1 fig. Laboratory batch-flow tests conducted on a highly ferruginous acid mine water with an activated carbon showed that ferrous iron is rapidly oxidized. This indicates that air oxidation of ferruginous acid in mine waters is catalyzed by activated carbon. The ferrous iron content of an acid mine water flowing through an aspirated activated carbon column was reduced from about 700 to about 10 parts per million in less than 1 minute. Highly efficient ferrous iron oxidation was achieved by conditioning the activated carbon by repeated treatment with acid mine water and air. The reaction proceeds rapidly in the acid environment (pH about 2.5) engendered by ferrous iron oxidation. The activated carbon was used repeatedly with little loss in efficiency, and no discoloration or solids deposition. In these batch tests, about one-third of the iron was adsorbed by the carbon, but with continuous flow, little iron adsorption is expected. Incorporating a catalytic oxidation step in the treatment of acid mine waters containing ferrous iron would greatly facilitate neutralization —precise control of pH, lower reagent costs, elimination of aeration equipment, and smaller holding ponds.

RI 7350. Dismantling a Typical Junk Automobile To Produce Quality Scrap, by Karl C. Dean and Joseph W. Sterner. November 1969. 17 pp. 1 fig. All components of 15 automobiles manufactured between 1954 and 1965 were analyzed, and it was determined that a representative junk automobile would have the following composition (all figures in pounds): steel, 2,532; cast iron, 511; copper, 32; zinc, 54; aluminum, 51; lead, 20; rubber, 145; glass, 87; miscellaneous, 142. Time and motion studies and a cost evaluation were made to determine if such a typical vehicle could be economically burned in a smokeless incinerator and hand-dismantled, and if the resultant steel could be baled into a high-quality No. 2 bundle containing less than 0.10 percent copper. The cost evaluation showed that processing the composite car would cost about $51 to produce about $56 worth of marketable ferrous and nonferrous metal products and provide an annual rate of return on investment of 19 percent.

INFORMATION CIRCULARS

IC 8225. Copper: A Materials Survey, by A. D. McMahon. 1965. 340 pp. 37 figs. Summarizes the demand-supply position in the United States and includes information on production, consumption, imports, exports, capacities, substitutes, and pertinent history. The properties and uses of copper and its principal alloys and compounds are described. Exploration, mining, metallurgical, and fabrication methods are discussed. Domestic and foreign primary and secondary resources and reserves are covered. An extended presentation of the structure of the industry, employment and productivity, research and development, legislation, taxes, and Government wartime controls is included. $1.75.

IC 8241. Analyses of Natural Gases of the United States, 1963, by Richard D. Miller and Geraldine P. Norrell. 1965. 102 pp. 1 fig. Contains routine analyses and related source data for 295 natural gas samples from 18 States collected during calendar year 1963 as part of a continuous survey of the United States for occurrences of helium in natural gas. This survey has been conducted by the Bureau of Mines since 1917. The analyses published herein were made by mass spectrometer and a special helium analysis apparatus, which are described in Bulletins 486 and 576. *(Out of print.)*

IC 8244. Minerals for Chemical Manufacturing. A Survey of Supply and Demand in California and Nevada, by Wallace W. Key. 1965. 164 pp. 16 figs. Results of the first detailed survey of mineral raw materials consumed for chemical manufacturing in California and Nevada are presented and analyzed from the standpoint of supplier and would-be supplier, as well as from the consumer and potential-consumer viewpoint. Data are included on over 50 inorganic mineral commodities and their uses by 800 California chemical plants which manufacture thousands of products under 31 different categories. The results of this study indicated certain changes in use patterns of minerals in chemical manufacturing; a shift in requirements from metals to nonmetals, from inorganics to organics, from natural to synthetic materials, and from distant to local sources of supply.

IC 8245. A Survey of Experimental Methods for Determining Enthalpies of Fluids, by Robert E. Barieau. 1965. 21 pp. Surveys the various methods that have been used to determine enthalpies and gives information on the organizations with such capabilities. The minimum information required for developing an enthalpy diagram is presented, and the relative merits of the various methods are discussed. It is concluded that methods that require no mass flow rate or energy measurements are to be preferred.

IC 8248. Quartzite Mining and Processing Methods and Costs at the Honey Brooke, Pa., Plant of George F. Pettinos, Inc., by A. T. Harris, Jr., and W. T. Millar. 1965. 21 pp. 11 figs. Describes the mining and processing methods for producing ground quartzite, known in the industry as amorphous silica, from a quartzite deposit near Honeybrook, Pa., by George F. Pettinos, Inc., and gives data on mining and processing costs. The quartzite is mined by the open-pit method. A mill at the mine regularly produces five standard grades of sand and one grade of crushed stone. Beneficiation is controlled by laboratory screen tests on samples taken during the preparation of the sand. Chief uses are for foundry operations, furnace lining, concrete aggregate, and other specialized uses.

IC 8249. Active List of Permissible Explosives and Blasting Devices Approved Before Jan 1, 1965, by N. E. Hanna and P. A. Richardson. 1965. 10 pp. Gives all permissible explosives (gelatinous and nongelatinous) and permissible blasting devices on the Bureau of Mines active list as of January 1, 1965, and shows all changes, additions, and transfers since February 28, 1961. Supersedes IC 8087.

IC 8250. Oilfields in Mahoning, Columbiana, Carroll, Jefferson, and Harrison Counties, Ohio, by Charles E. Whieldon, Jr., and C. I. Pierce. 1965. 20 pp. 11 figs. Gives data on the oilfields in Mahoning, Columbiana, Carroll, Jefferson, and Harrison Counties that were collected from scattered sources and compiled to make the information readily available to operators who may be interested in conducting secondary-recovery operations in the area. Presents general geology, oil production, oil-productive acreage, core data, reservoir calculations by townships, and miscellaneous data and reference material.

IC 8251. Coal Carbonization in the United States, 1900–62, by Eugene T. Sheridan and Joseph A. DeCarlo, 1965. 83 pp. 34 figs. Summarizes the history of the coke industry in the United States and describes significant trends and developments in coke-plant technology. Contains basic statistical tables on production of coke, coke breeze, and coal chemicals from 1900 to 1962.

IC 8252. Mercury Potential of the United States, by Bureau of Mines Staff. 1965. 376 pp. 16 figs. All mercury mines or prospects in the United States which have had any significant production have been described in reasonable detail, and all known mercury mines, prospects, or occurrences and the salient facts concerning each have been tabulated. This portion of the report provides a complete reference of mercury properties. Gives an engineering evaluation of mercury production potential at various price levels, ranging from $100 to $1,500 per flask (76-pound flask). This determination of resources available at high incentive prices gives a better overall picture of the domestic mercury industry's basic position and future than does a consideration of only those reserves competitive in present world markets. $1.75.

IC 8253. Rock-Dust Disseminator Used in Return Air Currents, Koehler Mine, Kaiser Steel Corp., Koehler, N. Mex., by A. Z. Dimitroff and A. C. Moschetti. 1965. 7 pp. 5 figs. An improvised rock-dust disseminator, consisting of a 10-gallon galvanized metal milk can that dispenses rock dust in return air currents by the injection of compressed air has reduced the float-dust explosion hazards at the Koehler coal mine. Because of its simplicity, its low operating cost, and the excellent results obtained, this disseminator may have valuable application in many underground coal mines. Its main advantage is the placing of rock dust into suspension at the same time float dust is in suspension so that both dusts settle out in a mixture. Once the dusts are intermingled in suspension, they are carried by the ventilating air currents into return airways, gobs, and caved areas.

IC 8254. Research and Technologic Work on Explosives, Explosions, and Flames: Fiscal Year 1963, by the Staff, Explosives Research Center. 1965. 35 pp. 10 figs. The principal activities of the Explosives Research Center are described briefly in part 1. Part 2 gives short abstracts of publications that appeared during fiscal year 1963; in general, the research reported in these publications was made before fiscal year 1963.

IC 8255. The Sulfur and Sulfuric Acid Industry of Eastern United States, by James R. Kerr, Lenox H. Rand, and James L. Vallely. 1965. 92 pp. 6 figs. Output of sulfur in the East is relatively small, and most of the area's sulfur requirements are met by gulf coast Frasch sulfur. Over the long term, recovered elemental sulfur from sour natural gas and petroleum may become the East's major source of sulfur. In 1958 sulfuric acid manufacture consumed over 80 percent of the area's sulfur requirements. The leading uses for sulfuric acid were the manufacture of superphosphates and chemicals. Over the years, unit requirements for sulfur and acid in many major markets have been reduced through improved technology, but new markets always have been developed to keep the industry vital and growing.

IC 8256. Recommended Safety Precautions for Active Coal Stockpiling and Reclaiming Operations, by R. W. Stahl and C. J. Dalzell. 1965. 7 pp. 5 figs. Gas accumulation and dust suspension are the major safety hazards in coal stockpiling and reclaiming operations. This report presents a schedule of safety precautions and plant design features devised by the Bureau of Mines to reduce danger from these and other sources.

IC. 8257. Silver: Facts, Estimates and Projections, by C. W. Merrill, E. T. McKnight, Thor H. Kiilsgaard, and J. Patrick Ryan. 1965. 22 pp. 3 figs. U.S Treasury stocks of silver have been reduced at such a rapid rate to meet industrial and coinage requirements that they may be exhausted in 3 or 4 years. This report shows that alleviation of the silver problem will require increasing supply or reducing demand. Examines possible long-range resource development and research programs and improved secondary recovery. Discusses possible reduction or elimination of silver in coinage and development and introduction of substitutes in the arts and industry. Work done under an agreement with the Geological Survey.

IC 8258. Fire and Exposion Hazards in Fluidized-Bed Thermal Coal Dryers, by H. A. Schrecengost and Maurice S. Childers. 1965. 21 pp. 4 figs. Fire and explosion hazards are inherent in certain types of coal dryers in that (1) high temperatures are employed, (2) the sizes and volatility of material handled are capable of propagating explosions, and (3) drying gases are seldom, if ever, low enough in oxygen content to prevent ignitions of dust clouds, distilled gases, or their combinations. This is especially true for fluidized-bed dryers in which the coal is dried in air suspension and in which atmospheric gas is constantly introduced to temper the heat furnace gases. Occurrence of fires on heated bedplates, in dust collectors, and in hot gas inlets was common in nearly all the dryers examined. Forceful explosions which produced external effects had occurred in 11 (39 percent) of the plants examined and internal "puffs" or "bumps" had occurred in at least 24 (79 percent).

IC 8259. Petroleum Coke on the West Coast of the United States. Its Production, Utilization, and Role in the Conservation of Petroleum, by William J. Kemnitzer and Curt D. Edgerton, Jr. 1965. 80 pp. 10 figs. Shows the growth of petroleum coking, determines trends and characteristics of marketing and utilization of coke on the west coast, and compares these data with those of the United States as a whole. Increasing coke production as well as significant market shifts away from California-produced coke have created excessive stocks of petroleum coke on the west coast. The causes of these market shifts were based mainly on economic factors and certain undesirable qualities of some of the petroleum coke produced in California.

IC 8260. Mineral Fillers for the California Pesticide Industry, by Wallace W. Key. 1965. 39 pp. 4 figs. The objectives of this report are to provide data on quantities, sources, specifications, and market conditions for minerals—clay, talc, limestone, diatomite, sulfur, and other minerals—used as fillers by California pesticide formulators. Specifications for mineral fillers have become more rigid and formulators have become more numerous in recent years. During 1962 over 1,200 firms registered 16,000 pesticide products with the Bureau of Chemistry in California. Factors which will tend to diminish future need for mineral fillers include the trend toward greater use of organic sprays rather than dusts and further development of biological controls, such as the development of sterile insect strains.

IC 8261. Brown Iron Ore Resources: Barbour, Butler, Crenshaw and Pike Countries, Ala., by James F. O'Neill. 1965. 59 pp. 6 figs. Brown iron ore resources in Barbour, Butler, Crenshaw, and Pike Counties were investigated in a drilling program and geological study by the Federal Bureau of Mines in cooperation with the Alabama Geological Survey and the University of Alabama. While an indicated 2,198,000 dry long tons of usable iron ore can be recovered, sink-and-float tests show that it may be possible for 4,654,000 dry long tons to be recovered by other than log washing. However, applicable commercial processes have not been demonstrated.

IC 8262. Minerals and the New Tariff Schedules of the United States, by F. J. Kelly. 1965. 154 pp. Reviews those portions of the Tariff Schedules of the United States Annotated 1963 that are of interest to the minerals industry. Shows to what extent rates of duty were altered and provides a bridge where possible from the old Schedule A classification system to the new TSUS system of statistical reporting of import data.

IC 8263. Heavy Crude Oil Reservoirs in the United States: A Survey, by W. D. Dietzman, M. Carrales, Jr., and C. J. Jirik. 1965. 53 pp. 1 fig. Report presents general information on more than 2,000 heavy oil reservoirs in more than 1,500 fields in 26 states. Information given on each heavy-oil deposit includes the following items: Field and formation, location, average or range of depth, average API gravity of oil, average thickness of formation, area extent of field, total productive wells drilled in field, discovery date of field, field status in 1963, cumulative production to January 1, 1964, and all known types of secondary-recovery initiated (active and terminated) in the reservoirs. The geographical location of heavy oil accumulations in the United States is shown by a map, and a brief discussion of 14 different areas is more than 10 billion barrels of oil and are estimated given. As af January 1, 1964, 75 percent of the heavy-oil reservoirs in the United States had produced more than 10 billion barrels of oil and are estimated to contain over 90 billion barrels of oil in place. It is also estimated that if the deposits which have had little or no production history, such as the one in Missouri, were included, the total remaining heavy oil in place would be in excess of 150 billion barrels. To find economical ways of recovering this vast reserve of heavy oil, industry is developing technology in several types of thermal-recovery methods. Some of the general considerations and more suitable limitations in selecting a prospect to study for thermal-recovery techniques are lithology, depth, viscosity of reservoir fluids, gravity of oil, reservoir thickness, oil in place, and permeability and porosity. Work done in cooperation with the Independent Petroleum Association of America.

IC 8264. **Brown Iron Ore Resources; Quitman County, Ga.**, by James F. O'Neill. 1965. 29 pp. 1 fig. Brown iron ore deposits in Quitman County were investigated; 91 holes were drilled, having an aggregate footage of 2,188 feet, and 71 holes penetrated 248 feet of iron mineralization. Average thickness of the ore zone was 3.5 feet under an average thickness of 14.7 feet of overburden. Drilling developed inferred reserves of nearly 30 million long tons of crude ore with an average analysis of 28 percent iron plus minor quantities of manganese. Tests indicated that the ore could be upgraded by current log washer practice, with the use of a ⅛-inch screen, and yield 4.4 million dry long tons of concentrate with an average analysis of 52.1 percent iron plus manganese. The weight recovery obtained was 14.7 percent. Studies showed that the weight recovery would be increased by changing the screen size without any appreciable sacrifice of grade. The average weight recovery was increased to 18 percent with a 10-mesh screen and to 22.8 percent with a 20-mesh screen. Screen-test studies indicated that there was no appreciable interlocking of the iron and manganese minerals and the clay and silica waste particles of the materials were retained on a 200-mesh screen. Clay was prominent in micron-size slimes. Silica was deleterious in the minus 20-mesh size. Work done in cooperation with the University of Alabama and the State of Georgia, Department of Commerce.

IC 8265. **Bibliography of Investment and Operating Costs for Chemical and Petroleum Plants. January-December 1964**, by Sidney Katell and William C. Morel. 1965. 132 pp. Contains abstracts of 767 articles or publications dealing mainly wth construction and operating costs. Other subjects covered include cost-estimation methods and theory, reports on construction projects, nuclear developments, water desalination and purification, and increasing use of computers in the process and development industry. Discusses such subjects as the following: Studies of the feasibility and economics of combination nuclear energy-water desalination plants, forecasts for the petroleum and chemical industries, developments in the beneficiation of low-grade iron ores, and cost comparisons between nuclear and coal-fired powerplants. Includes subject and author indexes. Work done in cooperation with American Association of Cost Engineers. *(Out of print.)*

IC 8266. **Review and Evaluation of Silver-Production Techniques**, by C. H. Schack and B. H. Clemmons. 1965. 41 pp. 14 figs. Extractive metallurgy techniques currently employed to recover silver from primary ores and secondary scrap are reviewed and evaluated to identify and delineate metallurgical problems whose resolution would increase the supply of silver from domestic materials. Practically all primary silver is recovered by froth flotation concentration of various types of ore, followed by smelting and refining of the separate lead, copper, and zinc concentrates. Any silver production gain from base metal ores, which contribute about two-thirds of the total primary silver, is directly dependent on improvement in the market for base metals. Statistical data on old and new silver scrap are inadequate to make reliable conclusions about increasing the recovery of silver from secondary sources. Available information indicates that efficient reclamation practices are employed by large users of silver and that recovery of additional secondary silver involves solutions of problems of collection rather than processing. Limited increases in silver production might be achieved by solving the problem of recovering silver from copper ores of the Copper range district, Michigan, and by devising economically feasible methods for recovery of silver from presently marginal or submarginal ores.

IC 8267. **Economic Trends in the Pacific Northwest Aluminum Mill Products Industry**, by Frank B. Fulkerson and Jerry J. Gray. 1965. 36 pp. Three of the five primary aluminum producers in the Pacific Northwest have facilities in the region to make aluminum mill products. Only one of the three produces a variety of shapes and forms. Principal reason for the lag in development of an aluminum mill products industry was found to be transportation cost. The long-range outlook is for expansion based mainly on growth of the western market for aluminum used in construction, containers and packaging, electrical applications, diesel trucks, mobile homes, and irrigation pipe. Consumption of western aluminum mill products in 1985 is projected at 1.1 million tons, compared with consumption of 250,000 tons in 1961.

IC 8268. **Zircon: A Review, With Emphasis on West Coast Resources and Markets**, by A. J. Kauffman, Jr., and Dean C. Holt. 1965. 69 pp. 9 figs. Compiles data on the zircon resources of the Pacific Northwest States, Alaska, and California, to determine the productive capability of industrial concerns to make ductile zirconium and hafnium, and to investigate markets for the nonmetallic products of zircon. West coast zircon resources are large but mostly marginal to submarginal. Development of a stable and profitable zircon mining industry on the west coast will depend upon recovery and utilization of the other associated heavy minerals needed by regional and national markets. The west coast has the only completely integrated facility for processing zircon sand to reactor-grade zirconium and hafnium and for making fabricated products from these metals. The future of the zirconium metal industry appears to be good because of increased use of the metal for nuclear propulsion and power-generating plants.

IC 8269. **Mining Methods and Practices at the Young Mine, American Zinc Co. of Tennessee, Jefferson County, Tenn.**, by James R. Boyle and Lloyd Williams. 1965. 27 pp. 18 figs. The mining methods and practices used at the Young zinc mine have resulted in a low-cost, high-yield operation. Zinc ore (sphalerite) occurs in limestone dolomite beds of the Kingsport Formation and is mined by modified room and pillar method. Utilizing trackless mining equipment which incorporates a high degree of flexibility, this operation has had a steady increase in productivity. *(Out of print.)*

IC 8270. **Water Utilization and Conservation by Petroleum Refineries in California**, by Curt D. Edgerton, Jr. 1965. 24 pp. 1 fig. This study was made to determine trends in fresh water usage by California petroleum refineries, to forecast fresh water requirements to 1975, and to evaluate water conservation practices.

The 1963 fresh water intake by California petroleum refineries was 84 million gallons per day. This is expected to increase to 128 million gallons per day by 1975. The fresh-water to crude-oil ratio is increasing in all regions except the Southern San Joaquin Valley. At present, the supply of fresh water available to almost all of the State's petroleum refineries, mostly from surface sources and company-owned wells, is adequate, although shortages may develop within the foreseeable future. Present conservation methods are centered around these four objectives: (1) Minimum intake of fresh water of the lowest possible quality commensurate with sound technologic practice; (2) optimum recirculation; (3) proper treatment before discharge; and (4) substitution of air cooling for water cooling.

IC 8271. **Block-Caving Copper Mining Methods and Costs at the Miami Mine, Miami Copper Company, Gila County, Ariz.,** by W. R. Hardwick. 1965. 96 pp. 50 figs. Describes the development of block-caving methods and practices by the Miami Copper Co. at the Miami mine. Gives a history of the district and outlines early prospecting and exploration including methods of sampling and estimation of ore tonnage and value at the Miami mine. Early mining methods are described, particularly those that influenced developments in the caving method. Mine exploration, development, and operating methods for block caving are described with particular attention to those factors, physical, economic, engineering, and managerial that have improved efficiency in the mining operations over a long productive period. Extraction, ventilation, wage system, safety, water supply, powerplant, and shop facilities are discussed. The last section gives a brief summary of such costs as are available for publication. *(Out of print.)*

IC 8272. **Research and Technologic Work on Explosives, Explosions, and Flames: Fiscal Year 1964,** by the Staff, Explosives Research Center. 1965. 31 pp. 13 figs. Part 1 describes briefly the principal activities of the Bureau of Mines Explosives Research Center from July 1, 1963, to June 30, 1964. Part 2 gives short abstracts of publications that appeared during fiscal year 1964; in general, the research reported in these publications antedates the report period. Part 3 describes a short-term investigation into safety problems associated with shipping of molten sulfur; this investigation is not at present destined for publication elsewhere. *(Out of print.)*

IC 8273. **Mining Method, Technique, and Cost of Splitting the Flood Control Gate Shaft, Littleville Dam, Huntington, Mass.,** by Rolf S. Paine and N. A. Eilertsen. 1965. 28 pp. 19 figs. The Bureau of Mines studied the presplitting technique used for controlling overbreakage in the walls of a vertical shaft at the U.S. Army Corps of Engineers Littleville Dam project near Huntington, Mass. The periphery of the shaft, the dimensions of which were 16½ feet wide by 21 feet long and 52 feet deep, was presplit (cracked) in the solid to a depth of 48 feet prior to full-depth sinking. Presplitting prevented overbreak in a fairly soft schist and provided sound self-supporting walls which required very little scaling.

IC 8274. **Microfilming Maps of Abandoned Anthracite Mines. Mines of the Eastern Middle Field,** by Ralph H. Whaite. 1965. 18 pp. 6 figs. Describes the Bureau of Mines program for microfilming maps of abandoned mines in the Pennsylvania anthracite region. A catalog of the maps that have been microfilmed in the Eastern Middle anthracite field—the first area to be covered in the programs—is presented. Additional catalogs will be published as significant mining areas are completed.

IC 8275. **Index Numbers for the Mineral Industries,** by Edward E. Johnson. 1965. 85 pp. 38 figs. The Bureau of Mines publishes in its Minerals Yearbook a series of indexes on the domestic minerals industry. Among these are the index of physical volume of mineral production, indexes of stocks, and indexes of average unit mine value and implicit unit value. This report describes the material coverage of these indexes and the methods used in their construction. Detailed descriptions are given for several other mineral-oriented indexes regularly published by other Government agencies. These descriptions give the index user a better understanding of what each index purports to measure and aids him in selecting the most appropriate index for his purpose.

IC 8276. **Water Requirements and Uses in New Mexico Mineral Industries,** by M. M. Gilkey and Ronald B. Stotelmeyer. 1965. 113 pp. 59 figs. This report on water requirements for the New Mexico mineral industry includes data on industrial operations closely related to mineral production. Background data are presented regarding the geography, hydrography, and water laws of New Mexico, as well as annual precipitation and evaporation problems in the State. Water systems at 46 operations are illustrated by schematic waterflow diagrams. Reported costs of the self-supplied new water range from 1 to 20 cents per 1,000 gallons and average 8 cents per 1,000 gallons for power and maintenance. Inadequacy of the supply of new water at many operations necessitates large-scale recirculation. Reported costs for recirculating water (power and maintenance) average 1.8 cents per 1,000 gallons.

IC 8277. **Bureau of Mines Research and Technologic Work on Coal, 1964,** by Bureau of Mines Staff. 1965. 118 pp. 50 figs. Twenty-ninth in a series, report describes research and related activity carried out by the Bureau during 1964 in the fields of coal mining; health and safety; explosives research and testing; coal storage, preparation, and transport through pipelines; electric power generation; coke, char, and chemicals from coal carbonization; fluid fuels and chemicals from coal by synthesis processes; new uses for coal and related products; composition and properties of coal and related products; chemistry of coal; analytical and test procedures; inspection, sampling, and analysis. *(Out of print.)*

IC 8278. **Iron Resources of South Dakota,** by C. M. Harrer. 1966. 160 pp. 35 figs. Iron occurrences in South Dakota and the associated resources—limestone and bentonite, coal-lignite, petroleum and natural gas, power, and water—are evaluated. Results of beneficiation tests on South Dakota taconite are discussed. In addition, pertinent features of taconite development, cost factors, the Western and Central United States trade area and markets are reported. Production of iron ores until 1963 has been small and for purposes other than the manufacture of iron. This investigation disclosed the probability of large resources of taconite in Pennington and Lawrence Counties. The average iron content is 29 percent, and a 65-percent or better iron concentrate might be produced. Ample resources are available for mining and processing taconite. An investment of at least $26 million would be required for a plant capable of turning out 1 million tons of agglomerated iron concentrate per year. The feasibility of such an enterprise is indicated, but intensive investigation and research must be completed to justify such an investment.

IC 8279. **Coal Research Organizations: Worldwide Activities and Publications,** by Mary S. Esfandiary and Harry Perry. 1966. 37 pp. This revision of a work published in 1961 includes the names and activities of coal research organizations of various types—government, university, private, and industry. The areas of investigation that each organization is engaged in are indicated in broad terms: Analysis and constitution, mining and geology, preparation, briquetting, combustion, high- and low-temperature carbonization, gasification, conversion to solid and liquid fuels, and health and safety. Publications issued by and describing the work of each organization are cited; almost all of the organizations also publish results of their investigations in the technical press. Selected technical and trade publications that publish information on the science and technology of coal and are not published directly by any of the organizations listed are cited in the pages following the list of organizations in each country. Work done in cooperation with Bituminous Coal Research, Inc.

IC 8280. Mining Methods and Costs at Section 23 Uranium Mine, Homestake-Sapin Partners, McKinley County, N. Mex., by W. E. Young and D. T. Delicate. 1965. 48 pp. 30 figs. Presents the mining methods and costs of a uranium mine typical of mines in the highly productive Westwater Canyon member of the Morrison Formation in New Mexico. Four mining methods have been used: The retreat-room-and-pillar method, a sublevel-slicing method (also called top-slicing), the horizontal-cut-and-fill method, and a modification of the ring-drill method. The application of the methods at this mine should be of benefit to operators with similar problems. Ore bodies in the mine are irregularly shaped and vary in size, in rock strength, in moisture content, and in uranium concentrations; different mining methods are required and mining costs are not constant. A 6-month period of operation was analyzed and mining costs, not including amortization, depreciation, or Federal taxes, averaged about $6.80 per ton.

IC 8281. Respiratory Protective Devices Approved by the Bureau of Mines as of October 1, 1965, by R. H. Schult, B. I. Ferber, and E. J. Kloos. 1966. 22 pp. Presents a list of all approved respiratory-protective devices. Devices that are currently manufactured and sold are listed with the manufacturer's current designation. Inactive devices, listed in appendix A, are no longer manufactured, but retain their Bureau of Mines approval status. The addresses of the manufacturers of approved active respirators are listed in appendix B. (*Out of print.*)

IC 8282. Survey of Sulfur Reduction in Appalachian Region Coals by Stage Crushing, by A. W. Deurbrouck and E. R. Palowitch. 1966. 37 pp. 1 fig. Reviews available data on the effect of crushing high-sulfur coals for the liberation of impurities in the light of increasingly stringent air pollution regulations. The survey, which provided information on Appalachian region coals only, indicates that such important coalbeds as the Upper and Lower Freeport and the Upper Kittanning show significant sulfur reductions when crushed to 14-mesh top size. For many other coalbeds amenability to sulfur liberation by crushing is indicated, although too few samples were available to draw firm conclusions. Work done under an agreement with the Public Health Service, U.S. Department of Health, Education, and Welfare.

IC 8283. Computing Reserves of Mineral Deposits: Principles and Conventional Methods, by Constantine C. Popoff. 1966. 113 pp. 51 figs. Reviews and analyzes, by a simple analytical and logical reasoning, the conventional methods of reserve computations of mineral deposits described in various domestic and foreign publications. It brings together, formulates, and evaluates the principles underlying interpretation of exploration data and ties such principles to the proposed classification of methods. The material is discussed in sufficient detail to allow general application.

IC 8284. Water Use in the Petroleum and Natural Gas Industries, by Paul M. Buttermore. 1966. 36 pp. 9 figs. Total new water use in the petroleum industry of the United States, excluding refining, was 5.3 billion barrels in 1962. Secondary-recovery operations and natural gas processing plants required about 2.5 billion barrels of new water input; each of these requirements was about eight times greater than that for well drilling, Total use, including recirculated water, was 45.3 billion barrels, of which 3.4 billion barrels was consumed. The greatest use of recirculated water was for natural gas processing, amounting to 38.2 billion barrels. Projections of total water use show that by 1975, 75.4 billion barrels will be used by the petroleum industry, of which 10.2 billion barrels will be new water. By 1985, the total use requirement will be 92.8 billion barrels, of which 13.1 billion will be new water. (*Out of print.*)

IC 8285. Water Use in the Mineral Industry, by Alvin Kaufman and Mildred Nadler (With Appendix on the Projection of Crude Material to 1985, by Barbara S. Lloyd). 1966. 58 pp. 15 figs. Analysis of 1962 water use indicates the following conclusions:

1. Total water use and new water intake is dependent on the quantity of material processed and the process water requirements of the particular industry or commodity.
2. Recirculation is dependent on the processing requirements of a particular commodity, the manner in which the water is used, cooling and condensing requirements in certain large industries, the quality of new water intake, and the need to treat new and discharged water.
3. Consumed water is dependent on the quantity of water recirculated, the temperature and humidity in the area, and the proportion of water used for cooling and condensing.
4. A threefold increase in water use by the mineral industry by 1985 is forecast. 40 cents.

IC 8286. Crude Oil: Qualitative and Quantitative Aspects. The Petroleum World, by Harold M. Smith. 1966. 41 pp. 14 figs. Presents the complete qualitative knowledge of the composition of petroleum as of April 1965. The material is presented in detail on two imaginative maps—the Hydrocarbon Hemisphere depicts the hydrocarbons that have been identified in petroleum, and the Heterogeneous Hemisphere shows the sulfur, nitrogen, and oxygen compounds that have been found. All compounds are placed on the maps according to boiling point. The accompanying text illustrates by structural formulas the several types of hydrocarbon and nonhydrocarbon compounds identified, presents some quantitative data, and points out the possible geochemical significance of a number of the compounds. The possibilities of the Petroleum World of the future are discussed as a function of needed research. 50 cents.

IC 8287. Injury Experience in Coal Mining, 1963. Analysis of Mine Safety Factors, Related Employment, and Production Data, by Forrest T. Moyer, Nina L. Jones, Mary B. McNair, and Virginia C. Berté. 1966. 86 pp. 3 figs. Includes data for 1963 on injury experience, with related employment statistics, at coal mines in the United States. These data are presented in tabular form under the following headings: general injury experience, selected injury experience, injury experience by States, major disasters, and historical coal-mine injury and employment data.

IC 8288. Water Requirements and Uses in Nevada Mineral Industries, by George H. Holmes, Jr. 1966. 66 pp. 40 figs. Contains information on the sources and adequacy of supply, requirements and uses, quality and costs, geography, hydrography, precipitation and evaporation characteristics, and Nevada water laws. Information also is given on the water requirements of one public utility powerplant and the source and consumption of water in four major cities. Water distribution at 24 operations is shown on schematic waterflow diagrams. Costs of delivering new water range from 2 to 26 cents per 1,000 gallons, with an average of 10 cents per 1,000 gallons for power and maintenance. Water supplies are adequate at most operations. Projection of water requirements indicates that the demand for new water will increase from 8.3 billion gallons in 1962 to 11.9 billion gallons in 1980, a 43-percent increase. Water requirements in the year 2000 are estimated at 14.8 billion gallons, an increase of 78 percent over 1962 water demand.

IC 8289. Iron and Steel Scrap in Arkansas, Kansas, Louisiana, Mississippi, Missouri, Oklahoma, and Texas, by Frank B. Fulkerson and Harry F. Robertson. 1966. 52 pp. 6 figs. Describes a study of the scrap iron and steel industry made to determine trends in processing, shipment, and consumption. Data were derived from statistical sources and through visits to scrap yards and steel mills. Dealers in 1963 supplied 1.8 million tons of iron and steel scrap to steel mills and foundries in the south-central area, compared with 2.1 million tons in 1955. Most of the scrap was processed and shipped within 200 to 300 miles of consuming centers. Exports provide a principal outlet for dealers along the gulf coast. The tonnage exported varies greatly from year to year. The largest scrap operations are in or near large cities, steel mill sites, or port cities for export of scrap. The short-run supply of prepared scrap seems to be inelastic to price changes; therefore, buyers probably are in a strong bargaining position at times of declining demand. One technological development is a press which can take complete automobiles with frames, wheels, springs, and other heavy parts still intact and reduce them to bundles. At Houston, Tex., and Kansas City, Mo., shredding plants reduce car bodies and other light scrap into flat pieces 4 to 6 inches in size.

IC 8290. Titanium Resources of the United States, by Edward C. Peterson. 1966. 65 pp. 17 figs. Recent studies indicate that the United States has substantial reserves of ilmenite, one of the major titanium minerals. However, the studies showed that sources of rutile, another important source of titanium, are limited. This paper summarizes and evaluates results and conclusions reached by the various investigations initiated by the Bureau of Mines and others pertaining to the titanium mineral resources of the Nation. Domestic occurrences of ilmenite that are economically exploitable by present-day beneficiation methods are found in Florida, New Jersey, New York, South Carolina, and Virginia. These deposits are estimated to contain 50.3 millions tons of titanium dioxide (TiO_2). Occurrences of ilmenite that cannot be processed economically under present technological conditions are found in California, Colorado, Minnesota, Montana, Oklahoma, Oregon, Rhode Island, and Wyoming. These reserves amount to 51.1 millions tons of TiO_2. Reserves of rutile found in the United States are estimated to be 1.8 to 2.1 million tons of TiO_2. Other than occurrences in Florida and South Carolina, rutile is found either in small scattered bodies or in deposits where the mineral cannot be recovered economically by present beneficiation methods. *(Out of print.)*

IC 8291. Gas Masks for Respiratory Protection Against Phosphine, by E. J. Kloos, L. Spinetti, and L. D. Raymond. 1966. 7 pp. 2 figs. The Bureau of Mines developed a test for evaluating gas masks designed to protect against phosphine gas; phosphonium iodide is used as a source of phosphine. Gas masks approved by the Bureau for respiratory protection against phosphine include the GMC-SS-1, Mine Safety Appliances Co.; the LG-10 and LG-10G, Willson Products Division, The Electric Storage Battery Co.; and the 084-PHOV-R, Acme Protection Equipment Co. *(Out of print.)*

IC 8292. Portable Methane Detectors. Effects of Gases in Mine Atmospheres, by H. A. Watson, R. L. Beatty, A. J. Beckert, and D. E. Dufresne. 1966. 12 pp. 4 figs. Laboratory tests on three commercial methane detectors, two combustion-type detectors and one interferometer-type detector, were made to determine their response to certain single and multiple flammable gases mixed with normal and abnormal air atmospheres. Although both types of detectors responded accurately to methane-normal air mixtures, they did not show correct concentrations for other single flammable gases in air. Uniquely, the response of the interferometer-type detector to hydrogen was in a negative direction. The effects of individual gases in multiple flammable gas mixtures were approximately additive. In oxygen-deficient atmospheres the methane response of the interferometer-type detector erred on the high side, but only in very low oxygen concentrations were the combustion-type detectors affected—showing low, erratic methane readings.

IC 8293. Analyses of 38 Crude Oils From Africa, by E. P. Ferrero and Dorothy T. Nichols. 1966. 47 pp. Analyses of 38 crude oil samples from 25 fields in Algeria, Libya, and Nigeria are presented in this report. The 38 crude oils are listed alphabetically by country and field. Also shown are the geographic and geologic sources of the samples analyzed, the companies that supplied the samples, the general characteristics and analytical and computed data, and the production for the fields from which the samples were obtained.

IC 8294. Methods and Costs of Constructing the Underground Facility of North American Air Defense Command at Cheyenne Mountain, El Paso County, Colo., by Merwin H. Howes. 1966. 69 pp. 52 figs. In constructing the NORAD Combat Operations Center, controlled blasting techniques were employed to achieve smooth walls and to avoid shattering the rock beyond excavation lines. Extraordinary measures were taken to stabilize the rock to permanently preserve the openings. Rock stabilization was accomplished by means of reinforced concrete and gunite linings, rock boltings, installation of chain-link fabric, and epoxy resin and cement grouting. A particular zone of weakness at a vital location was supported by exceptionally thick reinforced concrete lining, rock bolts, and cement grout.

IC 8295. Coal Resources of the Fabius-Flat Rock Area, Jackson County, Ala., by Reynold Q. Shotts and H. L. Riley. 1966. 36 pp. 10 figs. A study was made of the coal resources of an area in Jackson County, Ala., forming a part of the Flat Rock, Henegar, and Stevenson quadrangles. The area studied is a portion of the Plateau coalfield on Sand Mountain and is near the Tennessee Valley Authority's Widows Creek steamplant. Since no detailed geological study of this area had been published, some reconnaisance work was done. The coalbeds and adjacent strata such as sandstones, conglomeratic sandstones, and conglomerates were studied. Available drill logs, together with the areal geology, provided sufficient information to permit correlations of the coalbeds and an estimation of coal reserves. For all categories of reserves, computed on a regional basis, a total of 72,920,000 tons of coal more than 14 inches thick is estimated for the areas studied in the Stevenson, Flat Rock, and Henegar quadrangles. Of this tonnage, 40,001,000 tons is estimated to have less than 60 feet of overburden. The total measured coal reserves for the above three quadrangles are 16,359,000 tons, with 12,471,000 tons under less than 60 feet of cover.

IC 8296. Gas Masks for Respiratory Protection Against Amines, by E. J. Kloos, L. Spinetti, and L. D. Raymond. 1966. 5 pp. 1 fig. The Bureau of Mines evaluated all previously approved gas masks to determine their ability to provide respiratory protection against each of the following six selected amines: ethylenediamine, diethylamine, *n*-butylamine, ethylamine, methylamine, and hydrazine. Minimum requirements were a 24-minute service life at a flow rate of 64 liters per minute (32 liters per minute for hydrazine) and an amine concentration of 1.0 volume-percent (0.5 volume-percent for hydrazine). The three masks meeting these requirements were the LG4, Willson Products Division, The Electric Storage Battery Co.; the GMD-SS, Mine Safety Appliances Co.; and the 084-PHOV-R, Acme Protection Equipment Co. (*Out of print.*)

IC 8297. Bibliography of Investment and Operating Costs for Chemical and Petroleum Plants, January—December 1965, by Sidney Katell and William C. Morel. 1966. 115 pp. This report, covering the period January through December 1965, is a continuation of a series that began with the publication of Information Circular 7516 in October 1949. It is the seventh in a series of reports prepared in cooperation with the American Association of Cost Engineers. The abstracted articles are concerned with all phases of cost engineering in the field of chemical and petroleum plants and related subjects. They are from the following sources: 1. American Association of Cost Engineers Bulletin. 2. Bureau of Mines Information Circulars. 3. Bureau of Mines Reports of Investigations. 4. Chemical Engineering. 5. Chemical Engineering Progress. 6. Chemical Week. 7. Coal Age. 8. Coal. 9. Cost Engineering. 10. Hydrocarbon Processing and Petroleum Refiner. 11. Industrial and Engineering Chemistry. 12. Nucleonics. 13. Oil and Gas Journal. 14. Petroleum Management. 15. World Oil. The bibliography contains abstracts dealing with cost-estimating methods and theory in addition to construction and operating costs. Other subjects abstracted include capital spending, developments in the nuclear field, and reports on construction projects here and abroad. Work done in cooperation with American Association of Cost Engineers. (*Out of print.*)

IC 8298. Reconnaissance of Beryllium-Bearing Pegmatite Deposits in Six Western States: Arizona, Colorado, New Mexico, South Dakota, Utah, and Wyoming, by Henry C. Meeves, Clarence M. Harrer, Melford H. Salsbury, Albert S. Konselman, and Spencer S. Shannon, Jr. 1966. 34 pp. 3 figs. The Bureau of Mines, between 1956 and 1963, examined 18 major pegmatite districts in Arizona, Colorado, New Mexico, South Dakota, Utah, and Wyoming to evaluate their content of beryllium, a material in short domestic supply that has become increasingly important to modern industry. This examination report includes the salient statistics on the production of pegmatite minerals, other than quartz and feldspar, and brief descriptions of 170 specific pegmatite deposits.

IC 8299. Permissible Mine Equipment Approved by the Bureau of Mines During 1963–64. A Supplement to Bulletin 543 and Information Circular 8220, by F. R. Lee and R. L. Evans. 1966. 20 pp. Supplements Bulletin 543, Permissible Mine Equipment Approved to January 1, 1953, and Information Circular 8220, Permissible Mine Equipment Approved by the Bureau of Mines During 1953–62, and with these previous publications constitutes a complete list of permissible equipment through 1964. (*Out of print.*)

IC 8300. Use of Mineral Fillers, Granules, and Roofing Rock in California Asphalt-Consuming Industries, by Wallace W. Key. 1966. 56 pp. 6 figs. This report concerns types, quantities, specifications, and uses of nonmetallic minerals as a basis for improving their supply, conservation, and utilization. Supply-demand details concerning mineral fillers, roofing granules, and roofing rock used in asphalt are incorporated, along with highlights on production and sales of roofing, floor tile, and other related asphalt products of California. Comparable data for the United States are included. Although large quantities of commercially prepared mineral fillers are used in asphalt for paving and related applications in other States, addition of commercial fillers for these uses rarely is required in California because of the natural fines available. On the other hand, California manufacturers of asphalt products other than paving utilize about 300,000 tons of asbestos, diatomite, limestone, mica, soapstone, slate, and other nonmetallic minerals as fillers, mainly for roofing and flooring. Also, about 500,000 tons of roofing granules is produced in California, most of which goes into roofing manufacture in the State. In addition, a significantly large and growing tonnage of relatively coarse mineral aggregates is used on low-angle, built-up asphalt roofs to produce an attractive surface and offer protection against the elements. Nearly all minerals used in asphalt products manufactured in California come from local sources, except asbestos and mica, and there are indications that local deposits of these commodities could be utilized in some use categories.

IC 8301. Forms of Sulfur in U.S. Coals, by F. E. Walker and F. E. Hartner. 1966. 51 pp. The Bureau of Mines determined total sulfur and sulfur forms for coal from 283 countries in 29 States and 2 fields of the State of Alaska. Specifically, organic, pyritic, and sulfate sulfur were measured for approximately 2,900 samples, representing most of the coalbeds in the United States. 35 cents.

IC 8302. Analyses of Natural Gases of the United States, 1964, by B. J. Moore, R. D. Miller, and R. D. Shrewsbury. 1966. 144 pp. 1 fig. Publication contains routine analyses and related source data for 419 natural gas samples from 22 States collected during calendar year 1964 as part of a continuous survey of the United States for occurrences of helium in natural gas. This survey has been conducted by the Bureau of Mines since 1917. The analyses published herein were made by mass spectrometer and a special helium analysis apparatus, which are described in Bureau of Mines Bulletins 486 and 576. Six previous publications have been made to present the results of 6,293 gas analyses made by the Bureau of Mines Helium Activity, prior to 1964. The first three, Bulletins 486, 576, and 617, contain analyses and related source data on 5,214 gas samples collected from 1917 to 1961. The other three publications, issued as Information Circulars, supplement the three Bulletins and contain 1,079 analyses of samples collected in 1961, 1962, and 1963. This publication is the fourth annual publication which supplements the three Bulletins.

IC 8303. Manganese Occurrences in the Eureka-Animas Forks Areas of the San Juan Mountains, San Juan County, Colo., by William E. Young. 1966. 52 pp. 39 figs. There are many large rhodonite-bearing veins containing manganese in the Eureka-Animas Forks area of the San Juan Mountains in Colorado. The Sunnyside vein is the largest known vein in the area. As observed on the surface, the vein is mineralized over 8,000 feet and attains a maximum width of 200 feet. The average width of the vein and its branches and ramifications is 58 feet in the area that was mapped in detail. The weighted-average analysis of surface and underground samples from the northeastern extension of the Sunnyside vein is 8 percent manganese. Most other known veins in the area have a similar manganese content. The Hidden Treasure vein lies southeast of the Sunnyside-No Name-Mastadon vein. The weighted average of the analyses of surface and underground samples from this vein is 13 percent manganese. Exposures of the Scotia-Silver Chord vein are visible over a strike length of 4,000 feet on Treasure Mountain. Diamond-drill holes show that the vein contains 10 percent or more manganese to a depth of 400 feet. The vein has an average width of 28 feet. The Independence vein is exposed on the surface for a distance of 600 feet and has an average width of 6 feet. Three cut samples taken across the vein had an average content of 20.7 percent manganese. Sampling of the outcrops of eight veins in the Placer Gulch area also indicates manganese. Numerous other veins cropping out in the surrounding area are similar to the outcrop of the Sunnyside vein system mineralogically and are worth investigating.

IC 8304. Technology and Use of Lignite, Proceedings: Bureau of Mines—University of North Dakota Symposium, Bismarck, N. Dak., April 29–30, 1965, compiled by James L. Elder and Wayne R. Kube. 1966. 124 pp. 23 figs. The 1965 Lignite Symposium, the fourth in a series and the third sponsored by the University of North Dakota and the Bureau of Mines, was held at Bismarck, N. Dak., on April 29–30, 1965. These sysposia provide a forum for those interested in the technology and utilization of solid fuels, especially lignitic coals. As part of the meeting, a 200-mile field trip was taken including inspection of (1) the 200-megawatt, pulverized lignite-fired Leland Olds plant of Basin Electric Power Cooperative, under construction near Stanton, N. Dak.; (2) the site of the Glenharold mine of the Truax-Traer Coal Co., Division of Consolidation Coal Co., where a wheel excavator was being assembled; (2) the operating Beulah mine of Knife River Coal Mining Co., subsidiary of Montana-Dakota Utilities Co., near Beulah, N. Dak.; and (4) the 400-megawatt, hydroelectric Garrison Dam powerplant near Garrison, N. Dak. During the technical sessions, 13 papers were presented covering some of the recent trends, developments, and research in lignite technology. The text of these papers is compiled to provide a record of the symposium and to allow wider dissemination of the information. Proceedings of the previous symposia have been published.

IC 8305. Water Requirements and Uses in Montana Mineral Industries, by William N. Hale. 1966. 103 pp. 44 figs. This report gives a detailed study of water usage in the Montana mineral industries, along with projections for the future. The mineral industry of Montana in 1963 used 36.5 billion gallons of new water and reused or recirculated an additional 53.5 billion gallons, for a total water requirement or usage of 90 billion gallons. The petroleum industry was the major water user, followed by the copper and zinc industries. Many mineral industry operators provide their own water, and new water is withdrawn largely from surface sources. At present, sufficient water is available in rivers, streams, and reservoirs in Montana; however, shortages do exist locally near mineral industry operations using large quantities of water. Some is supplied from sources up to 44 miles distant. New water withdrawn by the State of Montana mineral industry is expected to increase from 36.5 billion gallons in 1963 to 51.5 billion gallons by the year 2000. The total-water requirement is expected to more than double or reach 182 billion gallons by the year 2000. 55 cents.

IC 8306. Research and Technologic Work at the Health and Safety Research and Testing Center: Fiscal Years 1960–65, by Staff, Bureau of Mines. 1966. 31 pp. 9 figs. This report describes the activities and publications of the Bureau of Mines Health and Safety Research and Testing Center, Pittsburgh, Pa., for the fiscal years 1960–65. It includes a discussion of work being conducted on roof control, dust explosions, ventilation, health, coal mine fire control, and electrical-mechanical testing and an abstract of each paper published during the report period.

IC 8307. Fluorspar Deposits of New Mexico, by Frank E. Williams. 1966. 143 pp. 46 figs. This report describes 147 known fluorspar deposits in New Mexico and briefly mentions 54 miscellaneous occurrences for which little or no information was obtained. Most miscellaneous occurrences are minor and too poorly exposed to be considered more than prospects. History and production of fluorspar in New Mexico, type of deposition, mineralogy, uses, and grade specifications are discussed. Total mine production of fluorspar in New Mexico is nearly 641,000 tons of various grades of crude ore and hand-sorted material. Fluorspar deposits occur in 13 of the State's 32 counties. Grant, Valencia, and Luna Counties account for 86.4 percent of the total production. During the investigation, 141 deposits were visited. A total of 72 character samples was collected for assay, and 3 larger samples were collected for bench-scale metallurgical tests. Results of these metallurgical tests indicate that an acid-grade product can be obtained with 95-percent recovery of the CaF_2 content of the crude ore. 70 cents.

IC 8308. Research and Technologic Work on Explosives, Explosions, and Flames: Fiscal Year 1965, by Staff, Explosives Research Center. 1966. 19 pp. 2 figs. Major activities of the Bureau of Mines Explosives Research Center during fiscal year 1965 (July 1, 1964, to June 30, 1965) are reviewed briefly. Part 1 summarizes significant accomplishments of the projects that were active during the report period. Part 2 presents short abstracts of the publications that appeared in the Bureau series and in other media during fiscal year 1965. Publications issued after June 30, 1965, are noted, where pertinent, in footnotes but are not abstracted.

IC 8309. Review of Bureau of Mines Coal Program, 1965, compiled by John D. Spencer. 1966. 96 pp. 51 figs. Advances were made during 1965 in many phases of a broad program designed to increase efficiency in the mining, preparation, and utilization of coal. Also recorded were achievements in activities devoted to mine health and safety, coal resources, and mine explosives. Featured in this report is a review of progress in environmental studies relating to coal mining and utilization. Environmental projects comprise a comprehensive program to facilitate mine reclamation and reduce air and water pollution associated with extraction and use of coal. Publications cited throughout this report present results of the coal program in great detail. Organizations, institutions, and companies contributing to the program are listed in appendix A. Centers and laboratories conducting the coal research and related research appear in appendix B. (*Out of print.*)

IC 8310. Feldspar Resources and Marketing in Eastern United States, by Stanley A. Feitler. 1967. 41 pp. 13 figs. This Bureau of Mines report deals principally with the resources and economic aspects of feldspar in the United States east of the Mississippi River. Although in a strict sense, all phases of the feldspar industry affect its economic structure, emphasis in this study is on supply, demand, and marketing. Although feldspar was originally mined for use in the manufacture of pottery and other ceramics, the glass industry, which began to use feldspar in the mid-1920's, now consumes more than half of the annual output. Most mining is open cut, and the methods used are similar to those used in mining crushed stone. Excess plant capacity has been chronic, and production is usually about 50 percent of capacity for the industry as a whole. Since 1947, feldspar consumption has grown more slowly than the average for all U.S. industry. This has fostered intense competition, especially for the glass market. Prices have not kept pace with inflation, and profits are small. The trend of consumption through 1970 for glass feldspar is expected to be upward; less rapid growth in consumption of ceramic feldspar is anticipated. 30 cents.

IC 8311. A Thermal-Recovery Project and Two Waterflood Projects in Carter, Garvin, and Stephens Counties, Okla., 1966, by Kenneth H. Johnston and Kenneth R. Baskett. 1966. 32 pp. 10 figs. This publication describes a thermal-recovery project and two waterflood projects in Carter, Garvin, and Stephens Counties, Okla., that will be visited during the 1966 annual tour by the Bureau of Mines in cooperation with the Kansas-Oklahoma Waterflood Association. Among the unique features of the projects are (1) the movement of heavy (15° to 28° API gravity) crude oil through the reservoir and into the well bore with energy furnished by burning a portion of the crude oil therein; (2) the use of an inverted nine-spot pattern with dually completed injection wells, to produce oil from deep (8,200 to 10,200 feet) reservoirs; and (3) the flooding of five sand lenses separately by using controlled water injections through multizone completed injection wells. Discussion of the individual projects includes information on their early history, method of completing and operating wells, source and treatment of injection fluids, oil production decline curves, and the results obtained from the development. Work done in cooperation with the Oklahoma Corporation Commission, State of Oklahoma.

IC 8312. Sulfur Content of United States Coals, by Joseph A. DeCarlo, Eugene T. Sheridan, and Zane E. Murphy. 1966. 44 pp. 8 figs. This report attempts to show the sulfur content of the coal presently produced in the United States and to assess the remaining reserves of the various ranks of coal in each State, according to sulfur content. In most instances, the analyses used were those of cleaned coals. Coals have been arbitrarily separated, according to sulfur content, as follows: Low sulfur—1.0 percent or less; medium sulfur—1.1 through 3.0 percent; and high sulfur—3.1 percent or more. 30 cents.

IC 8313. Salt Domes in Texas, Louisiana, Mississippi, Alabama, and Offshore Tidelands: A Survey, by M. E. Hawkins and C. J. Jirik. 1966. 78 pp. 22 figs. This report provides information on all of the 329 proved salt domes in the Gulf Coast States and offshore area of the United States. It includes specific data related to location, depth to the cap rock and to the salt, storage facilities for LPG, and production of salt, sulfur, petroleum, and rock related to or associated with the dome structure in the subject area. Also included is a brief history of the salt, sulfur, and petroleum industries as related to the salt domes. Gulf coast salt domes were the scene of the first discovery of a large deposit of rock salt in North America, the birthplace of the Frasch sulfur industry, and the location of the first large oil gushers that ushered in the modern liquid fuel age.

IC 8314. Pneumatic Transportation of Solids. Proceedings: Institute of Gas Technology—Bureau of Mines Symposium, Morgantown, W. Va., October 19–20, 1965, compiled by J. D. Spencer, T. J. Joyce, and J. H. Faber 1966. 184 pp. 137 figs. A symposium on pneumatic transportation of solids was held at Morgantown, W. Va., October 19–20, 1965, under the cosponsorship of the Institute of Gas Technology, Chicago, Ill., and the Bureau of Mines. Objective of the symposium was to present information on developments and projected programs in the technology of feeding, transporting, recompressing, and utilizing gas-solids mixtures. The 22 papers presented at the symposium covered the following fields: Solids feeding, gas-solids measurement, flow systems research, recompression of gas-solids mixtures, utilization of gas-solids mixtures, and research needed.

IC 8315. Wyoming Iron-Ore Deposits. Description, Beneficiation Processes, and Economics, by C. M. Harrer. 1966. 114 pp. 23 figs. The location, features, quality, and extent of iron ore deposits are evaluated in this report. The results of pioneer beneficiation on Wyoming taconites and their success are discussed along with developments in the iron ore mining industry, markets, and economics. Market potential, transportation, resource developments, taxation, cost of iron ore enterprises, and the future of Wyoming iron resources are evaluated. Although occurrences of iron ores in Wyoming were known prior to 1870, early production to 1900 was as a nonferrous metallurgical flux and as mineral pigment for paints. In 1901 the Hartville-Sunrise hematite deposits were available to the Western iron and steel industry, and in 1962 the first western taconite operation was placed in production at Atlantic City, Wyo. This investigation discloses the probability of other large iron deposits in Wyoming. Taconite in the Bradley Peak area of the Seminoe Mountains has a potentiality of 100 million tons; that in the Owl Creek Mountains may prove very large also. Pioneer beneficiation testing has been included, and results have been generally encouraging. Research continues on the large titaniferous magnetite deposits of Albany County, Wyo. At present high-density titaniferous magnetite is being mined and processed at Iron Mountain for heavy aggregate and as a sized coating for underwater pipelines. Ample mineral raw materials needed for mining and processing Wyoming iron ores are available. Investments for iron-ore processing plants will generally be large, particularly for taconite and titaniferous magnetite.

IC 8316. Analyses of Natural Gases of the United States, 1965, by B. J. Moore and R. D. Shrewsbury. 1967. 181 pp. 1 fig. This publication contains routine analyses and related source data for 528 natural gas samples from 21 States collected during calendar year 1965 as part of a continuous survey of the United States for occurrences of helium in natural gas. This survey has been conducted by the Bureau of Mines since 1917. The analyses published herein were made by mass spectrometer and a special helium analysis apparatus, which are described in Bulletins 486 and 576. *(Out of print.)*

IC 8317. Thermophysical Properties of Selected Gases Below 300° K, by R. A. Guereca, H. P. Richardson, J. L. Gordon, J. D. Walker, and J. L. Cooper. 1967. 210 pp. 83 figs. Preliminary to an experimental study of selected physical properties of helium and related gases, the Bureau of Mines Helium Research Center conducted a data-gathering literature survey. This report combines the results of the 1961-63 literature search into a usable format. The data accumulated on the physical properties are presented in tables and graphs. The data in the tables were chosen for exact representation and comparison of specific values. An attempt was made to select the most reliable and consistent value available for a given property without extensively analyzing each source reference. The methods of evaluation are discussed. The graphs show trends and anomalies which may be obscure in tabular form. The general physical properties primarily used to define or differentiate 15 gases that are of interest to the Bureau's Helium Activity are included in this compendium. Included as well are eight specific physical properties for the 15 gases and also for air.

IC 8318. Urbanization and the Mineral Aggregate Industry, Tucson, Ariz., Area, by Frank E. Williams. 1967. 23 pp. 4 figs. This Bureau of Mines report deals with the urbanization of Tucson, Ariz., a southwestern city with an arid environment. Zoning regulations concerning known aggregate sources are described, and information relating to projected needs for the urban area is furnished. History of growth is outlined not only for the local aggregate industry, but also for the entire urban area. Past conditions are pointed out and background material for future conditions is provided. *(Out of print.)*

IC 8319. Zero Pressure Thermodynamic Properties of Nitrogen Gas, by Robert E. Barieau and Philip C. Tully. 1967. 48 pp. The following zero pressure thermodynamic properties of nitrogen gas are tabulated:

$$C_p^\circ,\ H^\circ - H_0^\circ,\ S^\circ,\ \frac{H^\circ - H_0^\circ}{T},\ \ \frac{G^\circ - H_0^\circ}{T}.$$

These properties are tabulated in units of joules, gram-mole, degrees Kelvin and in calories, gram-mole, degrees Kelvin for every degree Kelvin from 50° to 550°. The same functions are also tabulated in units of British thermal units, pound-mole, degrees Rankine for every degree Rankine from 100° to 1,000°.

IC 8320. Urbanization and Its Impact on the Mineral Aggregate Industry in the Denver, Colo., Area, by Matthew J. Sheridan. 1967. 51 pp. 28 figs. The Bureau of Mines study described in this report was conducted in the Denver, Colo., area (1) to summarize existing conservation practices as related to the most beneficial utilization of deposits of sand and gravel; (2) to identify the conflicting positions of the aggregate producer, the mineral owner, nearby residents, and local government officials responsible for determining land status and for issuing operating permits; and (3) to show the need for planning in Denver and in other expanding communities toward obtaining the benefits of conservation of our rapidly dwindling mineral resources. In order to determine the effects of urbanization on the Denver aggregate industry, interviews were held with owners of sand and gravel operations, with producers of concrete and bituminous pavement, with city and county planning and zoning personnel, and with representatives of various interested organizations. The conservation and ultimate utilization of deposits of construction raw materials near expanding urban areas can best be accomplished by long-range land-use projection and the requisite cooperation of technically advised planning and zoning administrators, government officials, mineral producers, and land developers. 40 cents.

IC 8321. Longwall Mining in Bituminous Coal Mines With Planers, Shearer-Loaders, and Self-Advancing Hydraulic Roof Supports, by J. J. Shields. 1967. 35 pp. 26 figs. The Bureau of Mines observed two different types of longwall mining: the advancing longwall method and the retreating longwall method at seven bituminous coal mines located in five of the coal producing states. In two mines using the advancing face method, the coal faces were abandoned because of roof failures and poor production. In the other five mines using the retreating method, roof control was good as was production. The success of longwall mining depends on good roof control and good production. The use of self-advancing hydraulic roof suports, such as Westfalia, Dowty, and Wanheim props along with Westfalia coal planers and the Anderton and Eickhoff shearer-loaders have been a factor in recent successes. *(Out of print.)*

IC 8322. Vapor Pressure of Pure Liquid Nitrogen, by P. C. Tully, Will E. DeVaney, and J. C. Meeks, Jr. 1967. 45 pp. The vapor pressure-temperature relationships for saturated pure liquid nitrogen are calculated by the Strobridge equation using a digital computer. This information is presented in two tables: first, in pressure increments of 0.1 psi from 1.8 to 492.9 psia, and second, in temperature increments of 0.1° from 63.15° to 126.26° K. These tables should facilitate the calibration of temperature-measuring devices over this temperature range. 35 cents.

IC 8323. Modifications of the Pendant Drop Interfacial Tensiometer, by Erle C. Donaldson and Edwin Pavelka. 1967. 6 pp. 2 figs. The pendant drop interfacial tensiometer is being used to study interfacial phenomena that influence the production of crude oil. A description of the instrument showing the modification of the cell and cell holder is presented. The modified cell and cell holder allow formation of a precise and reproducible drop size, and the image of the drop is easily alined and focused. Interfacial tension measurements and observations of film formation can be conducted at various temperatures with the jacketed cell.

IC 8324. A Combination Statistical Design for Sensitivity Testing, by Roy L. Grant. 1967. 25 pp. 7 figs. The Bureau of Mines investigated the up-and-down method with factorial designs to determine if shorter and, therefore, less costly trial sequences could be used. Although sequences of 50 trials are usually recommended, sequences of 20 trials were arbitrarily chosen for the experiments with permissible coal mine explosives described in this report. These explosives were fired from a cannon pointed into a flammable natural gas-air atmosphere at the Bureau of Mines Explosives Research Center gallery to ascertain their safety properties. The investigation demonstrated that the shorter sequences led to useful conclusions with a reduction in cost of the experimental program.

IC 8325. Evaluation of Domestic Reserves and Potential Sources of Ores Containing Copper, Lead, Zinc, and Associated Metals, by F. D. Everett and H. J. Bennett. 1967. 78 pp. 18 figs. This report summarizes the results of a nationwide investigation completed in 1964 to determine the nonferrous base metal ore reserves and potential sources of ore and to evaluate criteria for their ultimate exploitation. Engineers of the Bureau of Mines contacted mining company officials, reviewed reports and Government records, and where necessary made personal appraisals in arriving at the results. The estimates are presented by metals in ores in geographic regions and include some of the problems affecting the reserves and potential sources. The recoverable metal in the measured ore category and in the total ore reserves was estimated as follows:

Metal	Metal, thousand tons	
	Measured reserves	Total measured, indicated, and inferred reserves
Copper	21,990	74,700
Lead	570	30,600
Zinc	2,680	21,980

At the 1963 rate of domestic mine production these total reserves would be adequate to provide copper for 62 years, lead for 121 years, and zinc for 42 years. Data also are given for gold, silver, and other coproducts. Reserve estimates greatly exceed those of previous investigations; some prior estimates of copper reserves are included for comparison (table 23). Projections of requirements for base metals indicated the United States will need approximately 45 percent more copper in 1970 and 110 percent more by 1980 than was consumed in 1960; similar projections for lead indicate increases of 20 percent by 1970 and 45 percent by 1980; zinc projections are 40 percent more by 1970 and 90 percent by 1980. Much of the production of gold and silver is a coproduct of base metals recovery and the projected need for the precious metals exceeds all the United States can produce. Some problems of the industry are mentioned. A graphic evaluation of the economic availability of the reserve and potential sources is shown. 45 cents.

IC 8326. Coal Resources of Southwestern Utah. Potential for Utilization in Steam-Electric Power-Generation Plants, by L. T. Grose, D. H. Hileman, and A. E. Ward. 1967. 78 pp. 22 figs. The Bureau of Mines conducted a comprehensive study of the Kanab, Kolob, Kaiparowits, and Harmony coalfields of southwestern Utah to obtain additional information and to determine the potentials of these coalfields as sources of energy for steam-electric power-generating plants. Field examinations were made to ascertain the geologic structure and the stratigraphy of the coalfields, the accessibility of the coal-bearing strata, and the general nature of the coal-bearing strata and the terrain. Many mines, both active and abandoned, were examined, and key personnel in the coal industry in the area were consulted. Available analyses of southwestern Utah coals were compiled, and tentative conclusions regarding the rank and quality of the coals were drawn. Water resources related to the areas of the coal reserves also were investigated. Existing literature and maps pertaining to the geology of the areas were reviewed. Production potentials of the coalfields and economic conditions affecting the possible utilization of the coal reserves as sources of energy for steam-powered electricity-generating plants were investigated and analyzed. The total reserves of subbituminous A and high-volatile bituminous C coals in the fields of southwestern Utah are estimated to be at least 8 billion short tons at depths generally less than 2,000 feet. It appears likely that this estimate will be increased as additional data are made available through exploration and other investigations. Sufficient coal is available in four southwestern Utah counties to supply three or four large steam-electric plants. If the States involved grant water rights to companies planning to build steam-electric plants, the cost of producing power with coal might be attractive and might justify the construction of one or more of these plants. 45 cents.

IC 8327. An Analysis of the Pacific Northwest Lead-Zinc Industry, by Richard W. Knostman. 1967. 53 pp. 15 figs. A study was made of the factors affecting lead and zinc production in the Pacific Northwest. Costs, ore reserves and potential resources, and domestic demand were analyzed. It was concluded that a projected 3.1-percent average annual increase in U.S. demand for zinc through 1975 and a corresponding 2.5-percent rise for lead will be supplied mainly from mines in the Eastern and Central States. Annual Pacific Northwest mine production of lead is estimated to fluctuate around 82,000 tons, while zinc output may average 135,000 tons through 1975. Measured, indicated, and inferred reserves in the Pacific Northwest, containing 1.56 million tons of lead and 2.59 million tons of zinc, are more than sufficient to maintain this level of production. Annual production from Pacific Northwest electrolytic zinc plants is expected to increase to over 300,000 tons of slab zinc by 1975. Lead smelters may experience difficulty in maintaining output at 1964 levels. (*Out of print.*)

IC 8328. Water Requirements and Uses in Wyoming Mineral Industries, by Millard M. Gilkey and Ronald B. Stotelmeyer. 1967. 92 pp. 44 figs. This Bureau of Mines report presents results of a detailed study of water usage in the Wyoming mineral industry, along with projections for the future. In 1964 the mineral industries of Wyoming used 20 billion gallons of new water, nearly all self-supplied, and reused 72 billion gallons, a total usage of 92 billion gallons. Consumption amounted to 2.8 billion gallons. About one-half of the 20 billion gallons of new water was obtained from surface sources and the rest from ground water. Reported costs, covering power and maintenance, for the self-supplied new water at mineral industry operations ranged from less than 1 cent to 20 cents per thousand gallons and averaged 8 cents. At one mineral-related operation, water was hauled by truck to supplement a well supply. The cost was $2.00 per thousand gallons delivered. However, the supplemental requirement was only 10 gpm. Cost figures for the recirculation of water, covering power and maintenance, averaged 2 cents. In terms of water usage, the value of product for the entire industry was $25 per thousand gallons of new water intake and about $180 per thousand gallons consumed. The study revealed that Wyoming has a water deficiency but that the shortage is less severe than in the arid Southwest. Projection of the water needs of the Wyoming mineral industries indicates that the demand for new water will increase from the 20 billion gallons used in 1964 to 25 billion gallons in 1980, a 25-percent increase. The projected new-water requirement for the year 2000 is 40 billion gallons, a 100-percent increase compared with the 1964 figure. 50 cents.

IC 8329. Iron and Steel Scrap in the Southeast, by V. A. Danielson, James F. O'Neill, and H. William Ahrenholz. 1967. 85 pp. 27 figs. The Bureau of Mines examined sources, consumption, and movement of iron and steel scrap in the southeastern States—Alabama, Florida, Georgia, Kentucky, North Carolina, South Carolina, and Tennessee. Officials of the scrap-processing and scrap-consuming industries were interviewed, data was obtained from the published literature, and a canvass was made by the Bureau of scrap consumers. The Southeast generated excess scrap which was shipped to domestic and foreign consumers in about equal proportion. Total 1963 demand in the Southeast was 3,336,000 net tons, of which purchased scrap was 75 percent, foreign exports 13 percent, and domestic exports 12 percent. Alabama, with 47 percent of the purchased scrap consumption in 1963, was the most important scrap-consuming State, and Kentucky, with 34 percent, was the second most important one. Southeast demand was 4.8 percent of the total U.S. demand. Projected 1980 consumption is 8,340,000 tons. Scrap prices showed a slight downward trend for the period 1953–63, although gross consumption increased slightly. A significant trend in processing scrap in the Southeast is the preparation of smaller bundles or "briquettes" weighing from 75 to 150 pounds, which are easier for consumers to handle and inspect. Another significant development is the "shredding" of automobile scrap which produces a dense, clean scrap especially desirable for use in electric furnaces. *(Out of print.)*

IC 8330. Densities and Porosities of Core Samples From Wells in Appalachian Oilfields, by Franklin D. Slagle and C. I. Pierce. May 1967. 75 pp. 1 fig. Porosity and bulk- and sand-grain-density values were determined for 2,040 core samples of 30 formations from 47 wells in New York, Ohio, Pennsylvania, and West Virginia, and are compiled for petroleum industry use in well-log evaluation and geologic studies.

IC 8331. Production Potential of Known Gold Deposits in the United States, by Field Staff, Bureau of Mines. 1967. 24 pp. 2 figs. As part of its regular program to provide timely information on domestic mineral commodities, the Bureau of Mines conducted an engineering appraisal of more than 1,300 lode and placer gold deposits in the United States to determine their gold production potential. While these deposits were estimated to contain over 400 million ounces of gold, only 9 million ounces, or slightly more than 2 percent, was found to be producible at $35 per ounce under prevailing mining and metallurgical technologies. The study revealed that any significant increase in available gold in the United States is most likely to come from the discovery of new sources, intensive exploration and development of the more promising known mineralized areas, and development of new or improved mining and metallurgical techniques.

IC 8332. Basic Properties of Matrix Algebra, by Katherine Harding. 1967. 32 pp. Basic concepts of matrix algebra and manipulations of matrices are presented in such a way that little competence in mathematics is required. Examples are always included to illustrate concepts and techniques. The paper is divided into six sections. The first four sections are devoted to some of the more basic concepts of matrix algebra, whereas the last two sections are concerned with specific applications. 30 cents.

IC 8333. Ringelmann Smoke Chart (Revision of IC 7718), by Staff, Bureau of Mines. May 1967. 4 pp. The Ringelmann Smoke Chart fulfills an important need in smoke abatement work and in certain problems in the combustion of fuels. A knowledge of its history and methods of preparation is, therefore, of interest to many. Since instructions on its use are not shown on the recent edition of the chart, those included in this revision of the previous Bureau of Mines publication now are a necessary complement to the chart. More detail regarding the use of the chart is included than was given in the earlier version.

IC 8334. Computer Usage for Evaluation of Design Parameters and Cost of Heat Exchangers With No Change in Phase and Pumping Costs of Both Fluids as Prime Parameters, by P. R. Jones and S. Katell. August 1967. 45 pp. 1 fig. A computer program was written for the design of a shell and tube type heat exchanger on a price optimum basis. The program was designed to meet the following requirements: (1) Triangular pitch, (2) single or multiple pass, (3) heating or cooling, and (4) no change in phase. Price optimum design was obtained for four standard tube sizes and standard pitch. Pressure drop, both inside and outside, was computed and the nearest standard shells having at least the required area were listed. With this information, the estimator can select the heat exchanger best suited for the need. The program was made adaptable to various fluids and to various tube sizes and spacing by reading in much of the required data such as physical properties of the fluids, tube data, and standard shell data in tabular form.

IC 8335. Potential Sources of Aluminum, by Staff, Bureau of Mines. 1967. 148 pp. 37 figs. The Bureau of Mines studied available information on the nature and occurrence of potential sources of aluminum in the United States, its Pacific island posessions, and Puerto Rico to obtain data for use in evaluating the production capability and costs of extracting the aluminum from such materials. The quantity, type, and grade of the materials range from 4 billion tons of bauxite, bauxitic clay, and kaolin averaging 33 to 42 percent Al_2O_3 to nearly 600 billion tons of anorthosite containing only 27 percent Al_2O_3. Principal deposits of bauxite, bauxitic clay, and kaolin occur in Arkansas, Georgia, Hawaii, and Oregon. Major anorthosite deposits are located in New York, Wyoming, California, Idaho, and Montana. About 11 billion tons of material in deposits of various types of clay, the kyanite group of minerals, laterites, and shales averaging 27 to 30 percent Al_2O_3 comprise additional resources from which aluminum some day may be extracted. Material meeting specifications of the study was found in only 28 States and the Pacific island possessions. Utilization of these large low-grade sources of aluminum awaits development of processes that are economically competitive with the Bayer process for extracting alumina from bauxite, which is at present the only commercial ore of aluminum. Changes in economic and political conditions also may play important roles in the eventual development of the potential sources of aluminum. $1.

IC 8336. Injury Experience in the Nonmetallic Mineral Industries (Except Stone and Coal), 1961–63, by Forrest T. Moyer, Donald E. Redmon, and Thomas C. Lukins. 1967. 172 pp. The overall disabling work injury experience, excluding officeworkers, at nonmetal mines and mills during the period 1961–63, as reported to the Bureau of Mines by operators, was 77 fatal and 7,201 nonfatal injuries during an aggregate worktime of 335,029,685 man-hours. These injuries, fatal and nonfatal combined, occurred at a frequency rate of 21.72 per million man-hours, comprising 0.23 for the fatal and 21.49 for the nonfatal injuries. The combined severity rate of the disabilities was 2,312 days lost or charged per million man-hours, consisting of 1,379 for the fatal and 933 of the nonfatal injuries. The average severity of all disabilities during 1961–63, was 106 days per injury. The number of days lost or charged, excluding officeworkers, at nonmetal mines and mills during 1961–63, was 462,000 days charged to fatal injuries and 312,461 days lost from nonfatal injuries. The outstanding causes for fatal injuries were explosions (18 fatalities occurred in a major mine-explosion disaster in a potash mine in Utah in 1963) and falls of rock or ore from back or side, while most nonfatal injuries were caused by handling materials, slips or falls of persons, haulage, and machinery. The parts of the body most frequently injured during the period 1961–63 were the trunk, hand and finger, and foot and toe. An average of 52,810 men were at work daily. There were 20 nonfatal disabling injuries reported for officeworkers at nonmetal mines and mills during the period 1961–63 during an aggregate worktime of 23,088,496 man-hours. These injuries occurred at a frequency rate of 0.87 per million man-hours. There were no fatal injuries reported.

IC 8337. Injury Experience in the Metallic Mineral Industries, 1961-63, by Forrest T. Moyer, Donald E. Redmon, and Thomas C. Lukins. 1967. 156 pp. The overall injury experience, excluding officeworkers, at metal mines and mills during the period 1961–63, reported by operators, was 174 fatal and 11,357 nonfatal disabling work injuries during an aggregate worktime of 451 million man-hours. These injuries occurred at a frequency rate of 25.55 per million man-hours, comprising 0.39 for the fatal and 25.17 for the nonfatal injuries. The combined severity rate of the disabilities was 3,779 days lost or charged per million man-hours, consisting of 2,314 for the fatal and 1,465 for the nonfatal injuries. The average severity of all disabilities during 1961–63, was 148 days per injury. The number of days lost and/or charged, excluding officeworkers, at metal mines and mills during the period 1961–63, was 1,440,000 days charged to fatal injuries and 661,290 days lost from nonfatal injuries. An average of 70,966 men were at work daily. The outstanding cause for fatal injuries was the fall of rock or ore from the back, while most of the nonfatal injuries were caused by handling materials, slips or falls of persons, machinery, falls of rock or ore from back and side, and haulage. Injury experience at primary nonferrous smelters, refineries, and reduction plants during 1961–63, excluding officeworkers, was 23 fatal and 3,214 nonfatal disabling injuries during a total worktime of 277 million man-hours. The injuries occurred at frequency rates of 0.08 per million man-hours for the fatalities and 11.61 for the nonfatal disabilities. The severity rate for all injuries of 1,085 days lost or charged per million man-hours comprised 498 for fatal and 587 for nonfatal injuries. The number of days lost, excluding officeworkers, at primary nonferrous smelters, refineries, and reduction plants during 1961–63 was 138,000 from fatal injuries and 162,385 from nonfatal injuries. An average of 34,938 men were at work daily on active plant days during the 3-year period. The injury experience for officeworkers at metal mines and mills during the period 1961–63 was 20 nonfatal disabling work injuries, (there were no fatal injuries reported), during an aggregate worktime of 28,694,-244 man-hours. These injuries occurred at a frequency rate of 0.70 per million man-hours. There were no fatal injuries reported for officeworkers at nonferrous smelters, refineries, and reduction plants during 1961–63, but seven nonfatal injuries were reported during an aggregate worktime of 30,814,772 man-hours. The frequency rate for these injuries was 0.23 per million man-hours for this period.

IC 8338. The Interindustry Structure of the U.S. Mining Industries—1958, by Kung-Lee Wang and Robert K. Kokat. 1967. 190 pp. This report describes the linkage of all mining sectors with all other manufacturing, services, and final demand sectors of the U.S. economy. Besides being a basic data source, it provides a framework for aggregate economic impact analysis with respect to the mining industries. The framework is an open-static input-output model specifying 48 mining industries as classified in the *Standard Industrial Classification Manual* for all mining activities and 76 nonmining industries which collectively exhaust all economic activities. The 124-sector model used in this report is an expansion of the preliminary 82-industry aggregation estimates made by the Department of Commerce. In the expanded model, 48 mining industries are substituted for the original 6. The methodology used to ascertain the industry-by-industry procurement cost estimates and production flows necessary to the construction and expansion of the basic 82-sector model included personal interviews, case studies of specific mining activity analysis, and published and unpublished data from the Bureau of Mines and the *Census of Mineral Industries*. The end products of this study are two tables arranged to show the direct purchases necessary for each industry to support the level of economic activity and the total purchases generated in each industry throughout the economy by each $1 of aggregate economic demand in 1958. The tables may be used for economic impact studies and market analysis by firms engaged in or closely associated with the mining industries. Some illustrations of their usages are presented. $1.

IC 8339. Fluorspar in the Eastern United States, by Ronald P. Hollenbeck. 1967. 35 pp. 11 figs. This study reviews and discusses the fluorspar industry in the Eastern United States, with emphasis on factors controlling the industry such as production, consumption, uses, and transportation. The greatest potential for increased consumption of fluorspar in the immediate future was found to be in the manufacture of fluorine chemicals and steel. Important factors affecting the future domestic industry include imports and the maintenance of adequate domestic fluorspar reserves. Exploration, commercial deposits, mining and milling, reserves, and new developments in the industry are covered. *(Out of print.)*

IC 8340. Selenium and Tellurium. A Materials Survey, by Arnold M. Lansche, with chapter on resources by David F. Davidson. 1967. 56 pp. 13 figs. Selenium and tellurium are recovered as byproducts of the smelting and refining of lead and copper ores. This report is a worldwide study of properties, uses, substitutes, and toxicology; history; resources; technology and production; supply and distribution; industrial structure; research and development; tariff legislation and Government programs; and strategic factors. This survey was prepared for the Office of Emergency Planning. 60 cents.

IC 8341. Copper Leaching Practices in the Western United States, by Herman W. Sheffer and LaMar G. Evans. 1968. 57 pp. 34 figs. This report describes and discusses present-day leaching technology employed to recover copper from low-grade mine and dump materials derived from the exploitation of copper ore deposits in the Western United States. Illustrations of the integral parts of the leaching, precipitation, and recovery operations at several copper-producing companies are presented. Schematic drawings are included to present typical flowsheets of leaching and precipitation operations. Operational problems common to most copper leaching and precipitation plants are discussed. Areas of present and future research to improve leaching techniques are cited. 75 cents.

IC 8342. Iron and Steel Scrap Survey in Illinois, Indiana, Iowa, Michigan, Minnesota, and Wisconsin, by Walter Pajalich. 1967. 49 pp. 24 figs. This Bureau of Mines report is a study of the organizational framework of the ferrous scrap industry, of the products produced, and of the factors affecting the consumption of ferrous scrap by the steel industry. Consumption data from 27 major iron and steel firms in the States of Illinois, Indiana, Iowa, Michigan, Minnesota, and Wisconsin during the period between 1957 and 1962 were grouped by type of iron and steel furnace production facilities to determine consumption pattern for various grades of scrap in comparison to ingot production, hot metal consumption, and home scrap generation. Grades of scrap affected by changes in scrap consumption were determined, and the pattern that emerged was analyzed. Correlation of scrap demand and its effects on scrap prices based on price of scrap receipts of No. 1 heavy melting scrap and No. 2 bundles in the Chicago area for the years 1957 through 1962 indicated that demand trends do not always affect the price of scrap. Past and present technological advancements in steelmaking processes are discussed, and their effects on the scrap industry are analyzed. 35 cents.

IC 8343. A Numerical Method for Determining Heat-Transfer Characteristics for a Dilute Gas-Solids Mixture in an Externally Heated Tube, by M. J. Lempel. July 1967. 20 pp. 8 figs. A theoretical study of the heat-transfer characteristics of a dilute gas-solids mixture in an externally heated tube is reported. Detailed equations are developed describing the system, and a numerical method is presented to solve the equations using a digital computer. The methods are applied to a system containing fine coal particles entrained in hydrogen, flowing through a hot tube. Heat-transfer coefficients and several other constants are evaluated in detail.

IC 8344. Iron and Steel Scrap in the Intermountain and Northwestern Plains States, by Harold J. Bennett. 1967. 71 pp. 14 figs. This report deals with the processing and marketing of iron and steel scrap in Arizona, Colorado, New Mexico, Utah, Wyoming, Nebraska, North Dakota, and South Dakota. The major individual consumers of iron and steel scrap were the steel mills in Arizona, Colorado, and Utah, foundries in Utah and Arizona, and copper leaching operations in Arizona, New Mexico, and Utah. About 2 million tons of iron and steel scrap was used by the iron and steel industry in 1964. Although there has been a decline in the amount of scrap used per ton of steel ingot produced because of changes in steelmaking methods, there has been a slight increase in the overall quantity of scrap used because of the increase in ingot production. It is estimated that the scrap consumption in the steel industry will increase by 19 percent by 1980. In addition to the scrap consumed by the steel industry, 273,000 tons of ferrous scrap were used by copper-leaching operations. Thirty-one percent of the ferrous scrap used by the steel industry in 1964 was purchased from dealers and other sources.

The CF&I Steel Corp. (formerly The Colorado Fuel and Iron Corp.) at Pueblo, Colo., complemented its blast- and open-hearth-furnace operations with basic-oxygen converters in 1962. The basic-oxygen and open-hearth furnaces were charged with 30 and 90 percent scrap, respectively. Future use of the open-hearths would probably be used to supplement ingot production requirements. Because it was more economical to use less scrap and a high molten-metal charge the United States Steel Corp. at Geneva, Utah, which uses the open-hearth process to make steel, charges the furnaces with 25 to 35 percent scrap. The Allison Steel Manufacturing Co. at Tempe, Ariz., uses a 100-percent-scrap charge in its electric furnace.

Although it was estimated that there were 327,000 tons of various grades of motor vehicle scrap generated in 1963, no estimates were made concerning the total quantity and grade of scrap available in the area. Most of the scrap used in the steelmaking industry originated within the area. It was advantageous to sell scrap generated in eastern Nebraska, North Dakota, and South Dakota to markets in the Midwest because of freight costs. *(Out of print.)*

IC 8345. Thickness of Bituminous Coal and Lignite Seams Mined in 1965, by W. H. Young. August 1967. 18 pp. 1 fig. Gives number of mines, production, output per man per day, and average thickness of seams mined at bituminous coal and lignite mines in the United States for the years 1920, 1945, 1946, 1950, 1960, and 1965. The data for 1965 are presented in greater detail.

IC 8346. Bibliography of Investment and Operating Costs for Chemical and Petroleum Plants, January-December 1966, by Sidney Katell and William C. Morel. 1967. 131 pp. Contains abstracts of 595 articles concerning all phases of cost engineering in chemical and petroleum plants, especially construction and operating costs. The related topics covered include cost estimating, foreign and domestic construction project reports, developments in petroleum production and refining, and developments in the nuclear field. Work done in cooperation with the American Association of Cost Engineers. *(Out of print.)*

IC 8347. An Analysis of 44 Recent Fatal Accidents With Front-End Loaders, by R. O. Pynnonen and Allen D. Look. September 1967. 10 pp. This publication is an analysis of reports to the Bureau of Mines of 44 fatal accidents that occurred during the operation of rubber-tired, front-end loaders in the mineral industry. The causes of the accidents, the nature of the work being performed, and recommendations for preventing similar accidents are included.

IC 8348. Fly Ash Utilization, Proceedings: Edison Electric Institute-National Coal Association-Bureau of Mines Symposium, Pittsburgh, Pennsylvania, March 14-16, 1967, compiled by John H. Faber, John P. Capp, and John D. Spencer. 1967. 345 pp. 111 figs. Contains the proceedings of the symposium and abstracts of all the papers. The symposium discussed the nature of the fly ash problem, including availability, specifications, limitations on its use, marketing, utilization in concrete and masonry products, specialized use, and recent developments in basic fly ash research $1.75.

IC 8349. Research and Technologic Work on Explosives, Explosions, and Flames: Fiscal Year 1966, by Staff, Explosives Research Center. September 1967. 21 pp. 2 figs. Major activities of the Bureau of Mines Explosives Research Center during fiscal year 1966 (July 1, 1965, to June 30, 1966) are reviewed briefly. Part 1 summarizes significant accomplishments of the projects that were active during the report period. Part 2 presents short abstracts of the publications that appeared in the Bureau series and in other media during fiscal year 1966. Publications issued after June 30, 1966, are noted where pertinent in footnotes but are not abstracted.

IC 8350. Description of a High Pressure High Accuracy Burnett Compressibility Apparatus, by John E. Miller. October 1967. 10 pp. 2 figs. A high accuracy Burnett apparatus for use at 12,000 psi and 0° to 65° C has been constructed at the Bureau of Mines Helium Research Center. The apparatus is patterned after Burnett's original apparatus, but the working pressure is much higher and elastic distortion can be essentially eliminated. An operating procedure to permit faster experimental measurements is suggested.

IC 8351. Magnetic Susceptibility of 19 Nickel- and Cobalt-Bearing Minerals, by H. E. Powell. October 1967. 12 pp. 3 figs. Magnetic susceptibilities were determined by the Bureau of Mines for 19 cobalt- and nickel-bearing minerals and for a suite of synthetic cobalt-nickel diarsenides analogous to the rammelsbergite and safflorite series. Relations between susceptibility and composition were found to be nonlinear for both impure natural minerals and pure synthetics.

IC 8352. Heavy Crude Oil. Resource, Reserve, and Potential Production in the United States, by Petroleum Staff, Mineral Resources Offices. 1967. 76 pp. 8 figs. This report presents data pertaining to proved reserves, production, and total resource of heavy crude oil (API gravity of 25° or less) in the United States. The information is presented for 22 heavy-oil-productive States within the five Petroleum Administration for Defense (PAD) districts. Also included are brief discussions of the overall crude-oil supply-and-demand situations in each district and proration practices that could affect development of the heavy-oil resource. Statistical data pertaining to the resource, reserve, production, and thermal projects are presented in the discussions of the individual States. This special Bureau study was confined to subsurface reservoirs that contain heavy oils which are mobile at reservoir conditions. In general, the recovery of commercial amounts of oil by primary method was considered evidence of reservoir oil mobility. Further, the resource evaluated is in rservoirs or parts of reservoirs significantly affected by drainage to oil-productive wells or defined by well bores. Heavy-crude-oil resource on January 1, 1966, was 106.8 billion stock tank barrels (stb), of which 45.9 billion stb was in reservoirs having characteristics considered to be most favorable for thermal-recovery operations. Estimated recoverable or proved reserve by operating methods in effect on this same date was 5.2 billion barrels. During the decade ending January 1, 1966, heavy-oil production was more than 3 billion barrels, about 5 percent of the total U.S. crude-oil output. In 1965 heavy-oil production was 372 million barrels, of which about 22 million barrels, or almost 6 percent, was produced from thermal-recovery operations. Heavy-oil forecast for the years 1966–80 is 5,816 million barrels. This forecast includes anticipated production resulting from finding additional reserve and from applying stimulative-recovery techniques to reservoirs from which oil is being recovered by primary recovery techniques. About 16 percent of the heavy-oil forecast is expected to be recovered from thermal operations. 45 cents.

IC 8353. New Concept of Electron Detachment for Air in Negative Corona at High Temperature, by C. C. Shale. November 1967. 11 pp. 2 figs. Current-voltage relationships for air at high temperature in negative corona are compared with relationships predicted by theory. Deviations are discussed. Based on the latest theoretical concept of electron detachment from negative ions and recent findings in basic research on free electron gases, results of applied research show the existence of free electrons in air at high temperature and high field strength-to-pressure ratios.

IC 8354. Mobile Diesel-Powered Transportation Equipment for Gassy Noncoal Mines and Tunnels Approved by the Bureau of Mines, 1961–66, by Rogers F. Davis, Joseph J. Seman, John R. Zelonka, and Frank E. Scott. November 1967. 6 pp. 2 figs. This publication has been prepared to supply manufacturers and industrial users with a listing of mobile diesel-powered transportation equipment approved or certified by the Bureau of Mines for use in gassy noncoal mines and tunnels. Listings are given, in chronological order, of approvals of diesel-powered shuttle cars and wheel-type loaders and certifications of diesel engines and safety components under Schedule 31, first published January 16, 1961.

IC 8355. Injury Experience in Coal Mining, 1964. Analysis of Mine Safety Factors, Related Employment, and Production Data, by Forrest T. Moyer, Nina L. Jones, Mary B. McNair, and Neil B. Bradley. December 1967. 92 pp. 3 figs. To keep the mineral and allied industries informed of trends in the causes of accidents and to point out the need for corrective measures, the Bureau of Mines collects, analyzes, and periodically publishes health and safety statistics. This report includes data for 1964 on injury experience, with related employment statistics, at coal mines in the United States, presented in tabular form.

IC 8356. Analyses of Natural Gases, 1966, by B. J. Moore and R. D. Shrewsbury. 1967. 130 pp. This publication contains routine analyses and related source data for 374 natural gas samples from 24 States and five foreign countries. These samples were collected during calendar year 1966 as a part of a continuous survey of the free world for occurrences of helium in natural gas. This survey has been conducted in the United States by the Bureau of Mines since 1917. In late 1965 the survey was expanded to include foreign gasfields. The analyses of foreign samples contained in this publication represent the first samples received as a result of this expanded program. The analyses published herein were made by mass spectrometer and a special helium analysis apparatus, which are described in Bureau of Mines Bulletins 486 and 576. Eight previous publications have presented the results of 7,244 gas analyses made by the Bureau of Mines Helium Activity prior to 1966. The first three, Bulletins 486, 576, and 617, contain analyses and related source data on 5,218 gas samples collected from 1917 to 1961. The other five publications, which were published as Information Circulars, supplement the three Bulletins and contain 2,026 analyses of samples collected in 1961, 1962, 1963, 1964, and 1965. This publication is the sixth publication supplementing the three Bulletins. 65 cents.

IC 8357. Review of Bureau of Mines Coal Program, 1966, by Staff, Bureau of Mines—Coal Research. November 1967. 119 pp. 58 figs. This report briefly describes the broad program of research and technologic work conducted by the Bureau of Mines on coal and related subjects during 1966. In addition to a description of investigations on mining, preparation, and utilization of coal, an account is given of the Bureau's work in mine health and safety, coal resources, mine explosives, and environmental conditions relating to coal mining and utilization. Details of most of the projects are reported in publications cited throughout this report. The Bureau centers and laboratories that conduct the coal research and related investigations and the organizations, institutions, and companies that have contributed to the Bureau's coal research and technologic program are listed in appendixes.

IC 8358. Miniature Oxygen Deficiency Alarm, by Merle L. Bowser and Robert A. Bradburn. January 1968. 7 pp. 5 figs. The Bureau of Mines has constructed a miniature oxygen deficiency alarm system using an electrochemical cell as the sensor. Distinct audible signals are produced at either of two preselectable oxygen levels which can be varied from approximately 10 to 20.9 percent oxygen. The high or cautionary range produces a 500-cycle-per-second tone pulsed at about 1-cycle-per-second rate, whereas the lower or more dangerous oxygen level produces a continuous 500-cycle-per-second tone.

IC 8359. Magnetic Susceptibility of 34 Manganese-Bearing Minerals, by H. E. Powell and Lee N. Ballard. January 1968. 10 pp. 1 fig. The magnetic susceptibilities of 34 manganese-bearing minerals were determined. The source of each sample and petrographic, spectrographic, and chemical analyses are given. Included are values for isomorphous series showing wide ranges of composition and for a few high-purity synthetic minerals.

IC 8360. Magnetic Susceptibility of Group IVB, VB, and VIB Metal-Bearing Minerals, by H. E. Powell and Lee N. Ballard. February 1968. 9 pp. 1 fig. The magnetic susceptibilities of 57 minerals containing titanium, zirconium, vanadium, columbium, tantalum, chromium, molybdenum, and tungsten were determined. The source and petrographic analysis of each sample are given. Included are values for isomorphous series of minerals showing wide ranges of composition and for a few high-purity synthetic minerals.

IC 8361. Firefighting Facilities at Coal Mines (Revision of RI 5363), by R. Ward Stahl and Robert T. Davis. February 1968. 40 pp. 11 figs. This publication is a revision of Report of Investigations 5363, updated to reflect the improvement in fire protection at selected coal mines. It contains suggestions on what may be considered good fire protective equipment, suggested methods of organizing the attack on fires at various locations underground, and helpful hints on testing and evaluating firefighting facilities.

IC 8362. Depth and Producing Rate Classification of Oil Reservoirs in the 14 Principal Oil-Producing States, by Petroleum Staff, Mineral Resource Offices. October 1967. 25 pp. 3 figs. This report presents depth and producing rate statistics pertaining to oil reservoirs (or fields) in each of the 14 States that produced more than 20 million bbl of oil during 1965. The combined oil production was about 2.6 billion bbl, or 96 pct of the U.S. total. Data are presented for each of the 14 States, each Texas Railroad Commission district, and four geographical areas of Louisiana. About 8 pct of the total oil produced in the 14 States was from depths of less than 2,000 ft, 24 pct from 2,000 to 4,000 ft, 22 pct from 4,000 to 6,000 ft, 16 percent from 6,000 to 8,000 ft, and 30 pct from 8,000 ft and deeper. The average production per well in the 14 States ranged from 4.4 bopd for wells less than 2,000 ft deep to 57.6 bopd for wells 8,000 ft and deeper. Data indicate that 9.5 pct of the 460,968 wells produced more than 1.2 billion bbl or 46.6 pct of the total oil. Oil production from reservoirs (or fields) not undergoing stimulative recovery operations, such as steam, air, gas, or water injection, was about 1.1 billion bbl or 42.1 pct of the total.

IC 8363. Mobile Diesel-Powered Equipment for Nongassy Noncoal Mines and Tunnels Approved by the Bureau of Mines, 1951–66, by Rogers F. Davis. February 1968. 29 pp. 2 figs. This publication has been prepared to supply manufacturers and industrial users with a listing of mobile diesel-powered equipment and subassemblies approved and certified by the Bureau of Mines under Schedule 24, first published in March 1949, and amended April 23, 1955, for use in nongassy noncoal mines and tunnels. This revised and supplemented listing supersedes IC 8183, published in 1963. Listings are given in chronological order of mobile diesel-powered equipment approved under Schedule 24 and diesel engine subassemblies certified under Schedule 24.

IC 8364. Petroleum and Oil Shale Research of the Bureau of Mines, Fiscal Year 1966, by Staff, Bureau of Mines—Petroleum Research. January 1968. 52 pp. During fiscal year 1966 the Bureau of Mines published 99 scientific and technical papers and engaged in 67 research projects on petroleum, natural gas, and oil shale. A basic appropriation of $3.4 million was supplemented by $1 million in cooperative funds from other Governmental agencies and industry groups. Petroleum conservation was advanced by development of scientific knowledge and improvement of technologic methods in both the extraction and utilization of petroleum, natural gas, and oil shale. Experimental work was carried out at research centers in Bartlesville, Okla., and Laramie, Wyo., and in laboratories in Morgantown, W. Va., and San Francisco, Calif.

IC 8365. Recommended Safety Standards for Shaft Sinking (Revision of IC 7810), compiled by Staff, Health and Safety Activity. March 1968. 23 pp. The recommended standards included in this publication have been carefully compiled by Bureau personnel in all areas where shaft sinking is practiced. Existing applicable State rules were considered and included. Representatives of the mineral industries, coal and noncoal, were given an opportunity to participate in preparing these suggested standards, and the Bureau hopes that their use will lead to greater safety and efficiency and prevent loss of life, injury, and property damage during shaft sinking. These recommended safety standards are detailed under 12 headings: (1) Fire prevention, (2) fire protection, (3) housekeeping and sanitation, (4) electricity, (5) explosives storage and transportation, (6) timbering and safeguarding personnel and equipment, (7) hoisting, hauling, and handling excavated material, (8) ventilation, (9) drilling, (10) blasting, (11) welding and burning, and (12) lighting. An appendix on firefighting equipment is included. This publication replaces IC 7810, published in 1957.

IC 8366. Hot Carbonate Purification Computer Program, by Paul Wellman and Sidney Katell. March 1968. 25 pp. 2 figs. A computer program is presented that may be used to calculate the bare equipment cost of the major processing units for any hot potassium carbonate gas purification system. The program is designed so that, with minor modifications, it could be used with a variety of computer systems.

IC 8367. Computing Volume of Helium in Cylindical Steel Containers at 10 to 10,000 PSIA (Revision of IC 8185), by H. S. Kalman. March 1968. 212 pp. 3 figs. A table of factors for rapid, accurate calculation of the volume of pure helium in cylindrical steel containers, at base conditions of 14.7 psia and 70° F, is presented. The table covers a pressure range from 10 to 10,000 psi in 10-psi increments and a temperature range of 0° to 120° F in 2° increments. The volume of helium is calculated from the observed pressure and temperature of the helium, expressed as a factor from the table, and the known internal volume of the container. The calculation requires a single multiplication. A discussion and evaluation of the accuracy obtainable and a derivation of the formula used (which takes into account compressibility of helium, thermal expansion of steel containers, and the strength of steel due to internal pressure) are presented. An example showing how the table can be used is given also.

IC 8368. Review of Major Proposed Processes for Recovering Manganese From United States Resources (in Three Parts). 3. Sulfur Oxide Processes, by John J. Henn, Ralph C. Kirby, and Lindsay D. Norman, Jr. March 1968. 36 pp. 11 figs. Ten proposed processes for the recovery of manganese from domestic resources as a high-grade oxide product are described. Nine of the processes employ sulfur dioxide, sulfuric acid, or a combination of both for leaching. The tenth process utilizes sulfur dioxide to sulfatize the ore at 600° to 850° C before water leaching. In addition to these ten complete processes, six processes from the patent literature are described. Methods for recovering $MnSO_4 \cdot H_2O$ are also reviewed.

IC 8369. Limestone Resources in Western West Virginia, by David J. Kusler and H. A. Corre. March 1968. 76 pp. 15 figs. This study is an appraisal of the feasibility of recovery and the possible chemical and physical uses of the limestone from the Greenbrier Formation in western West Virginia. Data on minability, occurrence, quality, and markets were obtained from published and unpublished sources and by a limited mail survey combined with personal contacts. The estimated costs of recovery by deep mining techniques are considerably higher than competitive surface and shallow subsurface operations. Compositional information available for this study was limited but indicated the suitability of the limestone for most physical uses and some chemical process uses. An appraisal of the uses and demand reveals that immediate markets may be difficult to establish, but for some uses long-term prospects may be encouraging, especially if the quality of limestone would be suitable for lime manufacture or use as metallurgical fluxstone.

IC 8370. Study of the Silver Potential, Creede District, Mineral County, Colo., by Henry C. Meeves and Richard P. Darnell. April 1968. 58 pp. 20 figs. This report describes work done in the Creede mining district, Mineral County, Colo., in 1965–66 as a part of a Bureau of Mines study of the silver production potential of the United States. The mining history of the district is briefly covered, and representative former and current mining operations are described. Mining and milling costs of the Emperius Mining Co. operation are given in some detail as being representative of the cost of mining typical Creede ore bodies under current technology. An estimate of the silver reserves and resources of the district is presented, subject to many uncertainties stemming from inaccessibility of old workings, lack of mining records, and low level exploration activity, all of which limit the opportunity to accurately evaluate ore potential. The report concludes with an analysis of future silver production trends in the Creede district. An increase of silver production to as much as 1 million ounces yearly is projected, possibly starting in 1969. As long as ore bodies in the zone of enrichment, in which silver is a major constituent, contribute a substantial part of Creede production, silver price will affect overall production rates appreciably. As the richer ore bodies become depleted, an increasing portion of production again will be coming from primary sulfide ores in which silver is a byproduct of lead and zinc. When this occurs, the level of silver production will be governed chiefly by lead and zinc production and prices and can be expected to decline to the 1960–66 level, which amounts to an average of 240,000 ounces per year.

IC 8371. Active List of Permissible Explosives and Blasting Devices Approved Before December 1, 1967, by C. M. Mason and P. A. Richardson. April 1968. 9 pp. The current Bureau of Mines active list of permissible explosives includes 95 brands. Twelve are gelatinous and the rest are the most commonly used granular ammonium nitrate type. The list of permissible blasting devices comprises five Cardox models.

IC 8372. Permissible Mine Equipment Approved by the Bureau of Mines During 1965–66. A Supplement to Bulletin 543 and Information Circulars 8220 and 8299, by F. R. Lee. April 1968. 25 pp. This publication lists permissible equipment approved by the Bureau of Mines during 1965 and 1966 (calendar years), except for breathing apparatus and explosives. The purpose of this publication is to inform the public about approved equipment safe for use in underground mines.

IC 8373. Helium: Bibliography of Technical and Scientific Literature, January 1, 1947, to January 1, 1962. A Supplement to Bulletin 484, compiled by Harold W. Lipper and Carla W. Cherry. 1968. 525 pp. References in this bibliography are all those technical and scientific articles pertaining to helium that are known to have been published before January 1, 1962. This publication is a continuation of Bulletin 484. Articles of a general nature from trade journals and popular magazines are included to preserve comprehensive coverage of the subject. $2.75.

IC 8374. An Engineering and Economic Study of a Gold Mining Operation, by Edward E. Johnson and Harold J. Bennett. 1968. 53 pp. 7 figs. The principal purpose of this study was the development of an engineering and economic model of a hypothetical large-scale open pit gold mining operation. The guiding concept in developing the model was the idea that, through study of a number of such models, it would be possible to evaluate a mineral property and to make reasonable estimates of the benefits to be derived from research in mining and metallurgy. The model by use of a computer is able to produce results easily and quickly when cost factors are varied. Cost factors may be varied as a result of assumptions of improved technology or of assumptions of assuming different approaches or methods to accomplish a particular segment of the mining or processing operation. The discounted cash flow rate of return was used to measure the effect of changes in costs or expected revenue. In this study, assumptions based on past processing practices were made in an effort to reduce costs of processing the ore. These assumptions were (1) eliminating the low-grade cyanide circuit, (2) reducing the quality of material to be processed by screening after crushing, and (3) using a combination of assumptions (1) and (2). All three assumptions resulted in reduced capital investment and operating cost that caused substantial increases in the rate of return. (*Out of print.*)

IC 8375. Tunneling Technology—Its Past and Present, by Thomas M. Nasiatka. 1968. 12 pp. This report briefly describes the present state of the art and the technological highlights of tunneling from its inception to the present. The discussion is concerned primarily with tunnels driven through relatively competent rock for mine development and various civil purposes. In addition to pinpointing the major technological breakthroughs in tunneling, this report indicates their general effect on the speed of tunneling. The tunneling speeds are based upon data from approximately 80 tunnels listed in the appendix. These data include length; cross section shape and dimension; type of rock; tunneling method; method of breaking, loading, and transporting the rock; average linear progress rate; and cost in values during the period of construction. Most of the tunnels described have diameters of 15 to 30 feet. 45 cents.

IC 8376. Technology and Use of Lignite. Proceedings: Bureau of Mines-University of North Dakota Symposium, Grand Forks, N. Dak., April 27–28, 1967, by Wayne R. Kube and James L. Elder. May 1968. 201 pp. 8 figs. The 1967 Lignite Symposium was held at Grand Forks, N. Dak., on April 27–28, 1967. This was the fifth of these technical meetings and the fourth which was cosponsored by the University of North Dakota and the Bureau of Mines. These symposia have provided a meeting place where current developments concerning technology and utilization of solid fuels (lignite) are presented. There was a registration of 255 persons from 24 States, the District of Columbia, six Canadian Provinces, Germany, and India. Many segments of coal or energy oriented organizations at many levels were represented. During the meeting, 18 presentations were made covering developments in electrical power generation, mining, estimation of reserves, combustion, gasification, and chemical and specialty uses of low-rank coals; these are compiled in this Information Circular to provide a record of the symposium and to permit wider dissemination of the information. Proceedings of the other meetings have also been published.

IC 8377. Gamma Irradiation of Coal, by Irving Wender, Charles Zahn, and Robert F. Stewart. May 1968. 39 pp. 2 figs. This report describes Bureau of Mines experiments and reviews the work of others on the exposure of coal and coal-derived products to gamma rays and some other types of radiation. Results are presented on tests of three bituminous coals and a lignite that had been pulverized to minus 200-mesh particles and exposed to 1,000 megaroentgens of gamma irradiation from spent-fuel elements of a nuclear reactor. Of about 20 chemical and physical tests in Bureau work, only mass spectrometry of gases evolved during vacuum pyrolysis of the coals to 450° C gave results indicating differences in the irradiated and unirradiated samples. Mass-spectral distribution curves for CO and CO_2 evolution showed fewer irregularities (reversals of curvature) for irradiated coals; thus, mass spectrometry appears to be the most sensitive method for determining radio-induced changes in coal. It is concluded that coal is not significantly altered by gamma irradiation owing to the resistivity of its highly condensed ring structure. High-level gamma irradiation, therefore, is unlikely to prove advantageous in coal processing and utilization. Specially treated coals, because of resistivity of coal to radiation damage, may be useful as an absorbent in processing radioactive wastes.

IC 8378. Injury Experience in the Metallic Mineral Industries, 1964, by Forrest T. Moyer, Donald E. Redmon, and Donald K. Walker. May 1968. 70 pp. Injury experience at metal mines and mills (excluding office workers) in 1964 was 60 fatal and 3,672 nonfatal disabling work injuries during an exposure time of 149 million man-hours worked. These injuries occurred at a frequency rate of 24.97 per million man-hours and had a severity rate of 3,687 days lost or charged per million man-hours. Employment at 2,363 metal mines and 291 mills, excluding office workers, was 68,140 men in 1964. The average number of days worked was 274. The principal cause of fatal injuries at all mines and mills was haulage accidents and in underground mines, only, was falls of ground. The principal cause of nonfatal injuries was handling material accidents. The frequency rate at metal mines and mills in 1964 was slightly below that of 1963, whereas the severity rate was higher. Injury experience at 94 primary nonferrous smelters, refineries, and reduction plants (excluding office workers) was 8 fatal and 999 nonfatal disabling work injuries during a worktime of 98 million man-hours worked. The combined injury-frequency rate in 1964 was 10.29 and the injury-severity rate was 1,005. The 36,956 employees worked an average of 329 days during 1964. The principal cause of injuries at these plants was handling material accidents. The injury experience for onsite office workers at metal mines and mills was 14 nonfatal disabling work injuries which occurred at a frequency rate of 1.57. Office workers at primary nonferrous smelters, refineries, and reduction plants had no disabling work injuries in 1964.

IC 8379. Microfilming Maps of Abandoned Anthracite Mines. Mines in the Wyoming Basin, Northern Anthracite Field, by W. L. Eaton and G. B. Gait. June 1968. 13 pp. 4 figs. This report is the second in a series concerning the Bureau of Mines program for microfilming maps of abandoned mines in the Pennsylvania anthracite region; a catalog of the microfilmed maps of mines in the Wyoming Basin of the Northern anthracite field is presented. The first report, IC 8274, published in 1965, was a catalog of microfilmed maps of mines in the Eastern Middle anthracite field. Additional catalogs will be published as the microfilming of significant mining areas is completed.

IC 8380. United States Coals in World Markets, by George Markon. 1968. 87 pp. 14 figs. The importance of U.S. coal exports as a component of the national economy, the potential for growth of these exports, and the international character of this sector of the coal industry are described in this report. The report summarizes some of the many background elements in the rise of U.S. coals to pre-eminence in highly competitive world markets. It presents some insight into this important sector of U.S. industry and the positive contribution of this sector to the Nation's balance of payments. It contains pertinent basic statistics on production, trade, and consumption of coal in most major markets for 1960–66. (*Out of print.*)

The report examines the movement of U.S. coals from mines to export markets, tracing and describing origins, exit ports, prices, and trends as well as inland and ocean freight rates and other data vital to an understanding of some of the practices and complexities of the U.S. coal markets abroad. A brief sketch of coal production and consumption in principal importing countries is also presented with a short review of some of the more current practices and problems of these countries. 65 cents.

IC 8381. Mineral Transportation Costs in the Pacific Northwest, Methodology and Application of a Statistical Analysis, by Jerry J. Gray, N. S. Petersen, and G. A. Kingston. 1968. 30 pp. 3 figs. Transportation charges for mineral commodity movements in western Oregon and western Washington were determined mainly by a stratified random sample canvass of producers. Total 1965 mineral production value for this area was $53.3 million; the cost or charge to move this production from the mine to the consumer or to the point of consumption was determined to be an additional $38.7 million. Thirty-seven companies were contacted as a sample out of a total population of 349; the statistically expanded sample production value deviated 3.6 percent from that obtained by the Bureau's annual canvass. The agreement between the sample results and the canvass totals demonstrated the effectiveness of the sampling method for obtaining data with a predesigned level of accuracy.

For comparison, the north-central Idaho and western Montana area was studied. A random sample experiment was designed, but because of the dominance of a few major companies, a random sample technique would have required more visits to producers than if only the larger firms were contacted. Eighty-four percent of the 1966 mineral value ($198.6 million) was accounted for by interviewing 27 firms out of a total population of 199. Total transportation costs or charges for the area were $26.7 million. The significant difference observed between the relationship of minerals production value and transport charges between the two areas investigated can be attributed to the difference in the minerals produced. The western Oregon and western Washington region is a nonmetals-producing area as opposed to the predominance of metals production in the Idaho-Montana region. 30 cents.

IC 8382. Refractory Use Patterns in the Iron and Steel Industry of the United States, by William S. Miska. 1968. 67 pp. 30 figs. The study is an economic evaluation of historical, current, and projected refractory uses in the iron and steel industry of the United States. The first part of the report presents a refractories classification and identifies principal trends in the refractories industry, such as value and volume of shipments, prices of finished refractory products, and the number of manufacturers and plants for refractories production and marketing. The main part of the report treats refractory use patterns and technologic developments affecting refractories usage in the iron and steel industry. Changes in use patterns in each furnace type, refractory, and installation costs and the future outlook for refractories in ironmaking and steelmaking are covered. The last part of the report identifies the principal raw materials used in refractories production and treats trends in refractory raw material consumption.

An appendix to the report contains historical time series graphs of shipments of refractory types used primarily by the iron and steel industry and principal refractory raw materials sold or used by producers. An equation of the line of best fit was calculated from the earliest to the latest year in each time series, usually 1950 to 1965; these were extrapolated in order to derive volume estimates for the year 1975. 50 cents.

IC 8383. Magnetic Susceptibility of Copper-, Lead-, and Zinc-Bearing Minerals, by H. E. Powell and Lee N. Ballard. June 1968. 11 pp. 1 fig. The magnetic susceptibility, the geographical source, and associated minerals are given for 44 copper-, 26 lead-, and 19 zinc-bearing minerals. Of the 44 copper minerals, all had a susceptibility of less than 15×10^{-6} cgs, and about 20 percent of them were diamagnetic. Of the 26 lead minerals, all had a susceptibility of less than 11×10^{-6} cgs, and almost half of them were diamagnetic. And, of the 19 zinc minerals, all except four had a susceptibility of less than 9×10^{-6} cgs, and about one-fourth of them were diamagnetic.

IC 8384. An Energy Model for the United States, Featuring Energy Balances for the Years 1947 to 1965 and Projections and Forecasts to the Years 1980 and 2000, by Warren E. Morrison and Charles L. Readling. July 1968. 127 pp. 16 figs. A simplified energy model for the United States is quantified for a recent historical period. The basic model and calculated quantified structures are used for a number of analytical case studies that estimate midterm and long-range shifts in patterns of energy resources demand and required supply. Historical data series are presented for the years 1947 to 1965 in the form of integrated energy balances by source, form, and consuming sector. In case studies I to XII, conditional projections of historical trends of energy demand and required supply are made for the midterm period 1966 to 1980. The projections are carried out by correlation of major energy components with relevant independent variables such as major economic indicators. Simulations of the medium-range projections to 1980 are carried out by varying the assumptions for the determining variables to produce high- and low-range projections for the midterm period. Case studies XIII to XXII are long-term contingency or technological forecasts to the year 2000. These cases assume technological changes or innovations that produce major shifts in the long-term pattern of energy consumption and the mix of required resources. The domestic resource base is assessed in its ability to meet projected or forecast demand for energy resources under the midterm and longrun assumptions made in the various case studies. Various energy issues or problems identified from the analyses of the case studies are discussed, and possible alternative approaches to solutions to these issues or problems are suggested. 70 cents.

IC 8385. Review of Bureau of Mines Coal Program, 1967, by John D. Spencer. June 1968. 99 pp. 43 figs. Air and water pollution and land reclamation relating to coal mining and utilization continued to be featured in research and technologic work on coal by the Bureau of Mines in 1967. Details of the environmental studies are given in this report, along with accounts of other research relating to the mining and utilization of coal. Other studies that were continued during 1967 included health and safety, mine explosives, coal preparation and transportation, coal utilization processes, chemistry and properties of coal, inspection and analysis, and international activities. Publications issued in 1967 are cited throughout the report and in appendix C. Bureau research centers and laboratories are listed in appendix A, and organizations contributing to or cooperating in the work, in appendix B.

IC 8386. Bibliography of Investment and Operating Costs for Chemical and Petroleum Plants, January–December 1967, by Sidney Katell and William C. Morel. 1968. 125 pp. This report, which covers the period January through December 1967, is the ninth in a series of reports prepared in cooperation with the American Association of Cost Engineers. The abstracted articles are concerned with all phases of cost engineering in the field of chemical and petroleum plants and related subjects. Although the bibliography deals mainly with construction and operating costs, other subjects are covered including cost-estimating methods and theory, reports on construction projects in the United States and abroad, developments in petroleum production and refining, and developments in the nuclear field. $1.00.

IC 8387. Research and Technologic Work on Explosives, Explosions, and Flames: Fiscal Year 1967, by Staff, Explosives Research Center. August 1968. 24 pp. 4 figs. The principal activities of the Bureau of Mines Explosives Research Center during fiscal year 1967 (July 1, 1966, to June 30, 1967) are reviewed in part 1. Part 2 presents short abstracts of the publications issued during this period in the Bureau series and in other media. Part 3 is a description of a short study on the shock initiation of hydrogen peroxide not destined for publication elsewhere.

IC 8388. Helium-4 Experimental PVT References: 1895 to 1968, by Robert E. Barieau. August 1968. 24 pp. A list of 163 references to original experimental PVT data on helium is presented for the period 1895 to 1968. The list is complete as of the start of the Helium Centennial Year, 1968, to the best of the author's knowledge. Citations were keypunched for easy updating and are listed alphabetically by author.

IC 8389. Injury Experience in Coal Mining, 1965. Analysis of Mine Safety Factors, Related Employment, and Production Data, by Forrest T. Moyer and Nina L. Jones. August 1968. 88 pp. 3 figs. Injury experience in the coal-mining industry was worse in 1965 as both the frequency and severity rates of injuries increased 2 and 6 percent, respectively, over comparable data for 1964. The retrogression in the safety record during 1965 resulted from the less favorable record at bituminous-coal mines, which more than offset the improved injury experience at anthracite mines. The 259 fatal and 11,138 nonfatal injuries occurred at a rate of 45.77 per million man-hours of exposure and resulted in a severity rate of 8,960 days lost per million man-hours. Although the number of fatalities was the second lowest annual total in the recorded history, it was 17 higher than in 1964. At anthracite operations the total of 8 fatalities in 1965 was the lowest annual figure in statistical history. The annual numbers of nonfatal injuries at all coal mines and the resulting rates of occurrence have varied little in the past 5 years.

IC 8390. Basic Coal Research in the United States, compiled by Staff, Bureau of Mines—Coal Research. 1968. 56 pp. Reports by researchers in government, industry and universities of the United States are given for various projects on basic coal research concerning the metamorphism, physical and chemical properties, and reactions of coal, and how many of these studies can lead to better utilization of coal. 45 cents.

IC 8391. Dimension Stone, by William R. Barton. 1968. 147 pp. 26 figs. The report was designed to bring into a single publication all the fundamental information on dimension stone by summarizing information on production, trade, use, substitute and alternate materials, and resources. The pertinent properties and principal specifications for stone are described along with exploration, mining, finishing, and use technology. A brief history and geologic background are also included. The geographic distribution, size, and structure of the industry are discussed, along with future outlook, costs, prices, tariffs, and legislation affecting the industry. $1.25.

IC 8392. Horizontal Boring Technology: A State-of-the-Art Study, by James Paone, William E. Bruce, and Roger J. Morrell. 1968. 86 pp. 63 figs. This report was prepared by the Bureau of Mines at the request of the Department of the Interior.

This paper describes the different machines and methods used in augering, impacting, pushing, drilling, and machine tunneling horizontal holes through soil and rock. A review of the borehole survey and guidance tools and techniques applicable to these methods is also given. Nonboring methods used for emplacement of power distribution and transmission lines are briefly discussed. (*Out of print.*)

IC 8393. Computer Usage for Evaluation of Design Parameters and Cost of Heat Exchangers With No Change in Phase and Shell Side Pumping Costs as Prime Parameters, by P. R. Jones and S. Katell. October 1968. 67 pp. 1 fig. A computer program was written for the design of a shell and tube heat exchanger on a price optimum basis for the following conditions: (1) triangular pitch; (2) single or multiple pass; (3) heating or cooling; (4) no change in phase; and (5) inside pumping costs immaterial.

Price optimum design was obtained for four standard tube sizes and standard pitch. The inside pressure drop was fixed and outside pressure drop was computed for the optimum baffle spacing and when the baffle spacing equaled the shell diameter. Standard shells whose areas equaled or exceeded the required area were also listed. The program was made adaptable to various fluids and to various tube sizes and pitch by reading in many of the required data such as physical properties of the fluids, tube data, and standard shell data in tabular form.

IC 8394. Copper Hydrometallurgy. A Review and Outlook, by Franklin D. Cooper. September 1968. 18 pp. This Bureau of Mines study reviews current and proposed methods of extracting copper from sub-mill-grade ore by leaching. The amount of copper produced by hydrometallurgy has increased dramatically in recent years and will probably be about 200,000 tons per year by 1970.

IC 8395. Analyses of Natural Gases, 1967, by B. J. Moore and R. D. Shrewsbury. 1968. 187 pp. This publication contains routine analyses and related source data for 547 natural gas samples from 22 States and three foreign countries. Of this total, 340 samples were collected during calendar year 1967. The remaining 207 analyses are of samples collected during previous years, but releases granting permission to publish the results were not received until 1967. All samples were collected as a part of a continuous survey of the free world for occurrences of helium in natural gas. The Bureau of Mines has conducted this survey in the United States since 1917, and in 1965 it was expanded to include foreign gasfields. $1.75.

IC 8396. Prospecting and Exploring for Radioactive Minerals: Supplement to Facts Concerning Uranium Exploration and Production, by Staff, Bureau of Mines, Mineral Resource Evaluation. 1968. 36 pp. This report includes a short history of uranium and its uses, mineralogy of common uranium minerals, and information on the use of electronic prospecting equipment and tests for detecting the presence of uranium. Details are given on geologically favorable areas and formations and practical methods of prospecting. Some information is given on the staking of claims, what lands are open to prospecting, and methods of securing mining rights. A forecast of the economic outlook for uranium is included. Approaches give sources of additional information and a list of libraries where unclassified Atomic Energy Commission reports may be consulted. Because the increasing use of uranium by industry has revived interest in prospecting and exploration for this element, the Bureau of Mines has issued this report, which brings up to date and expands the subject matter of a handbook on uranium exploration and production published in 1956. 45 cents.

IC 8397. Bureau of Mines Research on the Analysis of High-Purity Tungsten, by Staff, Bureau of Mines. October 1968. 10 pp. This report summarizes the work performed by the Bureau of Mines on the development of analytical procedures for determining metallic and interstitial impurities in high-purity tungsten. Fourteen published methods and seven unpublished methods are briefly described. Carbon, hydrogen, nitrogen, and oxygen, in microgram to higher quantity levels, can be determined by several methods. Trace levels of 29 metallic impurity elements can be determined by optical spectography, X-ray spectography, and other instrumental methods.

IC 8398. Helium: Bibliography of Technical and Scientific Literature, 1962, Including Papers on Alpha-Particles, by Philip C. Tully and Lowell Stroud. 1969. 367 pp. This bibliography contains 2,072 citations to technical and scientific literature about helium and alpha-particles abstracted by 12 abstract service publications during 1962. Citations are listed by 16 major subject classifications with several subclassifications to minimize areas of literature search. Automatic data processing was used to reduce the time and labor required to compile the bibliography. $3.25.

IC 8399. Computer Usage for Evaluation of Design Parameters and Cost of Heat Exchangers, With No Change in Phase and Tube Side Pumping Costs as Prime Parameters, by P. R. Jones and S. Katell. January 1969. 67 pp. 1 fig. This report, the third of a series of four reports concerned with computer programs in which optimum economic design is used for the evaluation of the design parameters and cost of heat exchangers, contains a computer program written for design and cost of a shell and tube heat exchanger. The total cost, which includes annual fixed charges and annual operating costs, was minimized. The program was written for the type of heat exchanger in which only the tube side pumping costs were significant and for triangular pitch, single or multiple pass, heating or cooling, and no change in phase.

Tube diameter was not optimized since the tube dimensions do not affect the cost very much. However, the tube dimensions do affect the shell diameter, number of tubes, and length of tubes, and price optimum design was obtained for four standard tube diameters. Standard heat exchangers having at least the required area are also listed.

The program was made adaptable to various fluids and to various tube dimensions by including many of the required data such as physical properties of the fluids, tube data, and standard shell data as input data.

IC 8400. Angular Positions of X-Ray Emission Lines of the Elements for Common Analyzing Crystals, by Martin Berman and Sabri Ergun. 1969. 309 pp. 3 figs. Tables of 2θ positions for all the transitions for nine common analyzing crystals for first, second, and third order reflections were compiled by the Bureau of Mines to facilitate elemental X-ray fluorescence analysis on multi-element systems. The tables are based on a compatible set of wavelengths for 2,346 observed X-ray transitions of the elements lithium to americium. The results are tabulated in order of increasing wavelength as well as by increasing wavelength for each element. $2.25.

IC 8401. Supply and Demand for Energy in the United States by States and Regions, 1960 and 1965 (in Four Parts). 1. Coal, by Grace N. Broderick. 1969. 21 pp. 4 figs. U.S. supply and demand data for coal, by States and regions, were tabulated for the years 1960 and 1965. Estimates are provided of State-by-State quantitative data for the coal industry that can be integrated into State and regional energy balances by source, form, and consumer sectors, and used for estimates of interstate and interregional energy flows. The tables give an estimated total supply of coal available for consumption; they also report the distribution of the supply among the major consuming sectors (household and commercial, industrial, transportation, and electricity generation). To enable comparison of coal data with those for other energy forms, tonnages were converted to British thermal units (Btu). Future energy analysis studies could be facilitated by changes in the categorization of information collected on the coal industry. The data shown are primarily on Bureau of Mines source material. $1.

IC 8402. Supply and Demand for Energy in the United States by States and Regions, 1960 and 1965 (in Four Parts). 2. Utility Electricity, by Franklin P. Hall and Grace N. Broderick. 1969. 11 pp. 2 figs. U.S. supply and demand data for utility electricity by States and regions were tabulated for the years 1960 and 1965. Estimates are provided of State-by-State quantitative data for the utility electricity industry that can be integrated into State and regional energy balances by source, form, and major consuming sectors, and used to determine basic flow patterns. The difficult problem of compiling interstate and interregional shipments of electricity was resolved by (a) assuming the negligibility of interregional shipments and (b) deriving a theoretical line loss percentage used for determining interstate shipments. The data developed were able to show an estimated total supply of utility electricity available for consumption. The tables also report the distribution of the supply among the major consuming sectors (household and commercial, industrial, and transportation). To compare the various energy sources of utility electricity, quantities were converted to their British thermal unit (Btu) equivalents. The Federal Power Commission, Edison Electric Institute, and Bureau of Mines are the sources of the data used in this study. 75 cents.

IC 8403. Supply and Demand for Energy in the United States by States and Regions, 1960 and 1965 (in Four Parts). 3. Dry Natural Gas, by Lulie H. Crump. 1969. 8 pp. 2 figs. U.S. supply and demand data for dry natural gas by source, form, and major consuming sectors—within and between States and defined regions—were tabulated for the years 1960 and 1965. State-by-State quantitative data are provided for the natural gas industry that can be arranged into regional groupings and used to determine regional flow patterns. The tables show the derivation of the total supply of gas available for consumption from total marketed production. The tables also report the distribution of the supply among the major consuming sectors (household and commercial, industrial, transportation, and electricity generation, utilities). The summarized data show an increase in the absolute demand for natural gas in all regions for the period 1960–65, although the relative positions of the various subregions, with respect to national consumption, remained about the same. To enable comparison of data on dry natural gas with data on other energy sources, quantities in terms of million cubic feet were converted to British thermal unit (Btu) equivalents. $1.

IC 8404. Waste Disposal Costs of a Florida Phosphate Operation, by J. R. Boyle. 1969. 24 pp. 13 figs. The Bureau of Mines developed cost estimates for the disposal of phosphate rock washer slimes by pond settling, from a study of the method used at the International Minerals & Chemical Corp., Noralyn Phosphate Operations, Polk County, Fla. Data were obtained by basing phosphate production and slime generation statistics on plant capacity rather than on actual company records. Cost estimates, which were prepared as a guide in evaluating alternative disposal methods and in identifying needed areas of research, could be applicable to any Florida plant using the same disposal method. To conserve mineral resources and to improve environmental conditions, the Bureau recommends further research directed toward developing alternative methods of disposal, including the recovery of water and P_2O_5 values from the slimes. 35 cents.

IC 8405. Factors in Selecting and Applying Commercial Explosives and Blasting Agents, by Richard A. Dick. 1968. 30 pp. 4 figs. In this report commercial blasting compounds are classified according to their nitroglycerin (or equivalent explosive oil) and ammonium nitrate content as dynamites, gelatins, blasting agents, military explosives, and blasting accessories. The ingredients and more significant properties of each explosive are tabulated and briefly discussed. Data are summarized from various handbooks, textbooks, and manufacturers' technical data sheets, together with the author's personal experience; however, this report is not intended to be a technical handbook, since it does not deal with blasting techniques. Instead, it seeks to acquaint the reader with the great variety of explosives available, their advantages and disadvantages, and their general areas of application.

Properties discussed are weight strength, cartridge strength, detonation velocity, density, detonation pressure, water resistance, and fume class. The weakness of the strength rating system and the importance of detonation pressure, density, and detonation velocity in rating explosives are discussed. The terms "blasting agent" and "slurry," which are often misused, are defined. 40 cents.

IC 8406. Waste Disposal Costs at Two Coal Mines in Kentucky and Alabama, by V. A. Danielson and D. H. White, Jr. 1969. 28 pp. 6 figs. The Bureau of Mines studied waste disposal methods at a coal mine in Kentucky and another in Alabama to develop cost estimates, to provide better knowledge of current practices, and to guide consideration of alternate disposal methods. Costs of the existing waste disposal systems at each mine were estimated using present-day costs of equipment and labor. Costs of waste disposal systems using alternate equipment were also estimated. Although total disposal costs were essentially the same for both operations, reclamation costs will differ because of different reclamation practices. 40 cents.

IC 8407. Dust Control in Mining, Tunneling, and Quarrying in the United States, 1961 Through 1967, by Floyd G. Anderson and Robert L. Beatty. March 1969. 50 pp. This report reviews and summarizes information on prevention and suppression of dust in mining, tunneling, and quarrying published in the United States from 1961 through 1967. Unpublished pertinent data developed or assembled by the Bureau of Mines during this period also are included.

IC 8408. Impact of Petroleum Development in the Gulf of Mexico, by L. K. Weaver, C. J. Jirik, and H. F. Pierce. 1969. 58 pp. 19 figs. The Bureau of Mines investigated the progressive impact that petroleum (crude oil and condensate) operations in the Gulf of Mexico have had on onshore operations and the expected effect of increasing activities in this area on future petroleum supplies from domestic sources. The data analyzed include capital expenditures, number of wells drilled, success ratio for exploratory wells, daily production per completion, annual producing rates, and oil reserves. The report compares offshore and onshore data and ascertains trends in petroleum industry operations. Observed data and trends indicate that in the near future Gulf of Mexico development and production will continue to increase relative to total U.S. petroleum activity. By 1975 annual oil and condensate production from the Gulf is expected to be in the range of 750 million to 1,150 million barrels and to account for approximately 20 to 30 percent of the estimated total domestic production. 70 cents.

IC 8409. Pennsylvania Anthracite Refuse. A Survey of Solid Waste From Mining and Preparation, by John C. MacCartney and Ralph H. Whaite. 1969. 77 pp. 18 figs. In the Pennsylvania anthracite region, the principal source of U.S. anthracite, refuse disposal problems are common since cities and towns are located over the anthracite measures. The Bureau of Mines surveyed refuse banks in the area, determining that 863 banks containing over 910 million cubic yards of material occupy a total area of about 19 square miles. The vast bulk of the refuse is located within 2 miles of the traffic centers of incorporated communities which have a total population of 625,000. Twenty-seven banks are burning, causing considerable distress in a number of communities. $1.25.

IC 8410. Design of Dams for Mill Tailings, by C. D. Kealy and R. L. Soderberg. 1969. 43 pp. 25 figs. The Bureau of Mines studied tailings disposal problems at mines throughout the United States to identifiy design principles that can be applied to all types of dams for mill tailings. Computer programs for stability analysis and phreatic waterline estimation are also reviewed in this circular, which presents the Bureau's recommendations for constructing effective, long-lasting tailings dams. 55 cents.

IC 8411. Supply and Demand for Energy in the United States by States and Regions, 1960 and 1965 (in Four Parts). 4. Petroleum and Natural Gas Liquids, by Lulie H. Crump and Philip N. Yasnowsky. 1969. 25 pp. 4 figs. U.S. supply and demand data for petroleum and natural gas liquids, by States and regions, were tabulated for the years 1960 and 1965. Estimates are provided of State-by-State quantitative data for the petroleum and natural gas liquids industry that can be integrated into State, regional, and national energy balances by source, form, and consumer sectors, and used for determination of interstate and interregional energy flows. Tables show the estimated total supply of petroleum available for consumption and the supply's distribution among the major consumer demand sectors (household and commercial, industrial, transportation, and electricity generation). To obtain summary figures for the major proportion of refined products by States, individual tables were compiled for the six major products. To enable comparison of petroleum data with those for other energy forms, conventional volumetric data in barrels were converted to their British thermal unit equivalents. Interregional shipments of crude petroleum and theoretical flow patterns of petroleum products are shown. 55 cents.

IC 8412. Preparation of Anhydrous Aluminum Chloride, by Robert L. de Beauchamp. June 1969. 19 pp. 1 fig. The Bureau of Mines reviewed aluminum chloride technology to determine the problems associated with its preparation from minerals and to ascertain the best areas for research to solve these problems. Commercial $AlCl_3$ production processes are described and the state of the art for the preparation of $AlCl_3$ from aluminous materials is evaluated. Areas for further research are indicated.

IC 8413. Radiation-Ventilation Relationships In Six Underground Uranium Mines, by R. L. Rock. 1969. 17 pp. 3 figs. The Bureau of Mines conducted radiation-ventilation studies in six large underground uranium mines to investigate the extent of radon-daughter exposure experienced by the miners and to analyze the ventilation systems to see what changes were required to achieve recommended radiation standards. The studies entailed tracing and measuring the mines' ventilating air, quantitatively and qualitatively, from its entrance into the mines, through production areas, and back to the surface.

The radiation-ventilation surveys showed that where basic principles of good ventilation were not followed, high alpha radiation levels invariably resulted. Some mines required more primary air for controlling radiation levels throughout active areas, but more efficient use of available air was generally possible. Premature contamination of intake air was prevalent where development openings intersected ore or passed by worked-out stopes. Several auxiliary systems were inefficient in secondary distribution, recirculating air already too highly contaminated for ventilation. Many of these common problems can be traced to the lack of mine planning with radiation control in mind. 30 cents.

IC 8414. A Method of Measuring the Costs and Benefits of Applied Research, by John W. Sprague. 1969. 43 pp. 1 fig. The Bureau of Mines studied the application of the concepts and methods of cost-benefit analysis to the problem of ranking alternative applied research projects. Procedures for measuring the different classes of project costs and benefits, both private and public, are outlined, and cost-benefit calculations are presented, based on the criteria of probability of success and internal rate of return. Because of increasing concern about environmental effects, the methodology and data requirements for estimating project-related pollution costs are discussed. Also, a case study of cost-benefit analysis for a heavy metals program is presented. 50 cents.

IC 8415. Bibliography of Investment and Operating Costs for Chemical and Petroleum Plants, January–December 1968, by Sidney Katell and William C. Morel. 1969. 132 pp. This report is the tenth in a series of reports prepared in cooperation with the American Association of Cost Engineers. The bibliography contains abstracts dealing with all phases of cost engineering in the field of chemical and petroleum plants with emphasis given to those concerning construction and operating costs. Related subjects covered include cost-estimating methods and theory, reports on construction projects in the United States and abroad, and developments in petroleum production and refining and in the nuclear field. $1.25.

IC 8416. Review of Bureau of Mines Coal Program, 1968, by John D. Spencer. June 1969. 94 pp. 37 figs. Surveys to establish the quantity and quality of coals available for metallurgical, industrial, and energy use, investigations to develop better mining methods, and studies aimed at improving the health and safety of those who mine the coal highlighted Bureau of Mines research and technologic work on coal in 1968. Also being developed are more efficient methods of coal preparation, transportation, storage, and utilization. Supplementing this effort are projects designed to assure minimum disturbance of land, water, and air resources. Research centers and laboratories of the Bureau of Mines are listed. Publications released during 1968 are cited with the various projects and in an appendix. Organizations that cooperated in the work in various ways are cited in an appendix.

IC 8417. Helium Symposia Proceedings in 1968—A Hundred Years of Helium. Helium Applications Symposium, Washington, D.C., October 23–24, 1968; Helium Centennial Symposium, Atlantic City, N.J., September 11, 1968, compiled by Harold W. Lipper. 1968. 292 pp. 123 figs. Papers presented at the Helium Applications Symposium discuss the broad spectrum of uses to which helium is currently applied in aerostatics, cryogenics, space, and undersea work. Papers from the Helium Centennial Symposium at the national meeting of the American Chemical Society cover the discovery of helium, its development by the Bureau of Mines into an important item of commerce, its source, and the history of liquid helium and liquid helium-3. $2.75.

IC 8418. A Statistical Analysis of U.S. Demand for Phosphate Rock, Potash, and Nitrogen, by Olman Hee. 1969. 55 pp. 6 figs. This study investigates the identity and relative importance of factors affecting the future demand for phosphate rock, potash, and nitrogen. The main objective is to analyze demand relationships for these chemical raw materials for some specified past period, and to utilize this information to make projections of consumption into some designated future period. The end-use approach is used, which divides total consumption of each chemical raw material into agricultural, industrial, and export use. Multiple regression analysis is employed to statistically measure the relative effects of the different factors on consumption in each end use. The general method centers on the construction of a consumer demand model, the fitting of the respective equations in the model, and the interpretation of the statistical results. Direct and cross price elasticities of demand are computed for each end use of the chemical raw materials. These give an insight into expected changes in consumption with respect to given changes in price. The results of this study indicate that price, consumer income, and level of technology are factors which measurably affect consumption of chemical raw materials. For phosphate rock and potash, the agricultural and industrial end uses showed an inelastic demand, whereas for nitrogen, all end uses (including export use) exhibited an elastic demand. Among the chemical raw materials, average annual growth of consumption of nitrogen for agricultural and export uses to 1980 is expected to be notably higher than that for phosphate rock and potash. 75 cents.

IC 8419. Injury Experience in Coal Mining, 1966. Analysis of Mine Safety Factors, Related Employment, and Production Data, by Forrest T. Moyer and Mary B. McNair. July 1969. 108 pp. 3 figs. The safety record of the coal-mining industry, both anthracite and bituminous, in 1966 was improved over that of 1965 in all general measures of injury experience. The improvement was more pronounced in the anthracite industry. The total of 10,679 disabling work injuries comprised 233 fatal and 10,466 nonfatal injuries, 26 and 692 fewer, respectively, than in 1965. The number of fatalities in 1966 was the lowest annual total since complete records were started in 1910. Similarly, the number of nonfatal injuries in 1966 was lower than in any year since 1930 when such data were first collected.

IC 8420. Computer Usage for Evaluation of Design Parameters and Cost of Heat Exchangers, With Change in Phase on Shell Side, by P. R. Jones, and S. Katell. July 1969. 62 pp. 1 fig. The Bureau of Mines has written a computer program for the design and cost of a shell and tube type heat exchanger, in which a change in phase occurs on the shell side. The total cost, which was minimized, includes the annual fixed charges and annual operating costs. The program was written to meet the following requirements: (1) triangular pitch, (2) single or multiple pass, and (3) heating or cooling.

Price optimum design was obtained for four standard tube diameters and pitch. Standard heat exchangers whose area equaled or exceeded the required area are also listed. The program was made adaptable to various fluids and to various tube dimensions by including many of the required data such as physical properties of the fluids, tube data, and standard shell data as input data.

IC 8421. Pozzolanic Raw Materials Resources in the Central and Western United States, by Staff, Bureau of Mines. 1969. 117 pp. 24 figs. This evaluation of the economic and technical considerations of using pozzolanic materials was made in order to guide those interested in concrete construction work. Five hundred and thirty-eight samples of pozzolanic raw materials were taken from 27 central and western States. These samples were evaluated by petrographic procedures, and about 200 of the most promising ones were given a complete series of physical tests to evaluate further their suitability as pozzolans. This investigation showed that deposits of natural pozzolanic materials were widely dispersed in the central and western parts of the United States but that exploiting these deposits would depend on whether they could compete economically with an increasingly abundant industrial waste product—fly ash. $1.25.

IC 8422. Mineral Resources Valuation for Public Policy, by Donald S. Colby and David B. Brooks. 1969. 34 pp. This Bureau of Mines report is essentially a handbook, or manual, for making the type of mineral resource valuation commonly required for such public policy problems as mineral leasing.

The principle of resource valuation through the capitalization of cash flow is well established. A mathematical procedure, based on a simplified accounting system, is detailed for calculating cash flow from revenue, plant costs, and operating expense. Variations of procedure cover cost depletion, percentage depletion, and depletion limited to 50 percent of net income. The influence of the depletion provisions of the tax regulations on the value of a resource to an owner and to an operator is analyzed.

The relationship of royalty, bonus payments, and sales price to resource value is also described, and methods for approximating resource values using these payments as input data are developed. 45 cents.

IC 8423. A General Computer Program for Solving Nonlinear Regression Problems, by Jarrell C. Grout. 1969. 35 pp. 2 figs. The Bureau of Mines has developed a computer program for use in solving nonlinear regression problems. The program is written in a general form so that, regardless of the functional relationship, the unknown parameters may be evaluated by either the Gauss-Newton or the Newton-Raphson methods of iteration. Variances and covariances of the parameters, as derived from the law for the propagation of errors, are also determined. 45 cents.

IC 8424. Specifications for Selected Hydraulic-Powered Roof Supports. With a Method to Estimate Support Requirements for Longwalls, by A. J. Barry, O. B. Nair, and J. S. Miller. September 1969. 15 pp. 4 figs. This report presents observations made by Bureau engineers regarding hydraulic-powered roof supports that are currently being used or have been used on nearly all operating longwalls in the United States. A comparative summary of specifications for various types of powered supports with a brief description of the mine conditions has been compiled to enable mining engineers and mine operators to readily evaluate the difference in design data. Some of the support data furnished in the field may vary from those listed in manufacturer's brochures because of the trend to customize various support components to meet specific mine conditions. A method of estimating support requirements for different assumed operating conditions is presented. Similar computations for specific mine conditions may be used to make preliminary estimates of support requirements.

IC 8425. Potential Applications for Nuclear Explosives in a Shale-Oil Industry, by Frank E. Williams, Paul L. Russell, and M. J. Sheridan. 1969. 37 pp. 16 figs. Nuclear detonation data were accumulated, studied, and evaluated by the Bureau of Mines to visualize how nuclear explosives might be used in a shale-oil industry. The evaluation shows that the Green River Formation at the semi-isolated locale of Piceance Creek basin, in northwestern Colorado, is thick and widespread enough to warrant consideration of nuclear mining in lieu of conventional methods. Because cost data for nuclear explosions are limited, cost comparisons are made largely by assumptions. Also described are the history of the shale-oil industry, the geology and size of oil-shale resources, and conventional mining methods and processing technology. Work done under an agreement with the U.S. Atomic Energy Commission. 50 cents.

IC 8426. A Computer Program for Calculating Capital and Operating Costs, by Paul W. Johnson and Frank A. Peters. 1969. 110 pp. A computer program for calculating capital and operating costs from material and energy requirements and equipment costs for use in preparing cost estimates for metallurgical process evaluations has been written by the Bureau of Mines' College Park process evaluation group. The program permits rapid recalculation of processing costs when changes of data or equipment are desired, and produces tables of capital and operating costs suitable for publication. Equipment cost summary tables for each process section and supplemental information for input-data checking is included in the computer printout.

The program is written in FORTRAN IV except for several subroutines which are written in machine assembly language for the IBM 7094. With a few modifications, the program can be used on other computers. $1.

IC 8427. Silver in the United States, by D'Arcy Banister and Richard W. Knostman. 1969. 34 pp. 15 figs. The production potential of the principal active and inactive silver mining districts in the United States has been evaluated, using 1964 economic conditions and assumed silver prices ranging up to $3 per ounce. On this basis, the United States has an estimated 5 billion ounces of unmined silver, excluding minor byproduct silver in gold deposits. Approximately 3.5 billion ounces are contained in deposits requiring higher silver prices to be economically minable, and about 1.3 billion ounces are in currently operating mines. An analysis of silver consumption trends since 1954 has also been made which indicates that the free world industrial market will climb to nearly 800 million ounces annually by 1985. 45 cents.

IC 8428. Heavy Oil Reservoirs in Arkansas, by W. G. Parks, S. O. Wood, Jr., and M. Carrales, Jr. 1969. 162 pp. 49 figs. Long-range projection of demand for domestic crude oil indicates a continued upward movement and accentuates the need for increasing the recovery from known crude-oil resources to supplement expected future discoveries. Consequently, industry and Government have given special attention to the viscous or heavy-oil deposits, because they offer the distinct possibility of large order increases in ultimate recovery.

This report presents data pertaining to 150 heavy-oil reservoirs in Arkansas including oil characteristics of samples from 38 of these reservoirs. To January 1, 1967, about 600 million bbl of heavy oil has been recovered from the 150 reservoirs in 83 oilfields; however, about 4.5 billion bbl, or 88 percent, of the oil remained in the ground. Of prime importance is that much of this heavy-oil resource is in reservoirs having characteristics considered favorable for thermal-recovery operations. Data for the thermal projects initiated thus far are presented in individual field discussions. Also discussed is the crude oil supply-demand situation in the State. Work done in cooperation with the Arkansas Oil and Gas Commission. $1.75.

IC 8429. List of Bureau of Mines Publications on Oil Shale and Shale Oil, 1917-68, by Marianne P. Rogers. 1969. 61 pp. This list is part of the long-range conservation program of the Bureau of Mines and is intended for use by those interested in the Bureau's publications dealing with oil shale and shale oil. The items included represent 51 years of research by Bureau of Mines employees on oil shale and shale oil and are available at U.S. depository libraries. Work done in cooperation with the University of Wyoming. 65 cents.

IC 8430. Disposal of Solid Wastes From Coal Mining in Washington, Oregon, and Montana, by M. R. Geer. 1969. 39 pp. 14 figs. The Bureau of Mines surveyed the solid wastes that have accumulated from coal mining in Washington, Oregon, and Montana. Location, amount, character, and condition were determined, and both economic and environmental factors were considered. Areas covered by waste comprise 800 acres in Washington, 5 acres in Oregon, and 1,200 acres in Montana. In a few cases waste is being utilized, particularly cinder from burned refuse dumps, as fill in road construction and as a ceramic raw material. It is estimated that wastes deriving from coal mined for electric power generation by 1974 may amount to 3 million tons of washery refuse, 2.7 million tons of fly ash, and 1,000 acres of spoil banks. 50 cents.

IC 8431. Transportation of Mineral Commodities on the Inland Waterways of the South-Central States, by Frank B. Fulkerson. 1969. 88 pp. 13 figs. Barge traffic on U.S. inland waterways over the past 15 years has been increasing at a rate much faster than intercity freight traffic by all modes. The Bureau of Mines, in a study to determine barge traffic projections for inland waterways in the South-Central States to the year 1980, gathered data on origin-destination patterns by commodity, quantity moved, equipment used, and rates charged; the trend of each of these factors over time; and the extent of competition between water transport and other means of transportation. $1.

IC 8432. Applying Marx and Langenheim Calculations to the Prediction of Oil Recovery by Steamflooding in Venango Sands, by Avis W. Effinger and James A. Wasson. November 1969. 34 pp. 3 figs. In conjunction with pilot steamflood tests in the Venango sands of Warren and Venango Counties, Pa., the Marx and Langenheim calculations were adapted and programed for digital computer solution to predict test performance. The Monte Carlo technique was incorporated in the calculations to provide values of several variables which could not be adequately defined from available information. The computation methods are explained and the FORTRAN IV program listing is presented. Data and results of the prediction calculations for Venango oil sands are also shown.

IC 8433. Injury Experience in the Metallic Mineral Industries, 1965, by Forrest T. Moyer and Mary B. McNair. November 1969. 69 pp. The safety record of the metal mining and milling industries in 1965 is reviewed by the Bureau of Mines. The overall injury-frequency rate of 23.77 per million man-hours was 5 percent lower than in 1964 and was the lowest annual rate in a statistical history beginning with 1931. The injury-severity rate of 3,521 days lost per million man-hours in 1965 represented a 5-percent improvement over 1964. However, the total of 3,825 disabling work injuries comprised 61 fatal and 3,764 nonfatal injuries, one and 92 more, respectively, than in 1964. At primary nonferrous smelters, refineries, and reduction plants, the injury-frequency rate of 8.97 per million man-hours in 1965 was 13 percent lower, but the severity rate of 1,173 days lost per million man-hours was 17 percent higher than in 1964. There were 12 fatal and 971 nonfatal injuries at these plants in 1965, 4 more and 28 fewer, respectively, than in 1964.

IC 8435. Grace Mine Iron Ore Waste Disposal System and Estimated Costs, by William Cochran. 1969. 17 pp. 6 figs. The mineral waste disposal system at the Grace mine, Morgantown, Pa., was designed to minimize environmental effects while allowing much of the waste from the iron mine, mill, and concentrator to be utilized. Standard cost estimating procedures were used by the Bureau of Mines to determine waste disposal costs. Mill tailings and rock waste disposal costs were estimated at $0.151 and $0.276 per ton, respectively, for the 1965-67 production period. Total waste disposal cost was reduced about 0.015 per ton by utilizing part of the waste as aggregate. The net average cost for disposal of all mineral waste was $0.189 per ton. 30 cents.

IC 8436. Respiratory Protective Devices Approved by the Bureau of Mines as of December 31, 1968. A Revision of Information Circular 8281, by R. H. Schutz and E. J. Kloos. 1969. 32 pp. This publication lists the respiratory protective devices approved by the Bureau of Mines as of December 31, 1968, and the names and addresses of their manufacturers. The purpose of this publication is to inform the public about approved equipment for safe use in mines and mineral and allied industries. 40 cents.

IC 8437. On Estimating Virial Coefficients From Experimental Data, by K. R. Van Doren. December 1969. 26 pp. The polynomial method for estimating virial coefficients from experimental data suffers from three serious defects: (1) There is no known relationship between the polynomial coefficients and the virial coefficients, (2) the values of the estimates depend upon the degree of the polynomial and the particular set of values used for the independent variable, as well as the random errors in the dependent variable, and (3) the variances calculated for the estimates do not represent the mean square errors of estimation. Attempts to overcome these defects have thus far been unsuccessful; these attempts have also failed to account for the fact that none of the virial coefficients is uniquely determined by the values of the dependent variable for a finite set of values of the independent variable. The conclusion is that virial coefficients cannot be reliably estimated from experimental data unless additional information about the virial expansion itself, such as its rate of convergence, is available.

IC 8438. Possible Applications of Plasma Technology in Minerals Processing, by Douglas A. Elkins and C. H. Schack. 1969. 13 pp. The unique characteristics of plasmas, their current applications, and ongoing research into new applications are described. Major technical and economic problems in application of plasma technology are discussed. Examples of potential applications of plasma in extractive metallurgy are described and evaluated. The report includes a selected bibliography of articles on plasma and related high-temperature technology. 25 cents.

TECHNICAL PROGRESS REPORTS

Technical Progress Reports, a new Bureau of Mines series initiated in 1968, make known new or improved systems and techniques in mining and metallurgy developed by the Bureau.

TPR 1. **Gold Resources in the Oxidized Ores and Carbonaceous Material in the Sedimetary Beds of Northeastern Nevada,** by Roland W. Merwin. March 1968. 16 pp. 6 figs. Sedimentary beds of northeastern Nevada associated with the Roberts Mountain thrust fault system were investigated by the Bureau of Mines, under the Department of the Interior's Heavy Metals Program, to assess the commercial potential of gold-bearing deposits in the area. Available data on the extent and gold content of these deposits were evaluated economically in the light of present mining and milling technology. Special consideration was given to recovery of gold under economic conditions, by a method now under development, from refractory carbonaceous materials known to constitute a major portion of the region's gold-bearing deposits.

TPR 2. **Investigation of Oxidation Systems for Improving Gold Recovery From Carbonaceous Materials,** by B. J. Scheiner, R. E. Lindstrom, and T. A. Henrie. July 1968. 8 pp. 1 fig. Carbonaceous gold-bearing materials which resist conventional treatment were investigated by the Bureau of Mines (1) to isolate and identify carbon compounds in the ores and to study the chemistry involved in prevention of gold recovery by the carbon compounds and (2) to develop a practical chemical treatment technique that would allow effective gold recovery from these materials by conventional cyanidation.

TPR 3. **Gold Resources in the Tertiary Gravels of California,** by Roland W. Merwin. 1968. 14 pp. 3 figs. Preliminary investigations of gold deposits in the United States indicated that the Tertiary gravels of California contain one of the largest known reserves of gold in the United States and that they are of such grade that a breakthrough in mining and/or metallurgy could stimulate industry to resume working these deposits. The exploitation of these gravels was virtually suspended in 1884 due to legal restrictions on hydraulic mining. The cessation of production occurred at the height of hydraulic mining activities that had resulted in the production of about $500 million at present gold prices and left unworked more than half of the then known gravels. This report covers the total known potential of the Tertiary gravels.

TPR 4. **Marine Heavy Metal Project Offshore Nome, Alaska,** by Richard L. Jenkins and Alvin H. Lense. August 1968. 11 pp. 3 figs. A host of mining problems have been explored and defined, and the essential first step in the development of an ocean floor mining system has been taken. It can be stated with assurance that relatively rapid penetrations of shallow ocean floor sediments can be accomplished from surface craft that will yield samples which can be processed and analyzed aboard ship.

TPR 5. **Gold Resources of the Mother Lode Belt, El Dorado, Amador, Calaveras, Tuolumne, and Mariposa Counties, California,** by Lyman Moore. August 1968. 22 pp. 1 fig. The Bureau of Mines compiled all available information on the Mother Lode gold belt from the literature and from company reports, supplemented by interviews with company officials and various knowledgeable individuals. A reconnaissance was made of the area and of several major deposits. This situation report summarizes the information obtained concerning the belt and provides background information for subsequent supplemental reports on the production potential of the most promising deposits. Preliminary estimates for some deposits indicate that large quantities of gold possibly could be produced economically using large-scale mining operations and a central milling operation.

TPR 6. **Detection Limit for Silver by Isotopic X-Ray Analysis,** by Philip G. Burkhalter. August 1968. 11 pp. 1 fig. The combination of monoenergetic X-ray sources, electronic discrimination, and scintillation detectors was used to determine the detection limit of silver in a silica matrix. The detection limit was measured using Sb, Te, and Ba *K* X-ray sources and also two different Pm^{147} bremmstrahlung sources. A 2σ detection limit of 15 ppm was measured using an annular source of I^{125} for 100-second counting intervals and a 2σ-HM electronic discrimination. The normalized detection limit for the various sources varied from 13 to 22 ppm. The inability of the scintillation detector to discriminate completely completely against Compton scatter was found to be the limiting factor for the sensitivity of silver using isotopic X-ray sources. A slightly lower detection limit can be obtained as the excitation energy is increased because the energy of the Compton scatter peak also increases. Further improvement in the detection limit is possible by reducing the scatter angle and thereby increasing the energy of the Compton scatter. The matrix effect of heavy elements common to silver ores was investigated. If strong X-ray interferences are avoided, a detection limit of 25 ppm or less can still be obtained with as much as 5 percent heavy metals present in the silica matrix.

TPR 7. **Analysis of Large Samples of Low Grade Gold Ores by Methyl Isobutyl Ketone Extraction and Atomic Absorption,** by Stephen L. Law and Thomas E. Green. August 1968. 7 pp. A method for determining small quantities of gold in large splits (500 grams) from field samples of low-grade ores is described. It is based on the dissolution of the gold in aqua regia, extraction of the gold into methyl isobutyl ketone (MIBK) in the presence of the insoluble residue, and determination of the gold in the MIBK phase by atomic absorption. The method is especially useful for samples from which representative small splits cannot be obtained.

TPR 8. Electrolytic Oxidation of Carbonaceous Ores for Improving Gold Recovery, by B. J. Scheiner, R. E. Lindstrom, and T. A. Henrie. January 1969. 12 pp. 8 figs. Carbonaceous gold-bearing ores of the type that occur in northeastern Nevada were investigated by the Bureau of Mines as part of its Heavy Metals Program. Specific objectives were to identify the carbon and organic compounds that prevent adequate gold recovery from this type of ore by cyanidation and to develop an economical process that would overcome the detrimental effect of the carbonaceous constituents. Activated-type carbon and long-chain organic compounds containing sulfur and nitrogen were found in the ore. Part of the material consisted of stable gold organic complexes.

TPR 9. Gold Recovery From Scrap Electronic Solders by Fused-Salt Electrolysis, by E. K. Kleespies, J. P. Bennetts, and T. A. Henrie. March 1969. 8 pp. 3 figs. The Bureau of Mines developed a process for recovering gold and refining tin-lead solders from scrap solder discarded by the electronics industry. During assembly of electronic systems, gold and other contaminant metals are introduced into solder baths which are periodically discarded. Contaminated solder can be refined by electrotransport in a molten-salt chloride electrolyte. Refined solder is recovered at the cathode, and the gold and other metal impurities are concentrated at the anode, increasing gold concentration from 60 to 15,000 ounces per ton without any significant loss. The gold is then reclaimed by conventional fire-refining methods.

TPR 10. Behavior of Coal-Gas Reservoirs, by Joseph Cervik. April 1969. 10 pp. 4 figs. Gas occurs in coalbeds in an adsorbed and a free gas state. Adsorbed gas is stored in the micropore structure and its transport is governed by Fick's law. The free gas occurs in the fracture system and flows according to Darcy's law. These two modes of mass transport are interdependent. Production decline curves of coal-gas wells are of the constant percentage decline type and thus show no indications of flow characteristics peculiar to coal-gas reservoirs. The effectiveness of surface boreholes as a degasification scheme depends upon both good fracture permeability and a high fracture density. Conventional methods of reservoir engineering analysis are not applicable to coalbeds.

TPR 11. Design and Development of Drill Equipment, by J. D. Hadden and Joseph Cervik. May 1969. 11 pp. 10 figs. Attempts to drill long holes in coalbeds horizontally (parallel to the bedding) often result in holes terminating prematurely in floor or roof strata. Such holes are used to determine the physical properties of the coalbed and methane migration characteristics. This report describes the methods used to overcome problems encountered when drilling long horizontal holes in coal. The drilling method and equipment, gas pressure measurements, and packer development are discussed. Also the equipment used in obtaining 7-inch-diameter coal cores is described.

TPR 12. Gas Migration Characteristics of Coalbeds, by J. D. Hadden and Albert Sainato. May 1969. 10 pp. 7 figs. The Bureau of Mines conducted drilling studies in the Pocahontas No. 3, the Pittsburgh, and a western coalbed to establish the gas migration characteristics for each. Gas pressures in the Pittsburgh coalbed were about 260 psi and in excess of 550 psi in the Pocahontas No. 3. Caving in drill holes prevented pressure measurements in the western coalbed. The Pittsburgh bed contained interesecting "clay veins" which formed gas pressure cells. Although these geological features hamper mining, they can be used to control the flow of methane into a mine working. Methane control techniques are proposed for the Pittsburgh and Pocahontas No. 3 coalbeds.

TPR 13. Use of Vertical Boreholes for Assisting Ventilation of Longwall Gob Areas, by C. H. Elder. May 1969. 6 pp. 2 figs. An experimental degasification program using a vertical borehole and vacuum pump to drain gas from the gob area of a longwall panel was successful at Bethlehem Mines Corporation, Cambria Division, No. 33 coal mine. Sixty-one million cubic feet of methane has been exhausted during a 9-month period. Daily production time in the panel increased as a result of lower methane levels in the returns. Removal of large quantities of methane in this way and the exclusion of it from the ventilating system will provide reduced cost in mine ventilation and provide a safer environment for the miners.

TPR 14. Sorption Investigations of Methane on Coal, by J. H. Perkins and Joseph Cervik. May 1969. 6 pp. 2 figs. The Bureau of Mines has conducted desorption work on fine coal particles at near atmospheric pressure. An apparatus has been developed that uses a capacitance manometer to measure desorption of methane from coal particles up to 2 inches in diameter and pressures up to 1,000 psi. This will make it possible to duplicate the desorption process as it occurs in its natural underground environment.

TPR 15. Development of Recording Methanometers and Recording Anemometers for Use in Underground Coal Mines, by J. C. LaScola and Joseph Cervik. May 1969. 17 pp. 11 figs. Development of methanometers and anemometers for underground use in coal mines is reviewed. The first semicontinuous recording methanometer was developed in 1961 in West Germany. The Bureau of Mines developed an instrument using pellesters that was a continuous recording methanometer. Expansion of Freon gas created a vacuum which pulled the methane-air mixture through a tube to an electrically heated, catalyst-impregnated pellester where the mixture was burned. The National Coal Board of England developed a continuous recording methanometer based on the principle of the Davy flame safety lamp. A thermopile was used to sense the heat output of the flame. Finally the Bureau of Mines improved its methanometer by eliminating the Freon gas and using a diffuser head to monitor methane-air mixtures. Development of recording anemometers proceeded from the use of a photocell and light source to sense rotation of the Biram-type anemometer blades to the use of a Hall detector to sense rotation by measurement of electromagnetic pulses.

TPR 16. Experimental in Situ Retorting of Oil Shale at Rock Springs, Wyo., by E. L. Burwell, H. C. Carpenter, and H. W. Sohns. June 1969. 8 pp. 1 fig. Preliminary results of an in situ oil shale retorting experiment conducted by the Bureaus of Mines in a shallow bed of Green River oil shale at Rock Springs, Sweetwater County, Wyo., are described. Eleven wells were drilled into a 20-ft-thick section of the shale lying between 68 and 88 ft deep, and attempts were made to connect the wells through the shale with a fracture system created by application of high-voltage electricity (electrolinking), hydraulic fracturing, and explosive fracturing. Ignition of the shale through the central well was easily achieved with a propane burner, and shale oil began to collect in three wells within 3 hours. Propane injection was discontinued after 7 days, and combustion continues, although attempts to control the direction of the combustion front have been unsuccessful. Production rates as high as 4½ barrels of oil per day have been recorded, but too little is known about underground conditions to permit an estimate of recovery efficiency at this time.

TPR 17. Personal Respirable Dust Sampler, by M. Jacobson and J. A. Lamonica. September 1969. 8 pp. 4 figs. Equipment for evaluating the respirable dust exposure of individual underground coal miners was designed, constructed, and tested by the Bureau of Mines. As a result, the guidelines for sampling and evaluating respirable dust concentrations in the breathing zone of individual miners were finalized, and the equipment was made commercially available. The equipment and techniques, which are described in this report, are consistent with the provisions of pending coal mine health legislation governing respirable gravimetric dust concentrations.

TPR 18. Effect of Lowering the Tin Content of Secondary Red Brass, by L. W. Higley, J. L. Holman, E. R. Cole, and H. Kenworthy. October 1969. 11 pp. 5 figs. Laboratory melts of the secondary casting alloy, leaded red brass (85 percent Cu-5 Sn-5 Pb-5 Zn), were made in which the tin content was reduced from 5 percent to 3 and 1 percent, with increased coper or zinc to offset the reduction in tin. The work was done as part of a Bureau of Mines program to promote more economic use of secondary nonferrous alloys; tin, nearly all of which is imported, accounts for nearly 20 percent of the raw materials cost of the 85-5-5-5 alloy. The mechanical properties and machinability characteristics of the resultant alloys were compared with minimum properties for leaded red brass as specified by ASTM, and with typical properties for leaded red brass as published by the Brass and Bronze Ingot Institute. Results indicate that much of the primary tin added to achieve composition in leaded red brass could be eliminated without significantly affecting strength, ductility, or machinability.

TPR 19. Studies on the Control of Respirable Coal Mine Dust by Ventilation, by D. S. Kingery, H. N. Doyle, E. J. Harris, M. Jacobson, R. G. Peluso, J. B. Shutak, and D. P. Schlick. October 1969. 13 pp. 7 figs. Ventilation experiments conducted by the Bureau of Mines using high-pressure fans as auxiliary ventilation units showed that face-generated dust could be effectively controlled in five mines employing continuous mining machines. By maintaining an airflow approaching 100 fpm across the entry, the experimental system reduced the concentration of respirable dust by factors as great as 6.4. In all mines where the system was used the face-generated dust concentrations were reduced to less than 3 milligrams per cubic meter and in some mines to less than 2 milligrams per cubic meter. For each mine in which the system is to be used additional engineering studies should be made.

TPR 20. Recovering Gold From Stripping Waste and Ore by Percolation Cyanide Leaching, by George M. Potter. December 1969. 5 pp. Simple and low-cost heap and vat percolation cyanide leaching methods were applied on a laboratory scale for recovering gold from submarginal mine strip material and from ores representative of deposits with limited reserves not justifying construction of a conventional cyanide treatment plant. Gold-bearing material, as coarse as 4 inches in size and assaying from 0.06 to 0.6 troy ounces per ton, was leached successfully with dilute cyanide-lime solutions. From 66 to 95 percent of the gold in the samples was dissolved and recovered in activated carbon. The amenable ores and materials invariably contained micron-size gold distributed throughout a porous, relatively cyanide-free gangue.

SPECIAL PUBLICATIONS

SP 1-66. List of Bureau of Mines Publications and Articles. January 1, 1960, to December 31, 1964, With Subject and Author Index, by Rita D. Sylvester. 1966. 297 pp. Supplements the 50-year list of Bureau publications issued from July 1, 1910, to January 1, 1960, and the 50-year list of articles by Bureau authors published outside the Bureau during the same period. Lists more than 2,000 major reports by Bureau authors which were published during the 5 years in regular Bureau of Mines series, in scientific, technical, or trade journals, or in other media, and tells how these may be obtained by the public. Summarizes the vast majority of these reports. Lists the libraries which maintain files of Bureau publications. Summarizes unpublished reports that are available for consultation at certain Bureau offices and libraries, and lists these places. Describes cooperative publications which were issued by organizations with which the Bureau of Mines cooperated on research. Patents isued to Bureau personnel are also listed, as well as instructions on how to apply for permission to use them. One of the outstanding features of this Special Publication is an exhaustive subject and author index. (*Out of print.*)

SP 2-66. List of Bureau of Mines Publications and Articles, January 1 to December 31, 1965, With Subject and Author Index. 1966. 89 pp. Describes publications by the Bureau and articles by its personnel in non-Bureau publications. Supplements the list of Bureau publications issued from July 1, 1910, to January 1, 1960, the list of articles published by Bureau authors outside of the Bureau from July 1, 1910, to January 1, 1960, and the list of publications and articles issued from January 1, 1960, to December 31, 1964. 50 cents.

SP 1-67. Automobile Disposal, a National Problem. Case Studies of the Factors That Influence the Accumulation of Automobile Scrap, by Staff, Bureau of Mines. 1967. 569 pp. 60 figs. The accumulation of junked automobiles is an eyesore detracting from the appearance of urban neighborhood and rural scenery, but the metal in these discarded vehicles is a major raw material resource. The Bureau of Mines, in cooperation with private and Government organizations, has completed a survey of the industries concerned with the disposal of scrap from junked automobiles in 34 selected districts, representing a variety of urban, suburban, and rural conditions. $4.50.

SP 2-67. Mining and Mineral Operations in the United States. A Visitor's Guide, by Staff, Bureau of Mines Area Mineral Resource Offices. 1967. 90 pp. 34 figs. This pamphlet, a guide to mines that may be observed or visited, is intended to aid tourists and students who are interested in mining. 35 cents.

SP 3-67. List of Bureau of Mines Publications and Articles, January 1 to December 31, 1966, With Subject and Author Index. 1967. 94 pp. Describes publications by the Bureau and articles by its personnel in non-Bureau publications. Supplements the list of Bureau publications issued from July 1, 1910, to January 1, 1960; the list of articles published by Bureau authors outside the Bureau from July 1, 1910, to January 1, 1960; the list of publications and articles issued from January 1, 1960, to December 31, 1964; and the list of publications and articles issued from January 1 to December 31, 1965. 50 cents.

SP 1-68. Clearing the Air. Bureau of Mines Programs in Atmospheric Pollution Abatement. 1968. 20 pp. This publication describes briefly the principal sources and causes of air pollution and outlines the Bureau of Mines programs on atmospheric pollution abatement.

SP 2-68. A Dictionary of Mining, Mineral, and Related Terms, compiled and edited by Paul W. Thrush and the Staff of the Bureau of Mines. 1968. 1268 pp. This dictionary contains 150,000 authoritative definitions of mining, mineral, geologic, metallurgical, ceramic, and general scientific terms. The work began as a revision of Bureau of Mines Bulletin 95, "A Glossary of the Mining and Mineral Industry," by Albert H. Fay, first published in 1918. Expansion of the mineral industries and development of new mining and related technologies in the past 50 years have considerably enlarged the vocabulary of mining and minerals. Hence, the need has grown for an up-to-date and comprehensive reference work. The new dictionary includes thousands of new terms supplied by the Bureau of Mines and cites numerous terms from major sources. $8.50.

SP 3-68. Wealth Out of Waste. Bureau of Mines Programs in Solid Waste Utilization, by Bureau of Mines. 28 pp. This pamphlet discusses the problem of mineral wastes, such as incinerator residues, mine and mill dumps, scrap autos, fuel associated wastes, and surface mining wastes, and research by the Bureau of Mines into the possibility of economically reclaiming the mineral values from these wastes.

SP 4-68. List of Bureau of Mines Publications and Articles, January 1 to December 31, 1967, With Subject and Author Index. 1968. 117 pp. Describes publications by the Bureau and articles by its personnel in non-Bureau publications. Supplements the list of Bureau publications issued from July 1, 1910, to January 1, 1960; the list of articles published by Bureau authors outside the Bureau from July 1, 1910, to January 1, 1960; the list of publications and articles issued from January 1, 1960, to December 31, 1964; the list of publications and articles issued from January 1, to December 31, 1965; and the list of publications and articles issued from January 1, to December 31, 1966. 65 cents.

SP 1-69. List of Bureau of Mines Publications and Articles, January 1 to December 31, 1968, With Subject and Author Index, compiled by Rita D. Sylvester. 1969. 119 pp. Describes publications by the Bureau and articles by its personnel in non-Bureau publications. Supplements the list of Bureau publications issued from July 1, 1910, to January 1, 1960; the list of articles published by Bureau authors outside the Bureau from July 1, 1910, to January 1, 1960; the list of publications and articles issued from January 1, 1960, to December 31, 1964; and subsequent annual editions. $1.25.

MISCELLANEOUS

MISC. For the Benefit of Man, prepared by the Office of Mineral Reports of the Bureau of Mines for the White House Conference on Natural Beauty. 28 pp. 31 figs. Discusses the adverse effects of surface mining, the restoration of strip-mined land, the control of coal fires in abandoned mines, the utilization of discarded cars, and the control of air and water pollution.

HANDBOOK

CMS. Federal Coal Mine Safety Act, as Amended. 30 U.S.C. 451. Title I—Advisory Powers Relating to Health and Safety Conditions in Mines. Title II—Prevention of Major Disasters in Mines. Bureau of Mines, U.S. Department of the Interior. January 1967. 63 pp. This publication contains the provisions of Title I and Title II of the Federal Coal Mine Safety Act, as amended (30 U.S.C. 451), and is issued as a service to all persons and agencies interested in health and safety in the coal mining industry of the United States.

SCHEDULES

Schedules and amendments to schedules are printed in the Federal Register. Copies of schedules or amendments to schedules may be obtained from the Branch of Publications Distribution, 4800 Forbes Avenue, Pittsburgh, Pa. 15213.

2G. Electric Motor-Driven Mine Equipment and Accessories. Federal Register, v. 33, No. 54, Mar. 19, 1968, pp. 4660-4671. (Supersedes S 2F.)

S 13E. Self-Contained Breathing Apparatus. Federal Register, v. 33, No. 140, July 19, 1968, pp. 10336-10342. (Supersedes S 13D.)

Amendments to S 19B. Supplied-Air Respirators. Federal Register, v. 32, No. 163, Aug. 21, 1968, pp. 11817-11818.

Amendments to S 21B. Filter-Type Dust, Fume, and Mist Respirators. Federal Register, v. 34, No. 117, June 19, 1969, pp. 9617-9619.

Amendments to S 32A. Methane Monitoring Systems. Federal Register, v. 31, No. 153, Aug. 9, 1966, pp. 10607-10610.

Amendments to various Bureau of Mines Schedules. Fees for Services:

- S 13D. Self-Contained Breathing Apparatus.
- S 19B. Supplied-Air Respirators.
- S 14F. Gas Masks.
- S 21B. Filter-Type Dust, Fume, and Mist Respirators.
- S 23B. Nonemergency Gas Respirators (Chemical Cartridge Respirators, Including Paint Spray Respirators).
- S 2F. Electric Motor-Driven Mine Equipment, Junction Boxes and Other Accessory Equipment.
- S 6D. Electric Cap Lamps.
- S 10C. Electric Mine Lamps Other Than Standard Cap Lamps.
- S 7C. Flame Safety Lamps.
- S 8C. Portable Methane Detectors.
- S 9B. Telephone and Signaling Devices.
- S 12D. Single-Shot Blasting Units.
- S 16E. Multiple-Shot Blasting Units.
- S 29A. Lighting Equipment for Illuminating Underground Workings.
- S 32. Methane-Monitoring Systems.
- S 22. Diesel Mine Locomotives.
- S 24. Mobile Diesel-Powered Equipment for Noncoal Mines.
- S 25B. Dust Collectors for Use in Connection With Rock Drilling in Coal Mines.
- S 28. Fire-Resistant Conveyor Belts.
- S 30. Fire-Resistant Hydraulic Fluids.
- S 31. Mobile Diesel-Powered Transportation Equipment for Gassy Noncoal Mines and Tunnels.

Federal Register, v. 30, No. 55, Mar. 23, 1965, pp. 3753-3757.

MINERAL INDUSTRY SURVEYS

Mineral Industry Surveys are processed reports that contain statistical and economic data on various mineral commodities, as well as information on employment and injuries in the mineral industries. These reports are issued at régular intervals so that information on mineral commodities may be made available quickly and in a convenient form. Most of the data contained in these reports appear in permanent form in the Minerals Yearbook. These reports may be obtained from the Publications Distribution Branch, Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pa. 15213, except for District V Petroleum Demand Reports and District V Petroleum Statements, which may be obtained only from the San Francisco Office of Mineral Resources, 450 Golden Gate Avenue, Box 36012, San Francisco, Calif. 94102. The list of Mineral Industry Surveys being published in 1969 follows:

WEEKLY

Bituminous Coal and Lignite.
Pennsylvania Anthracite.

MONTHLY

Aluminum Industry.
Cement.
Chromium.
Coal-Mine Fatalities.
Coal-Mine Injuries and Worktime.
Cobalt.
Coke and Coal Chemicals.
Copper Industry.
Copper Sulfate.
District V Petroleum Demand.
District V Petroleum Statement.
Gold and Silver.
Iron and Steel Scrap.
Iron Ore.
Lead Industry.
Lime.
Manganese.
Molybdenum.
Nickel.
Petroleum Forecast.
Petroleum Statement.
Sulfur.
Tin.
Tungsten.
Vanadium.
Zinc Industry.
Zinc Oxide.

QUARTERLY

Antimony.
Bauxite.
Bismuth.
Bituminous Coal and Lignite Distribution.
Cadmium.
Carbon Black.
Cobalt Refiners.
Ferrosilicon.
Fluorspar.
Gypsum.
Health and Safety Summary.
Magnesium, Primary
Mercury.
Natural Gas.
Platinum-Group Metals.
Selenium.
Titanium.

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Abrasive Materials.
Aluminum and Bauxite.
Antimony.
Asbestos.
Asphalt Shipments.
Aviation Turbine Fuels (Petroleum Products Survey 59). Prepared in cooperation with the American Petroleum Institute.
Barite.
Beryllium.
Bismuth.
Boron.
Bromine.
Burner Fuel Oils (Petroleum Products Survey 61). Prepared in cooperation with the American Petroleum Institute.
Cadmium.
Calcium Chloride and Calcium-Magnesium Chloride.
Carbon Black.
Cement.
Cesium and Rubidium.
Chromium.
Clay.
Cobalt.
Coke and Coal Chemicals.
Coke Producers.
Columbium and Tantalum.
Commodity Data Summaries. Preliminary data, in summary form, for most metals, nonmetals, and fuels.
Copper.
Diatomite.
Diesel Fuel Oils (Petroleum Products Survey 62). Prepared in cooperation with the American Petroleum Institute.
Explosives.
Feldspar.
Fluorspar.
Fuel Oil Shipments.
Gold and Silver.
Graphite.
Gypsum.
Injuries at Coke Plants.
Injuries at Slag Plants.
Injuries at Sand and Gravel Plants.
Injuries, Oil and Gas.
Iodine.
Iron and Steel.
Iron and Steel Scrap.
Iron and Steel Slag.
Iron Ore.
Kyanite.
Lead.
Lime.
Liquefied Petroleum Gas Shipments.
Lithium, Cesium, and Rubidium.
Magnesium and Magnesium Compounds.

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Manganese.
Mercury.
Mica.
Molybdenum.
Motor Gasolines, Summer (Petroleum Products Survey 58). Prepared in cooperation with the American Petroleum Institute.
Motor Gasolines, Winter (Petroleum Products Survey 60). Prepared in cooperation with the American Petroleum Institute.
Natural Gas.
Nickel.
Peat.
Peat Producers.
Pennsylvania Anthracite Distribution.
Pennsylvania Anthracite Fatalities.
Perlite.
Petroleum Refineries in the United States and Puerto Rico.
Petroleum Statement.
Phosphate Rock.
Platinum-Group Metals.
Potash.
Pumice.
Rare-Earth Elements and Thorium.
Rhenium.
Roof-Fall Fatalities.
Safety Competition, National Lime Association.
Safety Competition, National Limestone Institute.
Safety Competition, National Sand and Gravel.
Safety Competition, National Slag Association.
Safety in Mineral Industries.
Salt.
Sand and Gravel.
Selenium and Tellurium.
Sodium Compounds.
Stone.
Sulfur.
Talc, Soapstone, and Pyrophyllite.
Tin.
Titanium.
Tungsten.
Uranium.
Vanadium.
Vermiculite.
World Mineral Production.
Zinc.
Zirconium and Hafnium.

BIENNIALLY

National First-Aid and Mine Rescue Contest.
Natural Gas Processing Plants.

TRIENNIALLY

Crude Oil and Product Pipeline Mileage in the United States.

FOREIGN MINERAL REPORTS

Foreign mineral reports are issued to assist domestic producers and consumers of mineral commodities to keep abreast of developments in the mineral industries and markets abroad and provide a brief summary of significant information from U.S. Foreign Service offices and other sources, which may otherwise not be made available to the general public. These publications may be obtained from the Publications Distribution Branch, Bureau of Mines, 4800 Forbes Ave., Pittsburgh, Pa. 15213.

International Coal Trade. Issued monthly. Summarizes the latest salient statistical and economic data on worldwide coal trade.

Mineral Trade Notes. Issued monthly. Provides selected news notes and brief economic information on a variety of mineral commodities (except fuels) throughout the world.

International Petroleum Annual. Provides data for nearly all countries outside the Soviet bloc on production; imports and exports, showing countries of origin and destination; refinery runs of crude oil; calculated demand for major refined products; and world retail prices and taxes for refined petroleum products.

OPEN-FILE REPORTS

Open-file reports comprise data that have not been published because the research may be of limited interest, may have been reported elsewhere, or may be in too voluminous a form to be conveniently published. However, the Bureau of Mines has made these reports available as reference material at certain libraries and Bureau offices during normal working hours. The locations where any report may be seen are given in the listing for each open-file report. When making inquiries, the author and title of each report MUST be given, NOT the open-file report number (OFR). Because these reports are for reference only, open-file reports may not be removed from the libraries or offices where they have been placed. Photostatic copies can sometimes be obtained for a nominal fee, depending upon the facilities available at the individual locations.

Copies of some open-file reports have been placed in the Clearinghouse for Federal Scientific and Technical Information. To find out if an open-file report is available from the Clearinghouse, consult the listing of Bureau publications given in the section on Bureau of Mines publications available from the Clearinghouse.

OFR 1-65. Beryllium Investigations at the Lost River Mine, Seward Peninsula, Alaska, by Robert V. Berryhill and John J. Mulligan with a section on petrography by Walter L. Gnagy. 1965. 71 pp. 5 figs. Beryllium minerals, principally chrysoberyl, occur associated with fluorite in an extensive zone of altered limestones adjacent to the Lost River tin mine. Samples averaged 0.12 to 0.13 percent BeO; a few samples of the Cassiterite Dike averaged 0.07 percent BeO. Available at the Bureau of Mines office, Juneau Alaska, and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 2-65. Bureau of Mines Diamond-Drill Sampling Data, Lost River Tin Mine, Seward Peninsula, Alaska, by H. E. Heide and John J. Mulligan. 1965. 98 pp. 2 figs. Gives detailed description of diamond-drill data and drill logs of the investigation of the Lost River tin mine made in 1943-44. This information was published in a shorter form in 1946 as RI 3902, Investigation of the Lost River Tin Deposit, Seward Peninsula, Alaska. Available at the Bureau of Mines office, Juneau, Alaska, and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 3-65. The Production of Synthetic Mica, by K. H. Ivey, E. F. Nichols, and H. R. Shell. 1965. 53 pp. 9 figs. Gives results of experiments on synthesis of fluormicas. Furnaces used were (1) a double-wall, double-bottom, water-cooled, internal resistance furnace with a 6,000-pound capacity and (2) four sizes of single-wall, water-cooled, arc resistance furnaces with capacities of from 2,000 to 10,000 pounds of melt. Technical or commercial grades of silica, alumina, magnesia, feldspar, magnesium fluoride, and potassium silicofluoride were used, compounded to or near $K_2Mg_6Al_2Si_6O_{19.75}F_{4.5}$. Boron trioxide and potassium chloride were added in small amounts to some compositions. Fluorphlogite from both types of furnace and from different batch compositions was satisfactorily used to make glass-bonded synthetic mica products. Available at College Park Metallurgy Research Center, College Park, Md., and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 4-65. Thermal Decomposition of Organic Nitrogen and Sulfur Compounds. A Survey of Chemical Abstracts, 1956 to 1962, by Irven A. Jacobson, Jr. Consists of a bibliography of gas-phase thermal reactions of organic nitrogen and sulfur compounds. Included in each listing is a brief summary of the data. Supplements IC 7947. Available at the San Francisco Petroleum Research Laboratory, San Francisco, Calif., Morgantown Petroleum Research Laboratory, Morgantown, W. Va., Laramie Petroleum Research Center, Laramie, Wyo., Bartlesville Petroleum Research Center, Bartlesville, Okla., and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 5-65. Exploratory Tests on the Effects of Magnetic Fields on the Flow of Brine in Petroleum-Reservoir Rock Samples, by Richard A. Morris and C. I. Pierce. 1965. Gives laboratory data on the effects of magnetic fields on the flow of rock in petroleum reservoir samples. Several types of brine and different field strengths are tabulated. Available at the San Francisco Petroleum Research Laboratory, San Francisco, Calif., Morgantown Petroleum Research Laboratory, Morgantown, W. Va., Laramie Petroleum Research Center, Laramie, Wyo., Bartlesville Petroleum Research Center, Bartlesville, Okla., and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 6-65. Examination of Hannum Lead Prospect, Fairhaven District, Seward Peninsula, Alaska, by John J. Mulligan. 1965. 16 pp. 3 figs. Summarizes and brings up to date an open-file report of the same title released in 1957. Description and analyses of specimens taken in 1959 and 1963 are given. Available at the Bureau of Mines office, Juneau, Alaska, and the Central Library, U.S. Department of the Interior, Washington, D.C.

OR 7-65. Diamond-Drill Sampling Data Fluorite-Beryllium Deposits, Lost River Valley, Seward Peninsula, Alaska, 1964, by John J. Mulligan with a section on petrography by Walter L. Gnagy and a section on laboratory concentration tests by Richard Havens. 94 pp. 3 figs. Gives results of sampling from 16 diamond-core drill holes totaling 2,554 feet in typical fluorite-beryllium deposits of the Lost River valley, Seward Peninsula. Principal beryllium mineral associated with the fluorite is chrysoberyl. Analytical data have not been evaluated and work on these samples is continuing. Available at the Bureau of Mines office, Juneau, Alaska, and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 8-65. Examination of the Sinuk Iron Deposits, Seward Peninsula, Alaska, by John J. Mulligan, with a section by Harold D. Hess. 1965. 34 pp. 3 figs. Quotes material from various Federal and Territorial publications now out-of-print, summarizes more recent Bureau studies and discusses the significance of recent chemical, spectrographic, and petrographic analyses of samples collected on the spot. Although the various deposits are relatively small, totaling only about 600,000 tons of 10 to 45 percent iron-content rock, each deposit may also be an "iron hat," capping sulfide ores of lead and zinc with some copper and silver. Available at the Bureau of Mines office, Juneau, Alaska, and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 9-65. Preliminary Investigation of Limestone, Quartzite, and Dolomite Resources Near the Proposed Rampart Dam in Central Alaska, by Bruce I. Thomas. 1965. 11 pp. 2 figs. Presents results of preliminary laboratory analyses of "spot" samples taken by the Bureau from rock outcroppings about 15 miles southwest of the projected damsite. These raw material sources are outside the reservoir area, the report notes, and could be made readily accessible to the damsite by rail or by highway if proved suitable in all respects for construction uses. Available at the Bureau of Mines office, Juneau, Alaska, and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 10-65. Reconnaissance of the Avnet Manganese Prospect, Tanana Quadrangle, Central Alaska, by Bruce I. Thomas. 1965. 8 pp. 3 figs. Covers a reexamination undertaken by the Bureau because of anticipated economic changes, including low-cost power expected to be generated at the proposed Rampart Dam and improvements in the arterial highway system of central Alaska. Manganiferous material or "float" was found about 20 miles southeast of the site of the proposed dam and 100 miles northwest of Fairbanks. Available at the Bureau of Mines office, Juneau, Alaska, and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 1-66. Aerosols in Air Pollution Systems: A Non-Critical Review of the Literature, by David F. Dever. 1966. 27 pp. The literature of interest to air pollution investigators on the subject of generating, sampling, and analyzing aerosols is reviewed to December 1964. One hundred and fifty references are considered. Available for reference at the Central Library, U.S. Department of the Interior, Washington, D.C.; the San Francisco Petroleum Research Center, San Francisco, Calif.; the Morgantown Petroleum Research Laboratory, Morgantown, W. Va.; the Bureau of Mines library, Bartlesville, Okla.; and the Bureau of Mines library, Laramie, Wyo.

OFR 2-66. Well Logs of Bureau of Mines-AEC Colorado Corehole No. 1, Rio Blanco County, Colo., by Laramie Petroleum Research Center Staff. 1966. Five well logs, induction-electrical, gamma-ray neutron, sonic, compensated formation density, and laterolog, were run on the Bureau of Mines-Atomic Energy Commission corehole in two stages and were combined in their present form by Schlumberger Well Surveying Corp. Available at the Bureau of Mine Libraries at Denver, Colo., and Laramie, Wyo.

OFR 3-66. Investigation of the Bailey Copper Prospect, Willow Creek Mining District, South-Central Alaska, by Raymond P. Maloney. 1966. 7 pp. 4 figs. This prospect is about 45 airline miles northeast of Anchorage in the southwest corner of the Talus Mountains. Numerous gold mines and gold and molybdenum prospects in the area make it potentially important. Bornite, chalcopyrite, covellite, molybdenite, gold, and silver occur in a shear zone in quartz diorite. The shear zone appears to be about 200 feet wide and at least 1,500 feet long; glacial debris, rubble, and talus cover most of it; disseminated mineralization can be observed in bedrock exposed over an area about 50 feet wide, 500 feet long, and over a vertical distance of about 300 feet. A drilling program would be necessary to determine the size, grade, and character of the deposit. Available for reference at the Central Library, U.S. Department of the Interior, Washington, D.C., and the Bureau of Mines office, Juneau, Alaska.

OFR 4-66. Investigation of the Nixon Fork Area, Kuskokwim River Basin, Alaska, by Raymond P. Maloney. 1966. 24 pp. 8 figs. A reconnaissance examination of the copper-gold-silver deposits of the Nixon Fork area was made to determine the feasibility of additional work to determine the mineral potential of the area. Copper, gold, and silver mineralization was found in limestone and granite in an area about 1 mile wide and 2 miles long. Mineralization occurred chiefly as copper silicate but minor amounts of copper sulfides were found. Gold and silver were associated with copper mineralizations; minor amounts of bismuth were found. Metallurgical work was done to develop a method suitable for extraction of gold and copper from the complex silicate ores. Results indicated that additional research is required. Caustic leaching is a potential method for recovery of copper from chrysocolla ores associated with basic minerals; ammonia leaching and flotation methods were ineffective. A high gold recovery is not possible without simultaneous recovery of copper. Gold recovery methods include tabling, corduroy matting, flotation, and barrel amalgamation. Work was done in Juneau with commercially available reagents and equipment. Available for reference at the Central Library, U.S. Department of the Interior, Washington, D.C., and the Bureau of Mines office, Juneau, Alaska.

OFR 5-66. Investigation of the Purkeypile Prospects, Kuskokwim River Basin, Alaska, by R. P. Maloney and Bruce I. Thomas. 1966. 12 pp. 6 figs. The Purkeypile group of lode claims is in an isolated and extremely mountainous area near the western boundary of Mt. McKinley National Park. The group includes the Jiles-Knudson, Mespelt, and Hogback prospects which are located on sporadic mineral occurrences in or adjacent to altered sediments and granitic intrusives. Chip, grab, and a few channel samples, taken at various times by Bureau of Mines engineers, contained from trace to significant amounts of lead, zinc, silver, and gold; some samples also contained trace to minor amounts of copper, bismuth, antimony, tungsten, and uranium. This report presents the Bureau's sampling data and summarizes general information resulting from the several examinations by Federal and State mining engineers and geologists. Available for reference at the Central Library, U.S. Department of the Interior, Washington, D.C., and the Bureau of Mines offices, Juneau and Anchorage, Alaska.

OFR 6-66. Calcination of Raw and Agglomerated Anthracites in a Vertical-Shaft Retort, by W. S. Sanner. 1966. 50 pp. 17 figs. Experiments were conducted with a vertical-shaft calcining pilot plant to study the production of devolatilized lump anthracite for use testing in foundry cupolas and to study the calcination of agglomerated anthracite briquets for use as fuel in blast-furnace tests. Anthracite egg size (3¼- by 2$\frac{7}{16}$-inch) representative of the four anthracite-producing fields was calcined in an indirect-gas-fired retort, using both indirect and direct methods of preheating the charge to study the effects of each on decrepitation of the raw coal. Indirect preheating resulted in the most trouble-free operation but severely limited the plant throughput rate in order to avoid excessive decrepitation. Retort temperature could not exceed 1,600° F, product volatile matter ranged from 1 to 1.5 percent, recovery of sizes suitable for foundry use ranged from 60 to 82 percent, and the plant throughput rate ranged from 35 to 60 pounds per hour. Direct preheating of the coal charge prior to entering the indirect-fired retort made it possible to fire the retort at 1,800° to 2,000° F, increase the throughput rate to 235 pounds per hour, maintain similar product volatile matter, and recover about 80 percent of the plant feed for use testing in foundry cupolas. Agglomerated (anthracite, pitch binder, and bituminous coal) briquets for blast-furnace testing could not be successfully calcined in the vertical-shaft plant without major redesign of the discharger mechanism and the plant preheating system. A number of trials made after revisions to the preheater had to be terminated because the briquets could not be preheated rapidly at temperatures in excess of 700° F. As a result, the briquets softened and blocked the preheating system, making plant processing impossible. Available for reference at the Central Library, U.S. Department of the Interior, and the office of the Director of Coal Research, Bureau of Mines, Washington, D.C.; the Pittsburgh Coal Research Center, Bruceton, Pa.; and the Morgantown Coal Research Center, Morgantown, W. Va.

OFR 7-66. Sampling and Coking Studies of Coal From Castle Mountain Mine, Matanuska Coalfield, Alaska, by R. S. Warfield, W. S. Landers, and Charles C. Boley. 1966. 14 pp. 1 fig. A sample of high-volatile A bituminous coal consisting of cuttings from multiple auger holes was taken from a stripped segment of a 5.3-foot coalbed at the now idle Castle Mountain mine, Matanuska coalfield, Alaska. The sample was shipped to the Bureau of Mines Denver Coal Research Laboratory where studies of its coking properties were made. The ash content of the sample was reduced by float-and-sink methods from 16.5 percent to 10.4 percent. After bench-scale tests indicated good coking qualities for the "cleaned" coal, three 50-pound coking tests were conducted. Coke from the unblended coal was strong and seemed of foundry quality. Using 30 percent of the Castle Mountain coal as a blending coal with a Utah-base coal produced a coke with reasonably good characteristics. Available for reference at the Central Library, U.S. Department of the Interior, Washington, D.C., and the Bureau of Mines offices, Juneau and Anchorage, Alaska.

OFR 8-66. Relationship of Past Geologic Structural Processes to the Rock Masses Associated With Mining Districts, by Jacques B. Wertz. 1966. 131 pp. 57 figs. Research was conducted to determine (1) the effect of structure-forming processes on the rock masses containing an ore deposit and (2) the influence of the stresses resulting from these processes on the design of ground control methods that must be used during extraction of the ore. The results of the initial phase of the research, presented in this report, ascertains the relationship of these geologic processes to the rock masses associated with mining districts in southeast Arizona. Available for reference at the Central Library, U.S. Department of the Interior, Washington, D.C., and the Bureau of Mines library, Denver, Colo.

OFR 1-67. Cost Analysis of the U.S. Copper Industry in 1958, by Franklin D. Cooper and Kung Lee Wang. 1967. 217 pp. 7 figs. This detailed cost analysis shows actual and derived expenditures, for supplies and for those parts having less than 3 years service life, which were purchased and consumed in 1958 by the U.S. copper industry for all operations ranging from mining through refining. Expenditures for labor, fuels, and electricity are shown when necessary to clarify the presentation. Some information is presented on the state of the technology in 1958 and its effect on expenditures for supplies and parts. Available for reference during office hours at the Bureau of Mines library, Denver, Colo.; and the Central Library, U.S. Department of the Interior, and the Library of Congress, Washington, D.C.

OFR 2-67. Reservoir Oil Analyses, Clark's Fork North Field, Montana, by C. Q. Cupps and J. Fry. 1967. This report contains analyses of subsurface oil samples and related samples of produced oil and gas and some data concerning reservoir characteristics. Although a complete reservoir analysis was not made, these data are valuable in characterizing reservoir fluids and properties. Available for reference during office hours at the Bureau of Mines libraries at the Laramie Petroleum Research Center, Laramie, Wyo., and the Bartlesville Petroleum Research Center, Bartlesville, Okla.; the Morgantown Petroleum Research Laboratory, Morgantown, W. Va.; the San Francisco Petroleum Research Office, San Francisco, Calif.; and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 3-67. Reservoir Oil Analyses, Denver-Julesburg Basin, Colorado, by C. Q. Cupps and J. Fry. 1967. This report contains analyses of subsurface oil samples and related samples of produced oil and gas and some data concerning reservoir characteristics. Although a complete reservoir analysis was not made, these data are valuable in characterizing reservoir fluids and properties. Available for reference during office hours at the Bureau of Mines libraries at the Laramie Petroleum Research Center, Laramie, Wyo., and the Bartlesville Petroleum Research Center, Bartlesville, Okla.; the Morgantown Petroleum Research Laboratory, Morgantown, W. Va.; the San Francisco Petroleum Research Office, San Francisco, Calif.; and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 4-67. Reservoir Oil Analyses, Gebo Field, Wyoming, by C. Q. Cupps and J. Fry. 1967. This report contains analyses of subsurface oil samples and related samples of produced oil and gas and some data concerning reservoir characteristics. Although a complete reservoir analysis was not made, these data are valuable in characterizing reservoir fluids and properties. Available for reference during office hours at the Bureau of Mines libraries at the Laramie Petroleum Research Center, Laramie, Wyo., and the Bartlesville Petroleum Research Center, Bartlesville, Okla.; the Morgantown Petroleum Research Laboratory, Morgantown, W. Va.; the San Francisco Petroleum Research Office, San Francisco, Calif.; and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 5-67. Bureau of Mines—Atomic Energy Commission Colorado Corehole No. 2, Rio Blanco County, Colorado, by George F. Dana. 1967. Colorado Corehole No. 2 was drilled and cored as part of the program to locate suitable sites for pilot studies on the in situ processing of oil shale. This report contains the drilling and coring history of the well and analyses of over 1,000 feet of the cored oil shale section. Available for reference during office hours at the libraries of the Laramie Petroleum Research Center, Laramie, Wyo., and the Denver Mining Research Center, Denver, Colo.

OFR 6-67. The Cubic Field in $CaO\text{-}ZrO_2$, by Ronald C. Garvie. 1967. 9 pp. 5 figs. The cubic field in the $CaO\text{-}ZrO_2$ system was determined in the temperature range 1,300° C to 1,700° C using the X-ray lattice parameter method. The existence of a compound $CaZr_4O_9$ was postulated. Available for reference during office hours at the College Park Metallurgy Research Center, College Park, Md., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 7-67. Collection and Analysis of Marine Manganese Nodules, by H. H. Heady. 1967 30 pp. 11 figs. Manganese nodules were collected during January 1963 by the Division of Mineral Resources, Region II, Bureau of Mines, in cooperation with the University of California, from the ocean floor off the coast of Baja California, Mexico, at depths of 2 to nearly 3 miles. The tonnage lot consisted of nine samples which subsequently were subjected to laboratory study at Bureau of Mines research centers. The sample-collection phase of the investigation testified to the widespread abundance of manganese nodules on the ocean floor, but it also pointed to the general inadequacies of current sampling techniques for recovering seafloor minerals in quantity. Chemical analyses showed wide compositional variations between different nodule locations, while electron probe X-ray spectrographic analysis showed significant variations within individual nodules. Available for reference during office hours at the Reno Metallurgy Research Center, Reno, Nev., the Tiburon Marine Minerals Technology Center, Tiburon, Calif., and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 8-67. Maximizing Returns From Mine Production Through Use of Operations Research Techniques, by Thys B. Johnson. 1967. This report discusses the variability in smelter schedules and illustrates the techniques that can be used to evaluate returns from mine products with regard to various schedules. The influence of schedule premiums and penalties and the importance of methods of treatment and transportation costs and their effect on net returns is pointed out. The latter part of the report contains a discussion of mathematical techniques for analyzing and evaluating the effect of operational problems upon the design and development of mining operations that would be useful to mining engineering students as well as persons contemplating the development of small mining operations. Available for reference during office hours at the library of the Bureau of Mines, Denver, Colo., and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 9-67. Sampling a Gold-Copper Deposit, Golden Zone Mine, South Central Alaska, by J. J. Mulligan, R. S. Warfield, and R. R. Wells. 1967. 59 pp. 11 figs. The Bureau of Mines channel sampled and diamond drilled the Golden Zone mine and nearby gold-copper deposits in 1950 and 1951. Difficult drilling conditions made sampling costs prohibitive; the work had to be stopped before enough data was obtained to estimate recoverable reserves. The Golden Zone mine, in 1941 and 1942, produced 869 tons of bulk flotation concentrate, containing 1,581 ounces of gold, 8,617 ounces of silver, and 21 tons of copper, but was forced to close in 1942 and has not reopened. Available for reference during office hours at the Bureau of Mines offices in Juneau, Anchorage, and Fairbanks, Alaska, and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 10-67. Investigation of the Asbestos-Serpentine Deposits in the Spencer Lake Area, Maine, by Fred M. Murphy and K. M. Earl. 1967. The information in the report was obtained in an exploration project in the Spencer Lake area conducted in 1954. The report includes data on 3,756 feet of core recovered from 11 diamond drill holes. Also included are the results of chemical analyses, X-ray diffraction tests, spectrographic analyses, and magnetic separation tests of samples from the core. Tests were conducted to determine the asbestos, nickel, and chromium mineral contents of these samples. Available for reference during office hours at the Bureau of Mines Library, Pittsburgh, Pa., and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 11-67. Résumé of Information on Alaskan Bituminous Coals With Particular Emphasis on Coking Characteristics, by Robert S. Warfield. 1967. 20 pp. Alaska has several coalfields known to contain bituminous coal occurrences. This report summarizes the available information on these occurrences with particular emphasis on coking characteristics. Some of the coals are known to exhibit coking properties, others are known to be noncoking, and for some, it is known only that their rank is probably bituminous. By far the greatest amount of reserves is in the Arctic coalfield north of the Brooks Range. In parts of this field, structural geology appears simple enough that modern mechanized mining could be performed. Recent sampling and testing by the Bureau of Mines demonstrated that some of the Arctic coals have significant coking properties. Available for reference during office hours at the Bureau of Mines offices in Juneau, Anchorage, and Fairbanks, Alaska, and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 12-67. Sampling the Moth Bay Zinc-Copper Deposit, Revillagigedo Island, Southeastern Alaska, by Robert S. Warfield and R. R. Wells. 1967. 19 pp. 6 figs. The Bureau of Mines sampled surface and underground exposures and core drilled for possible extensions of the Moth Bay zinc-copper deposit during the summer field season of 1950. The deposit is less than a mile inland from the head of Moth Bay on Revillagigedo Island. Diamond-drill holes penetrating the mineralized section below the main drift encountered mineralization through a greater width but at considerably lower grade than was found on the drift level and in the surface outcrops. Large samples taken from representative underground exposures of the ore were concentrated by standard selective flotation methods to produce marketable copper and zinc concentrates with reasonably good recoveries. Available for reference during office hours at the Bureau of Mines offices in Juneau, Anchorage, and Fairbanks, Alaska, and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 13-67. Core Analysis Results of Appalachian Oil-Reservoir Rock, by C. E. Whieldon, Jr., and F. D. Slagle. 1967. This report should be of specific value to oil producers and prospectors in restricted areas. The material is too voluminous to be published as an Information Circular. Available for reference during office hours at the Morgantown Petroleum Research Laboratory, Morgantown, W. Va.

OFR 14-67. Relationship of Past Geological Structural Processes to the Rock Masses Associated With Mining Districts, by Jacques B. Wertz. 1967. This research was conducted with the ultimate objective of determining (1) the effect of structure-forming processes on the rock masses containing an ore deposit and (2) the influence of the stresses resulting from these processes on the design of ground-control methods that must be used during the extraction of the ore. The results of the initial phase of the research, which are presented in this report, ascertain the relationship of these processes to the rock masses associated with mining districts in southeast Arizona. Available for reference during office hours at the library of the Bureau of Mines, Denver, Colo., and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 15-67. Thermal Decomposition of Organic Nitrogen and Sulfur Compounds: A Survey of Chemical Abstracts, 1956-1962, by Irven A. Jacobson. 1967. This literature survey consists of references dealing with gaseous state thermal decomposition reactions of organic nitrogen and sulfur compounds. The reference source for the survey was Chemical Abstracts from 1956 to 1962. Original articles were not studied. The report is a continuation of IC 7947, published in 1960, which was based on Chemical Abstracts from 1930 to 1956. The report is in three parts: Part I lists nitrogen compounds; Part II, sulfur compounds; and Part III, compounds containing nitrogen and sulfur. Available for reference during office hours at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 1-68. Pozzolanic Materials Resources of California and Nevada, by Charles T. Weiler. 1968. The report contains information on the use of pozzolan and on the location, mineralogy, chemical analysis, and pozzolanic characteristics of 118 samples from 98 locations in California and of 36 samples from 29 locations in Nevada. Thirty-one of the samples were judged to have pozzolanic properties suitable for use in water storage and supply structures. Ten of these samples met all pertinent ASTM standards; the other 21 met all except one of these standards. Available for reference during office hours at the California Division of Mines and Geology, San Francisco, Los Angeles, and Sacramento, Calif.; and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 2-68. Well Data on Government-Owned Wells in the Cliffside Gasfield. 1968. This report contains information on six recently drilled wells in the Government-owned Cliffside gasfield, Potter County, Tex. Well logs and other data are being made available for public inspection to add to the general fund of geological information for this area. The six wells are Bivins A-14 and A-15, Bivins B-1 and B-2, Bush A-11, and Fuqua A-3. The data include electrical and radiation well logs, core analysis reports, and other data obtained in drilling these wells. Available for reference during office hours at the office of the Assistant Director—Helium, Bureau of Mines, Washington, D.C., and at the Office of the General Manager, Helium Operations, Amarillo, Tex.

OFR 3-68. Rutile, Monazite, and Other Heavy Mineral Resources of the Edisto River in South Carolina, by Robert F. Griffith. 1968. Heavy mineral reserve data for the stream alluvium deposits of the North and South Edisto Rivers in South Carolina in 1955-57 as part of a plan to expand heavy mineral mining operations on nearby Horse Creek. The minerals of economic importance in these deposits are rutile, monazite, zircon, and ilmenite. Available for reference during office hours at the Bureau of Mines offices in Knoxville, Tenn., and Tuscaloosa, Ala.; the Division of Minerals office, Arlington, Va.; the Central Library, U.S. Department of the Interior, Washington, D.C.; and the Office of the State Geologist, Columbia, S.C.

OFR 4-68. Bureau of Mines Circular Rule for Interconverting Atomic and Weight Percent in Binary Compounds, by R. P. Adams and R. A. Beall. 1968. A new metallurgist's slide rule that quickly and accurately converts weight-percent to atomic percent, and vice versa, for many binary alloys and compounds has been devised by the Bureau of Mines. The rule should prove to be extremely useful to those investigating both new alloys and established binary systems. It should save much time and effort in conventional calculations to determine weight-percent or atomic percent. Weight-percent refers to the percentage of a compound's total weight represented by a given element in it. Atomic percent expresses the relative number of atoms of each element in a compound. Weight-percent is a measurement used in making an alloy, while atomic percent is used to predict its structure and some of its properties.

Circular in form, the slide rule bears inner and outer scales and two movable arms of unequal length that pivot from its center. In use, the arms are set to indicate, first, the two elements of an alloy or compound, then, the conversion from known weight-percent to atomic percent or vice versa. Seventy-three elements in the periodic table appear on the rule. Available for reference during office hours at the library of the Albany Metallurgy Research Center, Albany, Oreg., and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 5-68. Design and Testing of Explosive-Anchored Tail-Block Anchor Pins, by Edward W. Parsons and Lars Osen. 1968. Following the successful earlier testing of the explosive-anchored rockbolt in some metal mines, some mine operators requested that the anchorage technique be further tested as tail-block anchors in soft ground and unconsolidated underground fill areas. A series of tests in five mines showed that several adaptations of the steel-tube explosive anchor provided improved anchorage even in relatively soft strata, but the aluminum-tube explosive anchor would not sustain continuous use by the underground scrapers. Although the steel-tube explosive-anchored tail-block assembly provided better anchorage than the conventional anchor devices, it may have very limited use and interest because of the fabrication and installation costs and the limited number of mines hampered by these operating conditions. Available for reference during office hours at the libraries of the Denver Mining Research Center, Denver, Colo., and the Twin Cities Mining Research Center, Minneapolis, Minn.; at the Spokane Mining Research Laboratory, Spokane, Wash.; and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 6-68. Explosive Forming of Small Hemispherical Shapes, by Jack C. Croeni, John S. Howe, Jr., and Clo E. Armantrout. 1968. 20 pp. 3 figs. The forming of small hemispherical shapes using shaped charges of explosives was investigated. Twelve variables were considered and 10 dimensionless parameters were examined using dimensional-analysis techniques. The parameters required to produce a satisfactory form were determined on a trial basis, and statistical analysis of these parameters showed that a relation involving $e/\sigma t^2$, W/D, and L/D where e=charge weight, σ=yield strength, t=blank thickness, W=maximum deflection, L=stand off distance, and D=die diameter was significant at the 1-percent level. However, calculated explosive charge weight values compared with actual values showed poor agreement when applied to such materials as copper, low-carbon steel, and titanium products. Available for reference during office hours at the library of the Albany Metallurgy Research Center, Albany, Oreg., and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 7-68. Projection of Applications and National Benefits of a New Rapid Excavation Technology, by Armando Lago, Paul D. Williams, Harold Nisselson, and Harvey D. Kushner. Prepared for the Bureau of Mines by Operations Research, Inc., Silver Spring, Md., September 1967. The purpose of this report was to provide an estimate of potential need for underground excavation during the period 1968-90 and to provide as estimate of the potential benefits to be gained by improving existing underground excavation technology. It represents the first attempt to project tunnel requirements and to estimate the potential market for subsurface excavation technology. Available for reference during office hours at the libraries of the Denver Mining Research Center, Denver, Colo., the Twin Cities Mining Research Center, Minneapolis, Minn., and the Pittsburgh Mining Research Center, Pittsburgh, Pa.; the Spokane Mining Research Laboratory, Spokane, Wash.; and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 8-68. Process Analysis of the U.S. Coal Industry in 1958, by Franklin D. Cooper and Kung-Lee Wang. 1967. 247 pp. Actual and derived expenditures in detail are shown for supplies, and for those parts having less than 3 years' service life, which were purchased and consumed in 1958 by the U.S. coal industry for all operations ranging from mining through cleaning and refuse disposal. The diversified technology in 1958 and its effects on expenditures are presented. Expenditures for some operations are clarified by including data for labor, fuels, and electricity when necessary. This report is a revision of OFR 18 (1964). Available for reference during office hours at the Bureau of Mines library at Pittsburgh, Pa., and the Central Library, U.S. Department of the Interior and the Library of Congress, Washington, D.C.

OFR 9-68. Refractory-Clay Deposits of Nebraska, North Dakota, and South Dakota, by R. W. Holmes and Joel Van Sant. 1968. 113 pp. This manuscript reports an inventory project intended to identify refractory clay-bearing areas; no clay of more than medium duty rating was found. Available for reference during office hours at the Bureau of Mines library, Denver, Colo., and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 10-68. Report on Tantalum Project, Raciada, New Mexico, by Herman W. Sheffer and Louis H. Goldsmith. 1968. 35 pp. The report presents the results of an investigation, completed in 1964, of pegmatite dikes in Mora and San Miguel Counties, N. Mex. The project was part of a program to encourage the development of a domestic supply of tantalum. The report indicated that, due to the limited extent of individual pegmatite outcroppings, significant reserves of pegmatitic minerals cannot be present and states that the analytical results did not indicate sufficient tantalum to justify further work. Available for reference during office hours at the Bureau of Mines library at Denver, Colo., and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 11-68. Hafnium-Zirconium Separation by Selective Reduction, by James E. Mauser. 1968. 23 pp. This investigation concerned selective reduction methods to recover most of the hafnium from zircon as hafnium-enriched zirconium tetrachloride. Successive contacts of batches of mixed tetrachlorides were made with a reductant regenerated between contacts by reheating to 900° C to disproportionate the deposited lower chloride. Sintering of the reductant was prevented by conducting reduction in a rotating-retort ball-mill furnace.

Zirconium sponge, powder, and turnings were successfully used as selective reductants, and maximum reduction occurred at 375° C with a fourfold increase in hafnium content over that of the original starting material. Mechanical losses, rather than co-reduction, lowered halfnium recovery with both increasing hafnium enrichment and with reuse of the reductant. Available during office hours at the Albany Metallurgy Research Center, Albany, Oreg., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 12-68. Rapid Excavation, A Report to the Bureau of Mines Covering Basic Information Developed by Panels of the Committee on Rapid Excavation. prepared by the Division of Engineering, National Research Council, National Academy of Sciences, National Academy of Engineering, September 1968. 92 pp. This report is essentially concerned with two questions: (1) What might be the market for underground excavation technology in the years 1970 to 1990, and (2) what might be the benefits from a research program whose objective is to significantly accelerate the development of such technology. Available for reference during office hours at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 13-68. Bucket-Wheel Simulator, by Charles B. Manula and Rajaraman Venkataramani. Prepared for the Bureau of Mines by the Department of Mining, College of Earth and Mineral Sciences, the Pennsylvania State University. April 1968. 105 pp. The purpose of this report was to develop a technological forecasting method to evaluate the bucket-wheel excavator as a high-volume, low-unit-cost machine for mining marginal auriferous placer deposits. Much information can be gained from the model with proper manipulation of the input data which consist of the mining dimensions, the soil characteristics, and machine specifications. No historical data are necessary. This is a deviation from most simulators where enormous quantities of time study data must be supplied to the computer. Available for reference at the libraries of the Denver Mining Research Center, Denver, Colo., the Twin Cities Mining Research Center, Minneapolis, Minn., and the Pittsburgh Mining Research Center, Pittsburgh, Pa.; the Spokane Mining Research Laboratory, Spokane, Wash., and the Alaskan Mining Research Laboratory, Juneau, Alaska; the Marine Minerals Technology Center, Tiburon, Calif.; and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 14-68. Data From Gasbuggy Experiment. A continuing open file is being established to which each of the principal participants in the experiment will contribute raw, uninterpreted data as they become available. The Bureau is contributing gas, water, and core analyses, at this time. Available for reference at the Bureau of Mines libaries, Denver, Colo., and Bartlesville Petroleum Research Center, Bartlesville, Okla.; Nevada Southern University Library, Las Vegas, Nev.; and Division of Technical Information Extension, Atomic Energy Commission, Oak Ridge, Tenn.

OFR 15-68. Bureau of Mines-Atomic Energy Commission Colorado Corehole No. 3, Rio Blanco County, Colorado, by George F. Dana. 1968. This is a preliminary report prepared for dissemination to the Atomic Energy Commission and Department of the Interior agencies concerned with the drilling, coring, sampling, and analyzing of oil-shale deposits in the Piceance Creek basin. Colorado Corehole No. 3 was drilled and cored as part of the program to locate suitable sites for pilot studies on in situ processing of oil shale. This report contains the drilling and coring history of the well and analyses of over 2,360 feet of the cored oil-shale section. Available for reference during office hours at the Bureau of Mines libraries at Denver, Colo., and Laramie, Wyo., and at the Geological Survey Public Inquiry Office, Denver, Colo.

OFR 16-68. Soil Sampling at the Egnaty Creek Mercury Prospect, Kuskokwim River Basin, Alaska, by R. P. Maloney. 1968. The report gives the general nature of the Egnaty Creek mercury deposit; describes the augering, trenching, diamond drilling, and soil sampling done by the Bureau of Mines; and presents some of the results of this work. Methods of tracing mercury mineralization by drilling 2-inch auger holes through frozen overburden are described. Tracing disseminated low-grade mercury mineralization by panning the walls of bulldozer trenches is also mentioned. Analyses of core and sludge have not been completed, but the core mineralization is described. The complete results of a soil sampling test are given on a map of the area and the method of analysis is described. The deposit, though very low grade, is of interest because of the wide extent of the mercury showing, its proximity to the Kuskokwim River, and its position in line with a series of mercury showings west of the Red Devil Mine. Available for reference at the Bureau of Mines offices, Juneau and Anchorage, Alaska, and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 17-68. Removal of Fly Ash by Fluidized Bed Techniques. Final Report to Bureau of Mines, by J. P. Pilney and E. E. Erickson (North Star Research and Development Institute). Mar. 8, 1968. 55 pp. 11 figs. The objective of this program was to determine the feasibility of using fluidized bed techniques to remove fly ash from gas streams. A literature search confirmed the potential for use of fluidized beds for removal of particles, but relatively little work has been directed toward deliberate use of a fluidized bed as a filter. The current program has indicated that fly ash can be removed effectively by passing an ash-containing gas stream through a shallow bed of fluidized particles. All three mechanisms studied—self-agglomeration in humidified air, coating the surfaces of sticky particles, and buildup of fly ash on the surface of other particles—can be used to remove fly ash. Available at the Morgantown Coal Research Center, Morgantown, W. Va.; at the office of the Solid Waste Research Program, Washington, D.C.; and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 18-68. Labor Productivity Analysis of a Selected Segment of the Sand and Gravel Industry, by Paul H. Mutschler. 1968. 10 pp. 8 figs. The object of this investigation is twofold: (1) to serve as a beginning point for future economic efficiency studies in the sand and gravel industry and (2) to see if there is any statistical correlation between plant output and labor productivity on a tons per man-hour basis (TPMH). Production data were gathered by individual plans and divided by number of hours worked by production personnel to arrive at a labor productivity value (TPMH). The results of the study revealed that continued improvement in economics of production were not statistically detectable through correlations made during this study after 500,000 tons of output has been reached. Diminishing labor productivity may be in evidence when single plant operations exceed this volume. Available at the Bureau of Mines library, Pittsburgh, Pa., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 1-69. Reconnaissance of Tatonduk River Beds, by A. L. Kimball. 1969. 11 pp. 4 figs. Reconnaissance was conducted briefly by Bureau of Mines engineers in June 1962 and September 1963. The red beds are dominantly hematitic tuffaceous shales and conglomerates having an estimated thickness of 1,800 feet and an exposure area of more than 6 square miles. Nearly 800 feet of stratigraphic thickness was chip sampled in a series of discontinuous sections that assayed 4.73 to 24.7 soluble iron. Assays of 20.10 percent soluble iron for a 133-foot thickness and 21.85 percent soluble iron for a 200-foot thickness were the highest obtained for significant thicknesses. Analyses of five bulk samples show the iron occurs as extremely fine, earthy hematite with only a trace of magnetic material and is not amenable to simple magnetic or gravity concentration. Available for reference during office hours at the Bureau of Mines library at Denver, Colo.; the Bureau of Mines offices in Juneau, Anchorage, and Fairbanks, Alaska; the Geological Survey offices, Denver, Colo., and Menlo Park, Calif.; and the State Public Information Office in Anchorage and the Resident Geologist, the State Division of Mines and Minerals, and the State Historical Library in Fairbanks, Alaska.

OFR 2-69. Coal Reserves of Greenup County, Ky., by Robert C. Johnson. 1969. 33 pp. 4 figs. Estimates were made of coal reserves in the two significant coalbeds of Greenup County, Ky. At least 10 coalbeds are present in Greenup County, but only two (Princess Nos. 3 and 7) have sufficient thickness, continuity, and areal extent to be significant sources of coal. Estimated recoverable reserves in these two beds total about 65.2 million tons. Of this total, 53.7 million tons were in beds of 28 inches and greater thickness. Strippable reserves were reported in two categories; 41.0 million tons of remaining recoverable reserves were in beds at least 28 inches thick under 120 feet or less of overburden; 11.5 million tons were in beds 14 to 48 inches thick under 60 feet or less of overburden. Discounts totaling 10.6 million tons for factors which may limit the mining of reserves resulted in a net recovery of 55.6 million tons for Greenup County. The coal is probably best suited for generating electric power. The basic data from which tonnages were derived consisted of drill logs, records of coal outcrop observations at prospects and mines, and geologic and coal reserve maps. Available for reference during office hours at the Knoxville Office of Mineral Resources, Knoxville, Tenn., and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 3-69. Rotary Diamond Coring Appalachian Area Oilfields Using Mud and Air, by R. L. Rough. 1969. This report contains excellent data concerning drilling and formation characteristics of oilfields in the Eastern United States. It supplements data in RI 7238 by the same author. Available for reference during office hours at the Morgantown Petroleum Research Laboratory, Morgantown, W. Va.

OFR 4-69. Testing of Northern Michigan and Wisconsin Glacial Lake Clays for Utilization as Iron Ore Pellet Binders, by William S. Miska. 1969. 31 pp. 5 figs. Glacial lake clay deposits in northern Michigan and Wisconsin were sampled, tested, and found to be unsuited for use as a bonding agent in iron ore pellet manufacturing. Although the project effort gave negative results, this report has been prepared to detail project rationale, sampling procedures and locations, and results of testing and analysis in the expectation that this information may be of use to persons interested in glacial lake clays and could serve to eliminate duplication of effort in future studies of clays from that area. Available for reference during office hours at the Bureau of Mines library, Minneapolis, Minn.; Michigan Technological University Library, Houghton, and Michigan State University Library, East Lansing, Mich.; University of Wisconsin Libraries, Superior and Madison, Wis.; University of Minnesota Library, Duluth, Minn.; and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 5-69. Combustion and Related Phenomena in a Constant Volume Bomb, by C. F. Ellis, J. O. Chase, and R. W. Hurn. 1969. 44 pp. 24 figs. A constant volume bomb was constructed in 1948. Continuing through 1956, starting again in 1959, and concluding in 1960, applications have been made to (1) a study of ignition characteristics of some diesel fuels and some pure hydrocarbons; (2) ignition susceptibility of some hydraulic fuels; (3) heat absorption rates from inert atmospheres by injected fuels and heat release rate by reaction with air atmospheres; (4) the effect of some ignition accelerators on ignition delay; (5) an exploratory study of the rate of thermal decomposition of *n*-hexane; and (6) an exploratory study relating ignition delay time to temperature variation for various hydrocarbons. Work done under an agreement with the Public Health Service, U.S. Department of Health, Education, and Welfare. Available for reference during office hours at the Bureau of Mines libraries at Pittsburgh, Pa., Bartlesville, Okla., and Laramie, Wyo.; the Morgantown Petroleum Research Laboratory, Morgantown, W. Va.; the San Francisco Petroleum Research Office, San Francisco, Calif.; and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 6-69. Reconnaissance Sampling of Decomposed Monzonite for Gold Near Flat, Alaska, by A. L. Kimball. 1969. 39 pp. 4 figs. The Bureau of Mines started an experimental reconnaissance sampling program to find methods for delineating and evaluating lode-gold deposits known to be the sources of stream placer deposits near Flat in the Iditarod mining district, Alaska. The Iditarod district yielded 1,329,404 fine ounces of placer gold from 1910 to 1966, more than 6 percent of the total placer gold produced in Alaska. The source of almost all the placer gold produced in the Iditarod district is lodes associated with two small bodies of decomposed monzonite, probably Tertiary in age, that have intruded Upper Cretaceous sedimentary rocks. Initial work included surface mapping and sampling the monzonites and adjacent rocks. Four hundred and fifty samples, taken with a tractor-mounted 4-inch power auger, were supplemented by 149 channel and grab samples and 72 specimens selected for petrographic analyses. Results of the preliminary reconnaissance indicate that the gold is not generally disseminated through the monzonites, but occurs in limited zones. Therefore, current work is directed toward finding methods for delineating such zones and determining the approximate grade. Available for reference during office hours at the Bureau of Mines offices in Juneau, Anchorage, and Fairbanks, Alaska, and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 7-69. A Quantitative Analysis of Mining Industry Finance, by Armando M. Lago. Prepared for the Bureau of Mines by Operations Research, Inc. December 27, 1968. 100 pp. 5 figs. Effective policy planning for the development and expansion of a healthy national mineral industry requires consideration of the factors affecting the supply of funds to the nonfuel mineral sector and the impact of these funds on its investment and exploration behavior. This study develops a quantitative econometric model of mineral industry financing, exploration, and investment behavior which will eventually permit the simulation of the response of the mineral sector to selected policy alternatives. Available for reference during office hours at the Bureau of Mines library, Denver, Colo., and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 8-69. Toward a Methodology of Studying Coal Miners' Attitudes, by Edward E. Knipe and Helen M. Lewis. March 1968. 34 pp. 1 fig. This study was designed to develop methods for studying the impact of technology in coal mining on the community relationships and family patterns of coal miners. In particular, methods were needed to investigate and compare the work organization and interaction patterns in coal mines with different technologies and to explore the relationships between work organization and the coal miner's relationship to his work group, the community, and his family. An appendix contains interview forms used for the miners and their wives. Available for reference at the Bureau of Mines library, Denver, Colo.; and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 9-69. Attitudes of Selected Zinc Miners and Their Wives in East Tennessee, by Helen M. Lewis and Edward E. Knipe. October 1968. 34 pp. This report summarizes the findings of interviewers of selected zinc miners and their wives in East Tennessee from the middle of April 1968 to the end of July 1968. These interviews were carried out for two reasons: First, to apply a questionnaire designed from an earlier study of coal miners to a non-coal mining population, and second, to gather information useful in comparing the attitudes of non-coal miners with coal miners. Although short and non-analytical this report helps to establish some of the basic social and psychological parameters associated with the zinc miner, his family, and the community in which he lives. Available for reference during office hours at the Bureau of Mines library, Denver, Colo.; and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 10-69. Data On Copper Occurrences Associated With Permian Formations in Texas, Oklahoma, and Kansas. 1969. The following data are being placed on open file: A table showing location and other information related to copper occurrences that have been developed to some degree. A table showing location and other information concerning outcrop samples taken in the course of investigation. Copies of 38 core drill hole logs and attendant assay data of samples taken. A location map showing geographic location of areas studied in some detail in Texas. Property ownership of lands drilled by the Bureau of Mines. Property survey maps of the Medicine Mounds and Truscott study areas in Texas showing outcrop sample sites and drill hole sites. A topographic map of the Buzzard Peak study area in Texas showing outcrop sample sites and drill hole sites. A correlation chart of Permian "red beds" in Texas, Oklahoma, and Kansas. Available for reference during office hours at the Bureau of Mines library, Bartlesville, Okla.

OFR 11-69. Microfilming of Mining Records in the Kuskokwim and Yukon River Basins, Alaska, by Raymond P. Maloney. 26 pp. 2 figs. Records of mineral location notices and assessment work from 1900 to 1965 from most of the Kuskokwim River basin and much of the lower part of the Yukon River basin and the Bristol Bay area are on microfilm. This is an area of mercury, gold, platinum, and iron mineralization which has seen considerable mining activity and has a good potential for additional discoveries. The report gives an idea of the wide extent of early exploration, prospecting, and mineralization, and indexes the film for quick location of areas of interest. Available for reference during office hours at the Bureau of Mines offices in Juneau, Anchorage, and Fairbanks, Alaska, and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 12-69. Use of Coal to Enhance Metabolic Treatment of Sewage, Final Report, prepared for the Bureau of Mines by Biospherics Research Incorporated. May 22, 1969. 150 pp. 6 figs. Eighteen different types and sizes of coal particulates were suspended in mixed liquors of sludge and raw sewage and recirculated with activated sludge in this investigation. The premise that the suspended coal particles concentrate nutrients and organic matter by physical adsorption and provide surface area for microbial growth in this enriched micro-environment was supported by the results. Efficiency of biodegradation by the sewage micro-organisms as measured by several parameters, appeared to have been increased. Considerable improvement in sewage treatment objectives was achieved with some of the coals. However, additional work is required to establish conclusively that coal does in fact stimulate metabolic activity. Microscopic photographs taken of coal particles introduced into aerated mixed liquors show that micro-organisms concentrate on the surfaces of the coal during the aeration process. These photographs support the premise that the addition of coal to mixed liquors does serve to provide micro-organisms with surface area for attachment and that the environment supports the micro-organisms. The fact that the organisms apparently grew on the surface is an indication that nutrients were available at or near the surface. Improvide phosphate uptake and enhanced BOD reduction together with the photographs support the theoretical basis of the program for some of the coals tested. The effects achieved warrant continued research in this potentially important new treatment process. Available for reference during office hours at the Bureau of Mines Library, Pittsburgh, Pa., and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 13-69. Lithologic and Fischer Assay Data on the Core From Bureau of Mines Washakie Basin Corehole No. 1. 1969. The report contains complete assays by the Bureau of Mines modified Fischer assay method for a core taken in a program to evaluate the oil shales of the Green River Formation. A complete lithologic description of the core is also given. Available for reference during office hours at the Bureau of Mines libraries at Laramie, Wyo., and Denver, Colo.

OFR 14-69. Methane: Bibliography of the Thermodynamic and Transport Properties Above 300 K, by R. T. Moore, R. H. Harrison, and D. R. Douslin. 1969. 133 pp. The thermodynamic and transport properties of methane are being critically reviewed and correlated by the Bureau of Mines in cooperation with the Working Panel on Aliphatic Hydrocarbons of the Commission on Thermodynamics and Thermochemistry of the International Union of Pure and Applied Chemistry (IUPAC). A necessary part of that work is the preparation of a complete bibliography. This bibliography of the properties of methane above 300 K published before December 1968 complements one, prepared by the U.S. Department of Commerce, National Bureau of Standards (Technical Note 367), for the thermophysical properties of methane at temperatures below 300 K. Available for reference during office hours at the Bartlesville Petroleum Research Center, Bartlesville, Okla.

OFR 15-69. Barcus Creek Corehole No. 1 Data, by Staff, Laramie Petroleum Research Center. 1968. Barcus Creek Corehole No. 1 was drilled to evaluate oil shale on proposed Test Lease Site 3a. Data on open file include oil yield by modified Fischer assay, oil yield histograms, borehole logs (resistivity, spontaneous potential, gamma-ray, caliper, and compensated formation density), and surveys of minerals and their distribution in the core samples as determined by X-ray diffraction. Available for reference during office hours at the Bureau of Mines libraries at Denver, Colo., and Laramie, Wyo.; and the Geological Survey Public Inquiry Office, Denver, Colo.

OFR 16-69. Sampling for Gold in River Bars, Kuskokwim River Basin, Alaska, by Raymond P. Maloney. 1969. 10 pp. 2 figs. River bars were sampled over a 50-mile interval of the Kuskokwim River to determine the possibility of their containing significant amounts of gold. One-quarter cubic yard samples were concentrated using a small sluice box; the concentrate was further reduced by hand panning and then assayed. Colors of very fine gold were seen in pan concentrates from all samples, but assay results varied from nothing to 2 cents per cubic yard. It is probable that 50 percent of the total amount of gold present in the samples was recovered in the concentrate. Additional investigation is necessary to determine the extent and importance of this potential gold source; however, large-scale channel dredging operations or recovery of the gold as a byproduct in harbor excavation might be of economic importance. Available for reference during working hours at the Bureau of Mines offices in Juneau, Anchorage, and Fairbanks, Alaska; and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 17-69. A Study and Model of the Exploration Process in the Non-Fuel Mineral Industry, prepared for the Bureau of Mines by the CONSAD Research Corp. Aug. 15, 1969. This report contains a model of the mining exploration process, an analysis of the structure of the mining exploration industry, methods for evaluating comparative costs and benefits of alternative exploration programs, and other useful data on non-fuel mineral industry exploration that is not easily available elsewhere. Available for inspection during office hours at the Bureau of Mines libraries at Denver, Colo., Minneapolis, Minn., and Pittsburgh, Pa.; at the Bureau of Mines offices at San Francisco, Calif., and Spokane, Wash.; and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 18-69. A FORTRAN IV Computer Program for Preparing a Regional Interindustry Transaction Table From Secondary Data Sources, by Mary Carasso. 1969. 26 pp. The purpose of this program is to prepare an interindustry flow table for a region that will show transactions that are "net" in terms of regionally produced products; i.e., the flows are of net of "imports." The program is designed to assist individuals working with input-output information and is particularly useful with regional information where "imports" into a state or group of states must be accounted for. Available for inspection during office hours at the Bureau of Mines libraries, in Denver, Colo., and Pittsburgh, Pa.; and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 19-69. A FORTRAN IV Computer Program for Manipulating Leontief Type Models, by Mary Carasso and Meir Carasso. 1969. 34 pp. At the option of the user, this program transforms, aggregates, and/or performs a variety of matrix manipulations for routine work with Leontief type models. The program is designed to assist individuals working with input-output information and is particularly useful with regional information where "imports" into a state or group of states must be accounted for. Available for inspection during office hours at the Bureau of Mines libraries in Denver, Colo., and Pittsburgh, Pa.; and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 20-69. Coal Reserves of Bibb County, Alabama, by Reynold Q. Shotts. 1969. 62 pp. 15 figs. Bibb County, Ala., has remaining recoverable coal reserves of 446 million tons, of which 19 million tons are recoverable by stripping. Bibb County coals generally contain less than 1.5 percent sulfur, are low in inherent ash, and are of high-volatile A bituminous rank. This report is related to a series of 44 county reports published by the Bureau of Mines between 1948 and 1956; a listing of these reports is given in Bureau of Mines RI 5267. Available for reference during working hours at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 21-69. The Social and Economic Effects of the Substitution of Low Sulfur Coal for High Sulfur Coal: A Pilot Study of Monongalia County, West Virginia. Final Report, prepared by Frederick A. Zeller, Wil J. Smith, Samuel M. Brock, and Douglas M. Brown. Appalachian Center, West Virginia Univ., Morgantown, W. Va. December 1968. 57 pp. This report is a pilot study designed to show what might happen immediately and in the long run to the economy of Monongalia County, W. Va., if strict (less than 2 percent sulfur) air pollution standards were enforced upon its coal customers who then substituted low-sulfur coal for the high-sulfur coal of Monongalia County. An econometric model was the basic tool of analysis. Employment and income multipliers were used to supplement the model. The construction and use of the model for estimating economic change is discussed. Available for reference during working hours at the Bureau of Mines library, Pittsburgh, Pa.; and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 22-69. Silver in the United States. Potential Resources, by Staff, Bureau of Mines. 1969. 300 pp. The rising demand for silver, deficit in production, and the depletion of U.S. Treasury reserves were instrumental in the Bureau of Mines undertaking an investigation of unmined silver resources in the United States. The production potential of the Nation's principal active and inactive silver mining districts is evaluated, using 1964 economic and technologic conditions and assumed silver prices up to $3.00 per ounce. All districts were researched, but only those having a past production or a potential exceeding 5 million ounces of silver were included in this report. It is estimated that the United States has about 4.9 billion ounces of unmined silver, excluding metal contained in gold deposits. Approximately 3.58 billion ounces are contained in deposits requiring higher silver prices to be economically minable; about 1.35 billion ounces are in currently operating mines. Available for inspection during office hours at the State of Idaho Bureau of Mines and Geology, Moscow, Idaho; at the Montana Bureau of Mines and Geology, Butte, Mont.; at the State of Oregon Department of Geology and Mineral Industries, Portland, Oreg.; at the Bureau of Mines offices at Juneau, Alaska, San Francisco, Calif., Denver, Colo., Dallas, Tex., and Spokane, Wash.; at the Reno Metallurgy Research Center, Reno, Nev.; and the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 23-69. The Commercial Demand for Gold in the United States, by Constantine Michalopoulos and Roger C. Van Tassel. Clark University, Worcester, Mass. July 1969. 85 pp. This study consists of an analysis and projection of commercial demand for gold in the United States. It indicates a slower rate of growth for commercial gold use than most forecasts. Available for reference during working hours at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 24-69. Adaption of Automation in the Cement, Salt, and Iron Industries in South-Central United States, by Andrew Kuklis and G. T. McIntyre. 1969. 74 pp. 30 figs. The application of automation principles and equipment was studied in the cement, salt, and iron-ore processing in South-Central United States to determine the general effects, possible advantages, and potential trends. This study may be useful to other segments of the mineral industry that inherently processes large quantities of mineral materials. Available for reference during working hours at the Bureau of Mines library, Bartlesville, Okla.; and at the Central Library, U.S. Department of the Interior, Washington, D.C.

OFR 25-69. Planning for Non-Renewable Common Mineral Resources in Urban-Suburban Environs, by Donald Bishko, James R. Dunn, and William A. Wallace. Urban-Environmental Studies, Rensselaer Polytechnic Institute, Troy, N.Y., Oct. 18, 1969. 181 pp. 15 figs. This research was undertaken to delineate in dollar terms the magnitude of the result of not planning for the consumption of common mineral resources, and to develop a computer simulation model which will provide planners with an indication of the effects of decisions affecting these resources. Available for reference during working hours at the Bureau of Mines libraries in Minneapolis, Minn., and Denver, Colo.; and at the Central Library, U.S. Department of the Interior, Washington, D.C.

COOPERATIVE PUBLICATIONS

The following reports, resulting from investigations conducted cooperatively by the Bureau of Mines and the agencies noted, have been written in part by members of the Bureau and published by the coperating agency.

WITH THE BONNEVILLE POWER AMINISTRATION, U.S. DEPARTMENT OF THE INTERIOR

BPA 1-65. Potential for the Coal Industry in the Pacific Northwest, by Harry Perry, Max R. Geer, Columbus R. Gentile, and Herschel F. Jones. Pacific Northwest Economic Base Study for Power Markets, v. 11, pt. 11A. 1965. 203 pp. 39 figs. Gives results of a study of the coal industry in the Pacific Northwest. Objectives were to assess the industry's present economic significance in the region, to appraise the use of coal for steam generation of electric energy, to forecast the future development of the coal industry in terms of production and consumption in 5-year intervals to 1985, with projection of trends to 2010, to determine the future impact of the coal industry on the Pacific Northwest economy.

BPA 2-65. Sulfur Consumption in the Pacific Northwest, by William N. Hale and Norman S. Petersen. Pacific Northwest Economic Base Study for Power Markets, v. 2, pt. 13F. 1965. 51 pp. 11 figs. Reviews presently utilized sulfur resources and estimates that apparent demand for sulfur in all forms will be 670,000 long tons by 1985. This includes about 464,000 long tons of equivalent sulfur in sulfuric acid and 206,000 long tons of sulfur for manufacturing sulfite pulp, compared with 126,000 and 164,000 long tons, respectively, for these uses in 1962.

BPA 3-65. Trends and Outlook for Manufacture of Artificial Abrasives in the Pacific Northwest, by N. S. Peterson and W. N. Hale. Pacific Northwest Economic Base Study for Power Markets, v. 2, pt. 7A. 1965. 37 pp. 3 figs. This study was undertaken to review the status and outlook for artificial abrasives manufacture in the region. The period 1949-62 is used as the base period, and the outlook for silicon carbide and aluminum oxide production in the Pacific Northwest is projected to 1985.

WITH THE GEOLOGICAL SURVEY, U.S. DEPARTMENT OF THE INTERIOR

The Wilderness Act (Public Law 88–577, Sept. 3, 1964) and the Conference Report on Senate bill 4, 88th Congress, direct the Geological Survey and the Bureau of Mines to make mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," or "canoe" when the act was passed were incorporated into the National Wilderness Preservation System. Areas classed as "primitive" were not included in the Wilderness System, but the act provided that each area should be studied for its suitability for incorporation into the Wilderness System. These mineral surveys constitute one aspect of the suitability studies.

GS 1-66. Mineral Resources of the San Rafael Primitive Area, California, by H. D. Gower, J. G. Vedder, H. E. Clifton, and E. V. Post. Geol. Survey Bull. 1230-A. 1966. 28 pp. 8 figs. 2 plates. 60 cents.

GS 2-66. Mineral Resources of the Spanish Peaks Primitive Area, Montana, by George E. Becraft, James A. Calkins, Eldon C. Pattee, Robert D. Weldin, and Joseph M. Roche. Geol. Survey Bull. 1230-B. 1966. 45 pp. 4 figs. 2 plates. 65 cents.

GS 3-66. Mineral Resources of the Flat Tops Primitive Area, Colorado, by W. W. Mallory, E. V. Post, P. J. Ruane, W. L. Lehmbeck, and R. B. Stotelmeyer. Geol. Survey Bull. 1230-C. 1966. 30 pp. 4 figs. 2 plates. 60 cents.

GS 4-66. Mineral Resources of the Mount Jefferson Primitive Area, Oregon, by George W. Walker, Robert C. Greene, and Eldon C. Pattee. Geol. Survey Bull. 1230-D. 1966. 32 pp. 8 figs. 1 plate. 55 cents.

GS 5-66. Mineral Resources of the Stratified Primitive Area, Wyoming, by K. B. Ketner, W. R. Keefer, F. S. Fisher, D. L. Smith, and R. G. Raabe. Geol. Survey Bull. 1230-E. 1966. 56 pp. 17 figs. 1 plate. 60 cents.

GS 1-67. Mineral Resources of the Devil Canyon-Bear Canyon Primitive Area, California, by Dwight F. Crowder. Geol. Survey Bull. 1230-G. 1969. 21 pp. 2 pl. 4 figs. 55 cents.

GS 2-67. Mineral Resources of the Mount Baldy Primitive Area, Arizona, by Tommy L. Finnell, C. Gilbert Bowles, and John H. Soulé. Geol. Survey Bull. 1230-H. 1967. 14 pp. 4 figs. 15 cents.

GS 3-67. Mineral Resources of the High Uintas Primitive Area, Utah, by Max D. Crittenden, Jr., Chester A. Wallace, and M. J. Sheridan. Geol. Survey Bull. 1230-I. 1967. 27 pp. 1 pl. 8 figs. 60 cents.

GS 4-67. Mineral Resources of the Pine Mountain Primitive Area, Arizona, by F. C. Canney, W. L. Lehmbeck, and Frank E. Williams. Geol. Survey Bull. 1230-J. 1967. 48 pp. 2 pl. 5 figs. 65 cents.

GS 5-67. Mineral Appraisal of the Salt Creek Area, Bitter Lake National Wildlife Refuge, Chaves County, New Mexico, by George O. Bachman. Geol. Survey Bull. 1260-A. 1967. 10 pp. 5 figs. 15 cents. (Publication includes GS 6-67.)

GS 6-67. Mineral Appraisal of the Bosque del Apache National Wildlife Refuge, Socorro County, New Mexico, by George O. Bachman and Ronald B. Stotelmeyer.

Geol. Survey Bull. 1260-B. 1967. 9 pp. 1 fig. 15 cents. (Publication includes GS 5-67.)

GS 7-67. Summary Report on the Geology and Mineral Resources of the Bear River Migratory Bird Refuge, Box Elder County, Utah, by Lowell S. Hilpert. Geol. Survey Bull. 1260-C. 1967. 10 pp. 1 fig. 15 cents.

GS 8-67. Summary Report on the Geology and Mineral Resources of Monomoy National Wildlife Refuge, Barnstable County, Massachusetts, by Carl Koteff. Geol. Survey Bull. 1260-D. 1967. 4 pp. 1 fig. 15 cents. (Publication includes GS 9-67.)

GS 9-67. Summary Report on the Geology and Mineral Resources of the Great Swamp National Wildlife Refuge, New Jersey, by James P. Minard. Geol. Survey Bull. 1260-E, 1967. 14 pp. 6 figs. 15 cents. (Publication includes GS 8-67.)

GS 10-67. Mineral Resources of the Desolation Valley rPimitive Area of the Sierra Nevada, California, by F. C. W. Dodge and P. V. Fillo. Geol. Survey Bull. 1261-A. 1967. 27 pp. 6 figs. 60 cents.

GS 11-67. Mineral Resources of the Ventana Primitive Area, Monterey County, California, by Robert C. Pearson, Phillip T. Hayes, and Paul V. Fillo. Geol. Survey Bull. 1261-B. 1967. 42 pp. 5 figs. 2 pl. $1.

GS 1-68. Summary Report on the Geology and Mineral Resources of Flattery Rocks, Quillayute Needles, and Copalis National Wildlife Refuges, Washington, by A. E. Weissenborn and Parke D. Snavely, Jr. Geol. Survey Bull. 1260-F. 1968. 15 pp. 8 figs. 1 plate. 55 cents. (Publication includes GS 2-68 and 3-68.)

GS 2-68. Summary Report on the Geology and Mineral Resources of the Oregon Islands National Wildlife Refuge, Oregon, by A. E. Weissenborn and Parke D. Snavely, Jr. Geol. Survey Bull. 1260-G. 1968. 4 pp. 4 figs. 55 cents. (Publication includes GS 1-68 and 3-68.)

GS 3-68. Summary Report on the Geology and Mineral Resources of the Three Arch Rocks National Wildlife Refuge, Oregon, by A. E. Weissenborn and Parke D. Snavely, Jr. Geol. Survey Bull. 1260-H. 1968. 4 pp. 4 figs. 55 cents. (Publication includes GS 1-68 and GS 2-68.)

GS 4-68. Mineral Resources of the Appalachian Region, by the U.S. Geological Survey and the U.S. Bureau of Mines. Geol. Survey Prof. Paper 580. 1968. 492 pp. 118 figs. This report evaluates the mineral resources of Appalachia in terms of their geologic setting and distribution, availability, and use and discusses the past, present, and future roles of the mineral industry. It was prepared by 67 specialists of the Geological Survey and the Bureau of Mines. The introductory part of the report describes the geography and physiography of Appalachia, discusses causes and effects of the current lagging economy in much of the region, and evaluates the mineral industry. A discussion of geology follows to provide the background for understanding the distribution and relative abundance of mineral commodities. The main part of the report consists of 50 sections which deal with history, production, geology, and resources of each mineral commodity that has been produced or that potentially may be produced in Appalachia. $4.50.

GS 5-68. Summary Report on the Geology and Mineral Resources of the Huron, Seney, Michigan Islands, Green Bay, and Gravel Island National Wildlife Refuges of Michigan and Wisconsin, by Carl E. Dutton. Geol. Survey Bull. 1260-I. 1968. 14 pp. 6 figs. 20 cents. (Publications includes GS 6-68.)

OP 6-68. Summary Report on the Geology and Mineral Resources of the Charons Garden Unit, Wichita Mountains National Wildlife Refuge, Comanche County, Oklahoma, by Edward L. Johnson. Geol. Survey Bull. 1260-J. 7 pp. 1 fig. 20 cents. (Publication includes GS 5-68.)

GS 7-68. Summary Report on the Geology and Mineral Resources of the Bering Sea, Bogoslof, Simeonof, Semidi, Tuxedni, St. Lazaria, Hazy Islands, and Forrester Island National Wildlife Refuges, Alaska, by Edward H. Cobb, Alexander A. Wanek, Arthur Grantz, and Claire Carter. Geol. Survey Bull. 1260-K. 28 pp. 10 figs. 20 cents.

GS 8-68. Mineral Resources of the Uncompahgre Primitive Area, Colorado, by R. P. Fischer, R. G. Luedke, M. J. Sheridan, and R. G. Raabe. Geol. Survey Bull. 1261-C. 1968. 91 pp. 19 figs. 3 pl. $1.75.

GS 9-68. Summary Report on the Geology and Mineral Resources of the Harney Lake and Malheur Lake Areas of the Malheur National Wildlife Refuge, North-Central Harney County, Oreg., by G. W. Walker and D. A. Swanson. Geol. Survey Bull. 1260-L. 1968. 17 pp. 3 figs. 20 cents. (Publication includes GS 10-68.)

GS 10-68. Summary Report on the Geology and Mineral Resources of the Poker Jim Ridge and Fort Warner Areas of the Hart Mountain National Antelope Refuge, Lake County, Oreg., by G. W. Walker and D. A. Swanson. Geol. Survey Bull. 1260-M. 1968. 16 pp. 3 figs. 20 cents. (Publications includes GS 9-68.)

GS 11-68. Summary Report on the Geology and Mineral Resources of the Okefenokee National Wildlife Refuge, Ga., by J. E. Smedley. Geol. Survey Bull. 1260-N. 1968. 1968. 10 pp. 1 fig. 20 cents. (Publication includes GS 12-68.)

GS 12-68. Summary Report on the Geology and Mineral Resources of the Passage Key, Island Bay, Cedar Keys, and Pelicna Island National Wildlife Refuges, Fla., by C. L. Perdue, Jr. Geol. Survey Bull. 1260-O. 1968. 13 pp. 5 figs. 20 cents. (Publication includes GS 11-68.)

GS 13-68. Summary Report on the Geology and Mineral Resources of the Edmunds Unit, Moosehorn National Wildlife Refuge, Washington County, Maine, by M. H. Pease, Jr. Geol. Survey Bull. 1260-P. 1968. 18 pp. 15 cents.

GS 1-69. Mineral Resources of the Mission Mountains Primitive Area, Missoula and Lake Counties, Montana, by Jack E. Harrison, Mitchell W. Reynolds, M. Dean Kleinkopf, and Eldon C. Pattee. Geol. Survey Bull. 1261-D. 1969. 48 pp. 5 figs. $1.25.

GS 2-69. Mineral Resources of the Blue Range Primitive Area, Greenlee County, Arizona, and Catron County, New Mexico, by James C. Rattee, E. R. Landis, David L. Gaskill, and R. G. Raabe. With a section on Aeromagnetic Interpretation, by Gordon P. Eaton. Geol. Survey Bull. 1261-E. 1969. 91 pp. 21 figs. $1.

GS 3-69. Mineral Resources of the San Juan Primitive Area, Colorado, by T. A. Steven, L. J. Schmitt, Jr., M. J. Sheridan, and F. E. Williams. With a section on Iron Resources in the Irving Formation, by Jacob E. Gair and Harry Klemic. Geol. Survey Bull. 1261-F. 1969. 187 pp. 20 figs. $1.75.

WITH THE KENTUCY GEOLOGICAL SURVEY

KNR. Industrial Sand in Pike County, Kentucky, by R. P. Hollenbeck, J. S. Browning, and T. L. McVay. Kentucky Geol. Survey, ser. 10, RI 7. 1967. 30 pp. 5 figs.

WITH THE MARYLAND GEOLOGICAL SURVEY

MNR. Expandable Clay in St. Marys Formation of Southern Maryland, by Maxwell M. Knechtel, Howard P. Hamlin, and John W. Hosterman. Maryland Geological Survey, RI 4. 1967. 17 pp. 5 figs.

WITH THE NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES

NMNR. Barite Deposits of New Mexico, by Frank E. Williams, P. V. Fillo, and P. A. Bloom. New Mexico Bureau of Mines and Mineral Resources, Circ. 76. 1964. 46 pp.

WITH THE NORTH CAROLINA DIVISION OF MINERAL RESOURCES, DEPARTMENT OF CONSERVATION AND DEVELOPMENT

NCNR. Titanium Deposits in North Carolina, by Lloyd Williams. North Carolina Dept. of Conservation and Development, Div. of Min. Res. Inf. Circ. 19, 1965. 51 pp. 8 figs. Records of 110 mineral deposits were investigated for titanium and associated minerals in North Carolina. The low mineral tenor or lack of data on the deposits eliminated their classification as ore reserves. However, records of drill holes and laboratory tests on samples showed that seven deposits were sufficient magnitude to justify estimating their total content of ilmenite, rutile, zircon, and monazite. The most extensively mined titanium mineral deposit in North Carolina is the Yadkin River deposit in Caldwell County, operated as an open pit. During the period 1942-52, the operation produced 215,400 tons of concentrate containing 51 percent TiO_2

WITH THE BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY, COMMONWEALTH OF PENNSYLVANIA

PNR. Properties and Uses of Pennsylvania Shales and Clays, by B. J. O'Neill, Jr., D. M. Lapham, M. G. Jaron, A. A. Socolow, R. D. Thomson, and H. P. Hamlin. 1965. 488 pp. 20 figs. Detailed sampling and extensive testing were carried out on 150 samples of Pennsylvania clays and shales to evaluate the potential for commercial use. Among the samples tested, 137 indicated properties suitable for common and decorative brick, floor tile, drain and chimney flue tile, refractories, lightweight aggregate, artware, pottery, filler, and pigments. Of particular importance are those clays and shales that can be made into lightweight aggregate. This report represents an evaluation of all major clay and shale formations in the State.

WITH THE SOUTH CAROLINA STATE DEVELOPMENT BOARD, DIVISION OF GEOLOGY

SCNR. Heavy Minerals in South Carolina, by Lloyd Williams. South Carolina State Development Board, Division of Geology, Bull. 35. 35 pp. 15 figs.

WITH THE STATE OF TENNESSEE, DEPARTMENT OF CONSERVATION, DIVISION OF GEOLOGY

TNR. Ceramic Evaluation of Clays and Shales of East Tennessee, by R. P. Hollenbeck and M. E. Tyrrell. State of Tennessee, Department of Conservation, Division of Geology, RI 25. 1969. 22 pp.

WITH THE VIRGINIA DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT, DIVISION OF MINERAL RESOURCES

VNR 1-65. Analysis of Clay, Shales, and Related Materials—Southwestern Counties, by Stanley S. Johnson, Marion V. Denny, and D. C. Le Van. Virginia Division of Mineral Resources, Min. Res. Rept. 6, 1965. 210 pp. 11 figs. Contains results of tests and determinations of properties required to evaluate the potential ceramic and nonceramic uses of 120 samples of clay, shale, and coal refuse from Bland, Buchanan, Dickenson, Giles, Lee, Pulaski, Russell, Scott, Smyth, Tazewell, Washington, Wise, and Wythe Counties. Tests indicate that 46 samples are potentially suitable for brick, 13 for common or inside brick, 2 for glazed brick, 1 for flue brick, 7 for decorative brick, 17 for tile, 6 for decorative tile, 3 for quarry tile, 2 for drain tile, 1 for flue tile, 12 for pottery, 7 for artware pottery, 1 for earthenware, 1 for insulating material, 1 for use in glazing, 60 for lightweight aggregate, and 1 for aggregate.

VNR 1-67. Analyses of Clay and Related Materials—Eastern Counties, by Stanley S. Johnson and Miles E. Tyrrell. Virginia Division of Mineral Resources, Min. Res. Rep. 8. November 1967. 232 pp.

MONOGRAPHS

A monograph is a detailed report of a cooperative investigation of a special subject in which the Bureau of Mines and another organization are mutually interested and usually relates to a study of problems encountered in production, distribution, or utlization of mineral fuels. The two monographs described here may be obtained from the Interstate Oil Compact Commission, Oklahoma City, Okla.

M 12. Surface and Shallow Oil-Impregnated Rocks and Shallow Oil Fields in the United States, compiled by Ball Associates, Ltd. 1965. 375 pp. 40 figs. Presents the results of a survey of occurrences of tar sands and oilfields to subsurface depths of 500 feet. Describes 546 occurrences of tar sands and 383 shallow oilfields in 27 States and includes 40 maps of shallow oilfields and tar-sand occurrences. Reserve figures are available for only a few deposits. Incomplete as these reserve figures are, they total 2.5 to 5.5 billion barrels of bitumen recoverable by known mining methods. This monograph should be of substantial interest and value, particularly in view of current interest and activity in thermal methods of stimulating petroleum production.

M 13. Oil Recovery From Gas-Cap Reservoirs: An Engineering Evaluation of Conservation Practices in Six Reservoirs, by Lewis K. Weaver and Kenneth F. Anderson.

1966. 106 pp. 70 figs. This report describes the performance of six gas-cap reservoirs (sometimes called combination reservoirs) that are examples of good engineering and good regulatory practices. The six reservoirs, each located in a different State, were selected to illustrate the multiplicity of problems to be coped with in efficient and scientifically sound production of oil and gas and to show the value of conservation. Since each reservoir has different geologic conditions, rock characteristics, and fluid properties, the methods of operation vary appreciably. Five of the methods are utilized operations; the sixth is not. In each reservoir the operators, in conjunction with the State regulatory bodies, improved the production practices to increase the ultimate hydrocarbon recoveries. Most data and comparisons of recoveries by unimproved and improved producing practices were furnished by the operators, unless otherwise noted. Whenever possible, data to January 1, 1966, are included. The anticipated increase in ultimate oil and condensate recovery due to the improved production practices in the six reservoirs is approximately 106.7 million barrels, or about 47.5 percent more than would have been recovered with unimproved production practices.

PATENTS

The following patents were granted to the Bureau of Mines during the period 1965 through 1969. These processes, which can be used by any U.S. citizen or organization without royalty payment upon authorization by the Department of the Interior, were developed by Bureau scientists. Applications for the use of any of these patents should be made to the Office of the Solicitor, Department of the Interior, Washington, D.C. 20240.

P 1-65. Removal of Oxygen and Aluminum Prepared by Alumino-Thermic and Similar Processes. C. J. Chindgren. U.S. Pat. 3,184,302, May 18, 1965.

P 2-65. Apparatus for Concentrating Trace Impurities in High-Purity Helium. W. M. Deaton and C. G. Kirkland. U.S. Pat. 3,194,054, July 13, 1965.

P 3-65. Inclined-Piston Deadweight Pressure Gauge. D. R. Douslin. U.S. Pat. 3,195,354, July 20, 1965.

P 4-65. Corrosion Inhibitor for Solutions of Alkaline Carbonates. J. H. Field and D. Bienstock. U.S. Pat. 3,181,929, May 4, 1965.

P 5-65. Upgrading Primary Manganese Matte. R. C. Kirby. U.S. Pat. 3,179,514, Apr. 20, 1965.

P 6-65. Sealing System for Blast Furnace Bells for High Pressure Top Operation. N. B. Melcher and W. W. Mahan. U.S. Pat. 3,221,906, Dec. 7, 1965.

P 7-65. Method of Agglomerating Iron Ore Fines. R. E. Perry. U.S. Pat. 3,185,564, May 25, 1965.

P 8-65. Process for Separating the Rare-Earth Elements by Means of Solvent Extraction. A. C. Rice. U.S. Pat. 3,192,012, June 19, 1965.

P 9-65. Synthesis of Large Crystals of Fluorophlogopite Mica. H. R. Shell, N. A. Pace, and E. F. Nichols. U.S. Pat. 3,222,142, Dec. 7, 1965.

P 1-66. Process for Preparation of Caustic-Resistant Containers for High-Temperature Use. W. A. Calhoun and Lee N. Ballard. U.S. Pat. 3,236,682, Feb. 22, 1966.

P 2-66. Process for the Recovery of Rhenium. Philip E. Churchward. U.S. Pat. 3,260,658, July 12, 1966.

P 3-66. Solvent Extraction Process for Recovery of Rhenium. Philip E. Churchward. U.S. Pat. 3,244,475, Apr. 5, 1966.

P 4-66. Inclined-Piston Dead-Weight Pressure Gauge. Donald R. Douslin. U.S. Pat. 3,260,118, July 12, 1966.

P 5-66. Elimination of Agglomeration by Freezing of Lignite or Other Moisture-Containing or Wetted Aggregates During Shipment. Robert S. Ellman and John W. Belter. U.S. Pat. 3,243,889, Apr. 5, 1965.

P 6-66. Flame Spraying of Catalytically Active Pulverized Metal Oxides on Supports. Albert J. Forney and Joseph J. Demeter. U.S. Pat. 3,271,326, Sept. 6, 1966.

P 7-66. Process for Improved Flotation Treatment of Iron Ores by Selective Flocculation. Donald W. Frommer and Arthur F. Colombo. U.S. Pat. 3,292,780, Dec. 20, 1966.

P 8-66. Synthesis of Fibrous Silicon Nitride. Robert C. Johnson, J. K. Alley, W. H. Warwick, and Haskiel Roy Shell. U.S. Pat. 3,244,480, Apr. 5, 1966.

P 9-66. Process for Separating Rare-Earth Elements by Ion Exchange. Roald E. Lindstrom and J. Oscar Winget. U.S. Pat. 3,228,750, Jan. 11, 1966.

P 10-66. Top Closure for High Temperature Electrostatic Precipitator. Lee Mafrica. U.S. Pat. 3,293,829, Dec. 27, 1966.

P 11-66. Reduction Roasting With Iron. Norwood B. Melcher. U.S. Pat. 3,273,993, Sept. 20, 1966.

P 12-66. Smelting Reduced Iron Ore Pellets in the Blast Furnace. Norwood B. Melcher, Morris M. Fine, and Philip L. Woolf. U.S. Pat. 3,282,678, Nov. 1, 1966.

P 13-66. Flotation of Mica. Frank W. Millsaps and James S. Browning. U.S. Pat. 3,278,028, Oct. 11, 1966.

P 14-66. Device for Securing Plug in an Infusion Hole. Richard H. Oitto, Jr. U.S. Pat. 3,287,920, Nov. 29, 1966.

P 15-66. Fraction Separation of Aqueous Rare Earths Using Amines. Andrew C. Rice. U.S. Pat. 3,259,472, July 5, 1966.

P 16-66. Recovery of Zinc From Die-Cast Scrap. John A. Ruppert and Paul M. Sullivan. U.S. Pat. 3,273,995, Sept. 20, 1966.

P 17-66. Binder and Surface Coating Made From Coal and Asphalt. Martin D. Schlesinger and Raymond W. Hiteshue. U.S. Pat. 3,264,957, Aug. 9, 1966.

P 18-66. Prerefining Blast Furnace Iron. Francis X. Tartaron. U.S. Pat. 3,271,128, Sept. 6, 1966.

P 1-67. Method of Quantitatively Determining Trace Impurities in Inert Gas Systems. D. M. Bailey, W. T. Abel, and P. G. Salgado. U.S. Pat. 3,332,745, July 25, 1967.

P 2-67. Flotation of Mica. J. S. Browning and R. B. Adair. U. S. Pat. 3,329,265, July 4, 1967.

P 3-67. Process for Conveying Mineral Solids Through Conduits. R. L. Adams. U.S. Pat. 3,341,256, Sept. 12, 1967.

P 4-67. Synthesis of Aluminum Borate Whiskers. John K. Alley and Robert C. Johnson. U.S. Pat. 3,350,166, Oct. 31, 1967.

P 5-67. Selective Extraction and Separation of Lanthanides With a Quaternary Ammonium Compound. D. J. Bauer and R. E. Lindstrom. U.S. Pat. 3,323,857, June 6, 1967.

P 6-67. Method of Producing a Nonagglomerating Char From a Strongly Caking Coal. S. J. Gasior and A. J. Forney. U.S. Pat. 3,355,363, Nov. 28, 1967.

P 7-67. Decaking of Caking Coals. S. J. Gasior, A. J. Forney, and J. H. Field. U.S. Pat. 3,357,896, Dec. 12, 1967.

P 8-67. Road Binder and Surface Coating From Coal. H. H. Ginsberg, M. D. Schlesinger, and R. W. Hiteshue. U.S. Pat. 3,341,344, Sept. 12, 1967.

P 9-67. Improved Method for Producing Molybdenum From Molybdenite (MoS_2). H. J. Heinen, C. L. Barber, and D. H. Baker, Jr. U.S. Pat. 3,330,646, July 11, 1967.

P 10-67. Undulatory Conveyor. Thomas E. Howard. U.S. Pat. 3,343,655, Sept. 26, 1967.

P 11-67. Water-Swelling Fluorphlogopite Mica and Fluoramphiboles and Methods for Making Same. K. H. Ivey. U.S. Pat. 3,360,333, Dec. 26, 1967.

P 12-67. Cast Iron or etal Product and Process Therefor. K. H. Ivey and H. R. Shell. U.S. Pat. 3,360,364, Dec. 26, 1967.

P 13-67. Preparation of Homogeneous Powders Composed of Ultrafine Particles. Arne Landsberg. U.S. Pat. 3,357,819, Dec. 12, 1967.

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PB 187 739. A Systems Approach to Recovering Gold Resources in Jefferson County, Mont. Introductory Review, by Robert W. Ageton, George T. Krempasky, and William L. Rice. October 1969. 16 pp. 5 figs. (Bureau of Mines RI 7305.)

PB 187 740. Vapor Pressures of Metal Halides. The $CdCl_2$-$SnCl_2$, $CdCl_2$-$ZnCl_2$, $PbCl_2$-$SnCl_2$, and $PbCl_2$-$ZnCl_2$ Binary Systems, by L. C. George, A. Visnapuu, Barbara C. Marek, and Robert M. Doerr. October 1969. 15 pp. 12 figs. (Bureau of Mines RI 7307.)

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PB 187 744. Effect of Increasing End Constraint on the Compressive Strength of Model Rock Pillars, by Clarence O. Babcock. September 1969. 18 pp. 7 figs. (Bureau of Mines RI 7298.)

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PB 187 832. The Commercial Demand for Gold in the United States, by Constantine Michalopoulos and Roger C. Van Tassel. July 1969. 85 pp. (Bureau of Mines OFR 23-69.)

PB 187 878. Vanadium. A Materials Survey, by Philip M. Busch. 1961. 95 pp. 21 figs. (Bureau of Mines IC 8060.)

PB 187 891. Mica. A Materials Survey, by Milford L. Skow. 1962. 241 pp. 27 figs. (Bureau of Mines IC 8125.)

PB 187 948. Coal Reserves of Bibb County, Alabama, by Reynold Q. Shotts. 1969. 62 pp. 15 figs. (Bureau of Mines OFR 20-69.)

PB 187 950. Adaptation of Automation in the Cement, Salt, and Iron Industries in South-Central United States, by Andrew Kuklis and G. T. McIntyre. 1969. 74 pp. 30 figs. (Bureau of Mines OFR 24-69.)

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PB 188 419. Heats of Formation of Three Oxides of Rhenium, by E. G. King, D. W. Richardson, and R. V. Mrazek. November 1969. 13 pp. (Bureau of Mines RI 7323.)

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PB 188 458. Planning for Non-Renewable Common Mineral Resources in Urban-Suburban Environs, by Donald Bisko, James R. Dunn, and William A. Wallace. Oct. 18, 1969. 181 pp. 15 figs. (Bureau of Mines OFR 25-69.)

PB 188 526. A Study and Model of the Exploration Process in the Non-Fuels Minerals Industry. Prepared for the Bureau of Mines by the CONSAD Research Corp., Aug. 15, 1969. (Bureau of Mines OFR 17-69.)

PB 188 535. Infrared Evaluation of Starch Products Used in Iron Ore Flotation, by A. F. Colombo and A. R. Rule. October 1969. 16 pp. 7 figs. (Bureau of Mines RI 7306.)

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PB 188 558. The System Al_4C_3-AlN-Al_2O_3. Powder Forming and Sintering Behavior, Phase Identification, and Refractory Composition Properties, by Jack L. Henry, James H. Russell, and Hal J. Kelly. November 1969. 24 pp. 7 figs. (Bureau of Mines RI 7320.)

PB 188 559. Energetics of Percussive Drills—Longitudinal Strain Energy, by Robert G. Lundquist and Carl F. Anderson. December 1969. 23 pp. 11 figs. (Bureau of Mines RI 7329.)

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PB 188 587. Fluidized-Bed Low-Temperature Carbonization of Bituminous Coal and Thermal Cracking of the Tar Vapors, by W. S. Sanner, B. W. Naugle, and D. E. Wolfson. 1969. 19 pp. (Bureau of Mines RI 7322.)

PB 188 588. Effect of Sodium Nitrate on the Incendivity of Explosives in Coal Dust-Gas-Air Mixtures, by C. M. Mason and P. A. Richardson. November 1969. 7 pp. 1 fig. (Bureau of Mines RI 7318.)

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PB 188 590. Production of Metallic Concentrates From High-Silica Iron Ores, by H. D. Jacobs and R. B. Schluter. 1969. 17 pp. 8 figs. (Bureau of Mines RI 7314.)

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PB 188 627. On Estimating Virial Coefficients From Experimental Data, by K. R. Van Doren. December 1969. 26 pp. (Bureau of Mines IC 8437.)

PB 188 628. Applying Marx and Lagenheim Calculations to the Prediction of Oil Recovery by Steamflooding in Venango Sands, by Avis W. Effinger and James A. Wasson. November 1969. 34 pp. 3 figs. (Bureau of Mines IC 8432.)

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PB 188 646. Chemical Reclaiming of Superalloy Scrap, by P. T. Brooks, G. M. Potter, and D. A. Martin. November 1969. 28 pp. 15 figs. (Bureau of Mines RI 7316.)

PB 188 653. Magnesium and Magnesium Compounds, by Hazel B. Comstock. 1963. 128 pp. 24 figs. (Bureau of Mines IC 8201.)

PB 188 656. Columbium and Tantalum. A Materials Survey, by William R. Barton. 1962. 110 pp. 24 figs. (Bureau of Mines IC 8120.)

PB 189 153. An Engineering and Economic Study of a Gold Mining Operation, by Edward E. Johnson. 1968. 53 pp. 7 figs. (Bureau of Mines IC 8374.)

PB 189 536. Contributions to the Data on Theoretical Metallurgy, XV. A Reprint of Bulletins 383, 384, 393, and 406, by K. K. Kelley. 1962. 154 pp. (Bureau of Mines B 601.)

PB 189 540. Thermodynamic Properties of a Redlich-Kwong Fluid in the Two-Phase Region, by B. J. Dalton and Robert E. Barieau. December 1969. 181 pp. 114 figs. (Bureau of Mines RI 7312.)

PB 189 541. An Ultrasonic Method for Determining the Elastic Symmetry of Materials, by Thomas R. Bur, Richard F. Thill, and Kenneth E. Hjelmstadt. December 1969. 23 pp. 10 figs. (Bureau of Mines RI 7333.)

PB 189 542. Suggested Orientation Conventions for Elastically Anisotropic Polycrystalline and Amorphous Materials, by Thomas R. Bur. December 1969. 9 pp. 1 fig. (Bureau of Mines RI 7334.)

PB 189 543. An Ultrasonic Method for Determining the Attenuation Symmetry of Materials, by Thomas R. Bur, Kenneth E. Hjelmstad, and Richard E. Thill. December 1969. 8 pp. 2 figs. (Bureau of Mines RI 7335.)

PB 189 544. Recovering Gold From Stripping Waste and Ore by Percolation Cyanide Leaching, by George M. Potter. December 1969. 5 pp. (Bureau of Mines TPR 20.)

PB 189 903. Methods for Determining Nitrogen Oxides in Automotive Exhausts, by Basil Dimitriades. May 1968. 29 pp. 9 figs. (Bureau of Mines RI 7133.)

PNE 1000. Project Gasbuggy, by Harry Gevertz, R. F. Lemmon, W. T. Hollis, M. A. Lekas, Don C. Ward, Charles H. Atkinson, and Norman Bonner. May 14, 1965. 57 pp. (Bureau of Mines OP 49-67.)

PNE 3001. Subsurface Fracturing From a Nuclear Detonation in Granite, by Charles H. Atkinson. U.S. Atomic Energy Commission, Plowshare Program Rept. 3001. 1965. 30 pp. 5 figs. (Bureau of Mines OP 10-65.)

ARTICLES IN OUTSIDE PUBLICATIONS

OP 1-65. Gas-Solids Suspensions as Heat-Carrying Mediums, by W. T. Abel, D. E. Bluman, and J. P. O'Leary. Pyrodynamics, v. 2, 1965, pp. 15-23. Suspensions of micronized graphite in inert gases were studied as heat-transport mediums for high-temperature systems such as nuclear reactors. Suspensions were circulated continuously by a centrifugal compressor to determine if the solids eroded the equipment and to compare the heat-transfer characteristics and power required to circulate the medium with the corresponding values for the carrier gas. Suspensions were circulated satisfactorily without significant erosion. In laminar and transitional flow, heavy deposits of graphite formed on cool heat-exchange surfaces, reducing the rate of heat transfer. In the turbulent regime, only thin films of graphite were observed, and heat-transfer coefficients were higher. The additional energy required to circulate solids at velocities necessary to prevent excessive deposition appeared to offset most of the advantage provided by the increase in heat-transfer coefficients.

OP 2-65. Hot Filament Methods of Determining Oxidizing Gases in High-Purity Gas Streams, by W. T. Abel, J. D. Spencer, and D. M. Bailey. Anal. Chem., v. 37, No. 13, December 1965, pp. 1711-1715. Describes a technique based on the use of a tungsten filament for determining traces of oxygen, carbon dioxide, or water in inert gases to as low as 10 ppm. Streams of helium containing traces of each oxidizing gas were passed over a hot tungsten filament giving correlations between rate of filament weight loss and oxidizing gas concentration. The technique proved sensitive and reproducible enough for onsite monitoring of these trace impurities in high-temperature gas systems. Applications of the method and reactions of tungsten with nonoxidizing as well as oxidizing gases are discussed.

OP 3-65. Solid and Gaseous Fuels, by R. F. Abernethy, and J. G. Walters. Anal. Chem., Annual Review, v. 37, No. 5, April 1965, pp. 222R-232R. Surveys the technical literature on the improved and new methods of sampling and analyzing coal and coke, and methods used for testing blast-furnace top, carbureted water, coal, coke-oven, liquefied petroleum, sludge, manufactured, natural, producer, synthesis, and water gases. Eighth in a series, review covers the period October 1962 to September 1964.

OP 4-65. Developing a Program To Determine the Economic Value of Mineral Deposits With Respect to Time, by Paul T. Allsman. Proc. 5th Ann. Symp. on Computers and Computer Applications in Mining and Exploration, March 15-19, 1965. College of Mines, University of Arizona, Tucson, Ariz., v. 1, 1965, pp. H-1 to H-27. Discusses problems of developing a program to determine if and when a mineral deposit can be economicaly exploited. The program will develop mathematical models to describe the varied character of mineral deposits, permit measurement of the level and projected growth of technology unique to exploiting deposits, and permit a determination of the present and projected feasibility of economic production from mineral deposits investigated.

OP 5-65. Determining Surface Areas From CO_2 Isotherms, by R. B. Anderson, James Bayer, and L. J. E. Hofer. Fuel, v. 44, No. 6, November 1965, pp. 443-452. Adsorption isotherms for CO_2 at $-78°$ C have been determined on porous inorganic solids, charcoal, carbon blacks, and a representative group of coals. On coal, CO_2 adsorbs slowly but in large quantities at $-78°$ C. Surface areas varying from 174 to 455 m^2/g were obtained from CO_2 isotherms for a representative group of coals of different ranks compared with values of 1 to 10 m^2/g from N_2 isotherms at $-195°$ C. Areas from CO_2 isotherms are of the same magnitude as those determined from methanol adsorption.

OP 6-65. Linear Solutions of Fick's Law, by R. B. Anderson, James Bayer, and L. J. E. Hofer. I&EC Process Design and Development, v. 4, No. 2, April 1965, pp. 167-171. Linear forms of solutions of Fick's law are applied to the rate of adsorption of methane on coal.

OP 7-65. Activation Energy for Diffusion-Controlled Adsorption Processes (letter to the editor), by R. B. Anderson and L. J. E. Hofer. Fuel, v. 44, No. 4, July 1965, pp. 303-306. Activation energies calculated from the temperature dependence of the quantity D/a, where D is the diffusivity and a is the constant of an adsorption equation, are larger than the corresponding values for D.

OP 8-65. Factors in Sulfur Poisoning of Iron Catalysts in Fischer-Tropsch Synthesis, by R. B. Anderson, F. S. Karn, and J. F. Shultz. J. Catalysis, v. 4, No. 1, February 1965, pp. 56-63. The poisoning of iron catalysts by sulfur compounds was found to be decreased by the potassium oxide present and by decrease in particle size from 6- to 8-mesh to 28- to 32-mesh.

OP 9-65. Radioactive Tracers in Miscible-Phase Petroleum Production Operations, by F. E. Armstrong, W. D. Howell, and Gordon E. Fletcher. U.S. Atomic Energy Commission, Division of Isotopes Development, TID-21199, 1964, 31 pp. An investigation was made to determine the utility of radioisotopes as tracers in the development of miscible-phase methods of petroleum recovery. Tritium was used in two field experiments to trace the flow of gasoline, of isopropanol, and of water. In both field experiments, which are still in progress as of this date, considerable useful data were obtained. No major problems were encountered, although the synthesis and handling of large quantities of tagged hydrocarbons required special precautions to avoid contamination. Use of radioactive tracers, in particular tritium compounds, affords an opportunity to obtain otherwise unavailable data concerning the performance and efficiency of miscible-phase petroleum recovery mechanisms.

OP 10-65. Subsurface Fracturing From a Nuclear Detonation in Granite, by Charles H. Atkinson. U.S. Atomic Energy Commission, Plowshare Program Rept. PNE-3001. 30 pp. 5 figs. A fracture-evaluation experiment in conjunction with the Shoal nuclear detonation in granite was undertaken to determine the extent of subsurface shock-induced fractures. Preshot and postshot geophysical logs in a hole drilled from the surface through the zone of fractures indicated that fractures extended at least 5.3 concave radii laterally from the point of detonation. Quantitative measurements of permeability increases resulting from the detonation were planned, but were not completed because of adverse test-hole conditions. General descriptions of the Shoal project, geology of the test site, and other effects of the detonation are included.

OP 11-65. Crude Oil Analysis as a Guide to Asphalt Potential, by John S. Ball. Ch. 3 in Bituminous Materials. Asphalts, Tars, and Pitches, ed. by A. J. Hoiberg. Interscience Publishers, New York, v. 2, Part 1, 1965, pp. 59-79. The use of Bureau of Mines crude oil analyses in estimating the amount and quantity of asphalt which can be recovered from the crude oil is described.

OP 12-65. Analytical Expressions for the Zero Pressure Thermodynamic Properties of Nitrogen Gas Including Corrections for the Latest Values of the Atomic Constants and the New Carbon-12 Atomic Weight Scale, by Robert E. Barieau. J. Phys. Chem., v. 69, No. 2, February 1965, pp. 495-499. The values of the zero pressure thermodynamic properties of nitrogen calculated by Goff and Gratch may be represented from 100° to 1,000° R (55° to 550° K) by relatively simple equations. These equations include corrections for the latest values of the atomic constants and also for the new carbon-12 atomic-weight scale. Equations are also given for these properties expressed in Btu/lb mole ° R as a function of degrees Rankine and in joules/g mole ° K as a function of degrees Kelvin.

OP 12A-65. Résumé of Roof Control, by Anthony J. Barry. Safety Newsletter, Coal Mining Sec., August 1965, pp. 2-3. Summarizes the activities of the Roof Control Research Group and discusses current and future research projects.

OP 13-65. Roof Controls in Underground Quarrying, by Anthony J. Barry. Trans. Nat. Safety Cong., v. 4. 1965, pp. 37-43. Describes current roof-control methods employed in representative underground quarries and suggests applications of methods and techniques that may contribute to the prevention of roof-fall accidents.

OP 14-65. Preparation of Biodegradable Synthetic Detergents From Low-Temperature Lignite Tar, by John S. Berber, Robert V. Rahfuse, and Howard W. Wainwright. I&EC Product Res. and Development, v. 4, No. 4, December 1965, pp. 242-247. Alkylbenzene sulfonate detergents were prepared from the olefins in low-temperature lignite tar. These tested for essentially 100 percent biodegradability.

OP 15-65. Evaluation of Dry Processes for Removing Sulfur Dioxide From Power Plant Flue Gases, by D. Bienstock, J. H. Field, S. Katell, and K. D. Plants. J. Air Pollution Control Assoc., v. 15, No. 10, October 1965, pp. 459-464. Recent developments in SO_2 removal from combustion gases by dry techniques in this country and abroad are reviewed. Process flowsheets, operating conditions, byproduct yields, and relative costs of a purification system for an 800-megawatt powerplant are discussed.

OP 16-65. Iron Phyllosilicates of the Cuyuna District in Minnesota, by Rolland L. Blake. Am. Mineral., v. 50, January-February 1965, pp. 148-169. Petrographic examination of 96 thin sections of least oxidized, silicate-rich samples of the thin-bedded facies of the Trommald iron formation in the Cuyuna district showed the following minerals in order of decreasing abundance: Mn-Mg-siderite, stilpnomelane, minnesotaite, magnetite, quartz, two unidentified iron silicates, goethite, hematite, pyrite, amphibole, and arsenopyrite. Three samples of stilpnomelane and one of minnesotaite were subjected to chemical, optical, spectrographic, X-ray diffraction, and differential thermal analysis.

OP 17-65. Use of Sodium To Remove Anthracene and Other Impurities From Phenanthrene, by Bernard D. Blaustein and Sol J. Metlin. Anal. Chem., v. 37, No. 2, February 1965, pp. 295-296. As recovered from tar, phenanthrene contains anthracene, carbazole, fluorene, and dibenzothiophene. Treatment with molten sodium reduces all these impurities to extremely low levels. The phenanthrene is recovered by vacuum distillation.

OP 18-65. Pitfalls Determining 2V in Micas, by F. Donald Bloss. Am. Mineral., v. 50, Nos. 5-6, June 1965, pp. 789-792. Accurate determinations have shown that, at least for the synthetic fluormicas, the reported values for the optic axial angle $2V$ were seriously in error and low. A single crystal must be used—not one interlayered or twinned. The higher order isochromes in the interference figure should be examined for offsets. Single crystals are characterized by the absence of offsets occurring as the isochromes pass across the isogyres at 45° off extinction. The postulation is made that some values of $2V$ for natural micas may also be erroneous.

OP 19-65. Elimination of Container Effects in Activation Analysis of Oxygen, by K. G. Broadhead and H. H. Heady. Anal. Chem., v. 37, No. 6, May 1965, pp. 759-760. Presents a technique for improving the fast neutron activation analysis of oxygen in metals. The activated sample is removed from its container just prior to counting to eliminate the problem of high background due to the container. Oxygen can thereby be determined at the 10 ppm level with an accuracy of ± 50 percent.

OP 20-65. 14-MeV-Neutron Production of Isomeric States for Several Rare-Earth Elements, by K. G. Broadhead, D. E. Shanks, and H. H. Heady. Phys. Rev., v. 139, No. 6B, Sept. 20, 1965, pp. B1525-B1528. Fast-neutron cross sections have been determined for the following reactions, using 14-MeV neutrons from the $H^3(d,n)He^4$ reaction: $Y^{89}(n,n'\gamma)Y^{89m}$, 400 mb; $Nd^{142}(n,2n)Nd^{141m}$, 545 mb; $SM^{144}(n,2n)Sm^{143m}$, 400 mb; $Tb^{159}(n,2n)Tb^{158m}$, 160mb; $Er^{168}(n,2n)Er^{167m}$, 190 mb. Possible sources of error affecting the cross-section measurements have been discussed and evaluated numerically. The overall accuracy was determined to be about ±12 percent.

OP 21-65. Electron-Probe Microanalysis of the Odessa Iron Meteorite, by James D. Brown and Michael E. Lipschutz. Icarus, v. 4, No. 4, September 1965, pp. 436-441. Recently, studies of phase transformation and alteration during the reheating of iron meteorites were performed on samples of the Canyon Diablo and Odessa meteorites. This report describes results of quantitative analyses of major and minor phases of two specimens of the Odessa iron meteorite made with Bureau of Mines modified electron-probe microanalyzer, using as standards pure metals and previously analyzed schreibersite. These analyses provide additional data for the above studies.

OP 22-65. Flotation of Spodume-Beryl Ores, by James S. Browning. Min. Eng., v. 13, No. 7, July 1961, pp. 706-708. Describes methods for separating spodume and beryl ores by flotation.

OP 23-65. National Report: United States of America, by Bureau of Mines Staff. Proc. 4th Internat. Conf. on Strata Control and Rock Mechanics, Columbia University, New York, 1964, pp. 559-564. Presents a summary of Bureau of Mines efforts to overcome roof-control problems associated with the underground recovery of minerals.

OP 24-65. Krypton 85 Tracer Aids Evaluation of Underground Combustion Oil-Recovery Tests, by Edward L. Burwell and William D. Howell. Producers Monthly, v. 29, No. 1, January 1965, pp. 21-23. Gas tracer tests using radioactive krypton 85 were performed in undeground combustion oil-recovery field experiments in Venango County, Pa. The transit times of injected gas through the reservoir, permeability trends, and relative percent of gas production from pattern wells were determined. Information obtained from the radioactive tracer tests, supplemented by reservoir and production data, aided in the control and evaluation of the field experiments.

OP 25-65. Basic Minerals, by Gabriel F. Cazell. Chem. and Eng. News, v. 42, No. 46, Sept. 6, 1964, pp. 124-129. Presents forecast of refined minerals production for year 1964, based on actual data for the first quarter of the year and on a general forecast of industrial and business activity for the year as a whole.

OP 26-65. Book review, by Theodore Christos. "Gas Analysis by Chromatography," by P. C. Jeffery and P. J. Kipping. Anal. Chem., v. 27, No. 3, March 1965, pp. 77A-78A.

OP 27-65. Identification of Some Naturally Occurring Alkylthiophenes in Wilmington, Calif., Crude Oil by Use of a Series of Gas-Liquid Chromatography Stationary Phases, by H. J. Coleman, C. J. Thompson, R. L. Hopkins, and H. T. Rall. J. Chromatography, v. 20, No. 2, 1965, pp. 240-249. Describes in detail the systematic liquid-solid and gas-liquid chromatographic procedures used for the concentration and identification of eight alkylthiophenes in a Wilmington, Calif., crude oil distillate having a boiling range of 111° to 150° C; presents quantitative data for each of the identified thiophenes.

OP 28-65. Identification of Thiols in a Wasson, Texas, Crude Oil Distillate Boiling from 111° to 150° C, by H. J. Coleman, C. J. Thompson, R. L. Hopkins, and H. T. Rall. J. Chem. and Eng. Data, v. 10, No. 1, January 1965, pp. 80-84. Describes a systematic procedure for the concentration and identification of 35 individual thiols present in a Wasson, Texas, crude oil distillate boiling from 111° to 150° C. The procedures applied included distillation, alumina adsorption, chemical extraction, gas-liquid chromatography, microdesulfurization, and infrared spectroscopy. Many C_5 and C_6 thiols, not commercially available, were synthesized, and GLC retention times and infrared spectra of some of these are presented.

OP 29-65. Flame Spectrometric Determination of Lithium in Oilfield Waters, by A. Gene Collins. Internat. J. Air and Water Pollution, v. 9, No. 3, 1965, pp. 145-149. A flame spectrometric method was developed for the determination of trace quantities of lithium in oilfield waters. The intensity of the lithium emission increased when organic solvents were added to the sample. It is possible to determine less than 0.015 milligram per liter (mg/l) of lithium by this method, and after concentration of the sample by evaporation $10^{-2.1}$ mg/l can be determined. Application of this method aids in water pollution studies.

OP 30-65. Calcium Ion Measurements Provide Insights to Anionic Flotation, by A. F. Colombo, R. T. Sorensen, and D. W. Frommer. Trans. SME, June 1965, pp. 100-109. An analytical method has been developed and used in batch and continuous tests to provide initial insights into the effect of soluble calcium ion in anionic flotation of silica from iron ores.

OP 31-65. Preventing Mine Subsidence in Pennsylvania, by Joseph A. Corgan. Coal, v. 19, No. 5, May 1965, pp. 7-11. Deals with a successful cooperative project in overcoming hazards from mine subsidence in an area in Wilkes-Barre, Pa., with a surficial area of 58 acres. Gives details of methods used and costs.

OP 32-65. Tetramethyllead: Far Infrared Spectra, Molecular Vibrations, and Chemical Thermodynamic Properties. Resolution of an Entropy Discrepancy, by G. A. Crowder, G. Gorin, F. H. Kruse, and D. W. Scott. J. Molecular Spectroscopy, v. 16, No. 1, May 1965, pp. 115-121. Far infrared spectroscopy and a normal-coordinate analysis for tetramethyllead yielded the first vibrational assignment consistent with the observed entropy of the vapor. A table of the chemical thermodynamic properties was prepared.

OP 33-65. Liquid-Vapor Frequency Shifts and Torsional Frequencies in Far Infrared Spectra, by G. A. Crowder and D. W. Scott. J. Molecular Spectroscopy, v. 16, No. 1, May 1965, pp. 122-129. Shifts of low frequencies between liquid and vapor states and frequencies for hindered internal rotation were observed far a variety of compounds.

OP 34-65. Blasting Agents: History, Hazards, and Protection, by Glenn H. Damon. Fire J., v. 59, No. 2, March 1965, pp. 52-57. Prevention of fire is the most important safety factor in handling ammonium nitrate-base blasting agents. In this article the most pertinent Bureau of Mines recommendations are discussed in detail.

OP 35-65. Effect of Retorting Temperature on the Composition of Shale Oil, by G. U. Dineen. Chem. Eng. Progress Symp. Ser., v. 61, No. 54, pp. 42-47. Shale oils were produced by entrained-solids retorting at 1,000°, 1,200°, 1,400°, and 1,600° F. The higher temperature oils contain more naphtha and are more aromatic than the 1,000 F° oil. Higher retorting temperatures favor the production of parent ring compounds to the extent that about a dozen compounds comprise over half the 1,600° F oil.

OP 36-65. Pressure Measurements in the 0.01-03 Torr Range With an Inclined-Piston Gauge, by D. R. Douslin and A. Osborn. J. Sci. Instr., v. 42, June 1965, pp. 369-373. An inclined-piston pressure gage is described that will supply a long-standing need in thermochemical research for accurate vapor-pressure determinations in the low and intermediate pressure range.

OP 37-65. Field Performance of a Pilot Waterflood—A Progress Report, by J. R. Duda and Harry R. Johnson. Producers Monthly, v. 29, No. 12, December 1965, pp. 8-10. Reports on the results of a pilot waterflood begun in January 1963. An assumed gas saturation of 20 percent now appears to have been too high; field data indicate an initial average gas saturation of about 15 percent. Field performance indicates the pilot waterflood in the Kane sand should produce 37,000 to 42,000 barrels of oil with the injection of 300,000 barrels of water into the pattern. Ultimate oil recovery may be as much as 50,000 to 55,000 barrels.

OP 38-65. The Effect of Anisotropy on the Determination of Dynamic Elastic Constants of Rock, by W. L. Duvall. Trans. SME, December 1965, pp. 309-316.

Equations commonly used to obtain elastic constants of rock samples can result in appreciable error if the rock is even slightly anisotropic. Consideration of the equations that relate bar velocities and free medium velocities to elastic constants for orthotropic, transversely isotropic, and isotropic solids shows that a combination of the two methods can be used to determine average elastic constants for a single sample of rock. Determination of elastic constants in different directions requires a large number of tests on oriented samples. Use of both resonant frequency and ultrasonic pulse methods is recommended so that determination of both Young's modulus and modulus of rigidity is independent of the determination of Poisson's ratio.

OP 39-65. Seismic Energy Available From Rockbursts and Underground Explosions, by W. I. Duvall and D. E. Stephenson. Trans. SME, September 1965, pp. 235-240. Gives a theoretical solution for the energy that is radiated outward when either a cylindrical or spherical cavity located underground in a uniform stress field is suddenly created or enlarged. The method of derivation shows that the stress field in the solid rock surrounding the opening does work on the rock because of elastic displacements that result when the size of the cavity is increased. The amount of this work is sufficient to account for both the increase in the strain energy in the rock surrounding the opening and the seismic energy that radiates outward. Thus, the source of the radiant seismic energy is mainly the gravitational potential energy and not the strain energy stored in the rock. The amount of the radiant seismic energy is directly proportional to the volume of rock removed from the opening or relieved of stress. Seismic energies from rockbursts are compared with earthquake energies.

OP 40-65. A Small Angle X-Ray Scattering Study of the Colloidal Nature of Petroleum, by C. W. Dwiggins, Jr. J. Phys. Chem., v. 69, No. 10, October 1965, pp. 3500-3506. Petroleum colloids were investigated using small angle X-ray scattering. Radii of gyration were obtained for several crude oils, for crude oils diluted with solvents, and for a crude oil at different temperatures. Additional parameters were obtained for two oils. In general, the colloids of petroleum can have different average radii of gyration and probably exhibit some polydispersity. No large temperature effect was detected. However, the colloid size can be changed greatly by some added solvents, while other solvents produce little or no change in colloid size.

OP 41-65. Estimation of Well Capacities and Gas Reserves, by J. L. Eakin, R. V. Smith, and J. S. Miller. Ch. 4 of sec. 4, Production, Gathering, and Conditioning of Natural Gas. Gas Engineers Handbook, Fuel Gas Engineering Practices. American Gas Association. The Industrial Press, New York, 1965, pp. 28-47. Describes methods of estimating well capacities using back-pressure testing of natural gas wells and gives examples of application of the methods; discusses methods of estimating nonassociated, associated, and dissolved gas reserves.

OP 42-65. Integration of Partial Differential Equation for Transient Radial Flow of Gas-Condensate Fluids in Porous Structures, by C. K. Eilerts, E. F. Sumner, and N. L. Potts. Soc. Petrol. Eng. J., v. 5, No. 2, June 1965, pp. 141-152. The second-order, nonlinear, partial-differential equation representing the transient radial flow of gas-condensate fluids in reservoirs has been integrated by using finite-difference equations and electronic computers. Effect was given to pressure-dependent permeability, viscosity, and compressibility and to distance-dependent permeability. The influence of a second-degree velocity term in the Darcy equation was investigated. Implicit methods were used and practical, convergent solutions were obtained with material balance to less than 6×10^{-4} for recovery of one-half the reserve at constant flow rate. Integration results provide the productive period of a reservoir for a given constant rate and the fraction of the fluid initially in place that can be recovered in that period.

OP 43-65. Identification of Some Oxygenates in Automobile Exhausts by Combined Gas Liquid Chromatography and Infrared Techniques, by C. F. Ellis, R. F. Kendall, and B. H. Eccleston. Anal. Chem., v. 37, No. 4, April 1965, pp. 511-516. Sodium bisulfite scrubber solutions of oxygenates from automobile exhaust yield gas liquid chromatography (GLC) chromatograms at 90° C. The individual oxygenates were collected for infrared confirmation.

OP 44-65. Countercurrent Distribution of High-Boiling Neutral Oils From Low-Temperature Coal Tar, by Patricia A. Estep, Clarence Karr, Jr., William C. Warner, and Edward E. Childers. Anal. Chem., v. 37, No. 13, December 1965, pp. 1715-1720. High-boiling neutral oils from a low-temperature coal tar were analyzed by countercurrent distribution and spectroscopy. About 50 compounds were identified and their amounts determined.

OP 45-65. Two Unique Wall and Roof-Scaling Machines, by Arthur M. Evans. Min. Cong. J., v. 51, No. 3, March 1965, pp. 66-68. Describes two unique machines that scale loose rock from roofs and walls of rooms up to 75 feet high without exposing miners to hazards of falling rock.

OP 46-65. Ore-Scrap Magnetic Roasting: A New Basis for the Beneficiation of Iron Ore, by M. M. Fine and N. B. Melcher. J. Metals, v. 16, No. 9, September 1965, pp. 709-714. A completely new concept in magnetic roasting of iron ore—the use of scrap iron as a reductant—has been validated in batch and continuous laboratory experiments demonstrating iron recoveries of well over 90 percent.

OP 47-65. 1-Pentanethiol: Heat of Vaporization and Heat Capacity of the Vapor, by Herman L. Finke, Isham A. Hossenlopp, and William T. Berg. J. Phys. Chem., v. 69, No. 9, September 1965, pp. 3030-3031. Reports results obtained from experimental determinations of the vapor heat capacity and heats of vaporization of 1-pentanethiol. Derived values of the second virial coefficient are tabulated.

OP 48-65. Thermodynamic Properties of *n*-Propyl, *n*-Butyl, and *n*-Decyl Substituted Cyclohexane From 10° to 370° K, by H. L. Finke, J. F. Messerly, and S. S. Todd. J. Phys. Chem., v. 69, No. 6, June 1965, pp. 2094-2101. Experimental measurements of low-temperature thermodynamic properties were used to calculate the thermodynamic functions for these alkyl-substituted cyclohexanes. Literature data was used to extend entropies to the ideal gas state. Entropy increments per methylene group between *n*-butyl and *n*-decylcyclohexane were found to agree with previously studied homologous series.

OP 49-65. Procedures in Sampling and Handling Auto Exhaust, by D. R. Fleming, Basil Dimitriades, and R. W. Hurn. J. Air Pollution Control Assoc., v. 15, No. 8, August 1965, pp. 371-374. Sampling and handling techniques suitable for automotive exhaust produced both under steady state and cyclic engine operation are described and discussed. Advantages and limitations for each of the described techniques are discussed in detail.

OP 50-65. Catechols From the Carbonization of North Dakota Lignite, by Philip G. Freeman. Proc. North Dakota Acad. Science, 1964, v. 18, pp. 104-108. The low-temperature carbonization products of North Dakota lignite are shown to contain amounts of catechol, 2-methyl catechol, and 4-methyl catechol which are economically significant.

OP 51-65. Visible Spectra of Thin Sections and Polynuclear Condensed Aromaticity of Pittsburgh Coal Vitrain, by R. A. Friedel. Nature, v. 201, No. 4921, Feb. 22, 1964, pp. 811-812. New data have been obtained for the visible spectra of ground thin sections of Pittsburgh vitrain. The discrepancy between data for microtome ultrathin sections and ground thin sections is somewhat greater than before. Absorbance data from microtome sections at 6400 A are greater than those from ground thin sections by factors as high as 7.8. The data establish limiting concentrations of large polynuclear aromaticities that absorb in the visible region of the spectrum. The magnitude of the effect of holes in this ground section has been studied quantitatively. Obvious holes produce errors, but only in a small region of the spectrum.

OP 52-65. Indenols in Coal Tars. The First Preparation of Indenol, by S. Friedman, M. L. Kaufman, B. D. Blaustein, R. E. Dean, and I. Wender. Tetrahedron, v. 21, pp. 485-490. Thermal (650° C) dehydrogenation of 4- and 5-indanols over chromia-alumina yields first synthesis of corresponding indenols. Indenols exist as double bond isomers, separable by gas chromatography.

OP 53-65. The Occurrence of Metastable Tetragonal Zirconia as a Crystallite Size Effect, by Ronald C. Garvie. J. Phys. Chem., v. 69, No. 4, April 1965, pp. 1238-1243. Active powders of metastable tetragonal ZrO_2 were prepared by precipitation and calcination. The existence of the metastable phase was correlated with the intrinsic properties of active powders: small crystallite size, large specific surface, and appreciable excess energy.

OP 55-65. The Decaking of Bituminous Coal, by Stanley J. Gasior, Albert J. Forney, and Joseph H. Field. Min. Eng., v. 17, No. 3, March 1965, pp. 74-78. Methods for decaking coal in fixed-bed and free-fall systems are described. The decaked coals can then be gasified efficiently.

OP 56-65. Our Ocean Environment, by Wendell Gayman. Society of Aerospace Material and Process Engineers, San Francisco, Calif., May 25-28, 1965, 19 pp. (preprints). Gives a brief description of the major environmental characteristics of the sea and enclosing ocean basins. Presents data on the more important physical and chemical properties of sea water and on the dynamics of surface layers. Concluding section briefly describes marine organisms and seafloor sediments. Stress is placed on the relation between physical and chemical parameters and the distribution of mineral and biological resources.

OP 57-65. Mineral Development in Mainland China During 1964, by Edgar J. Gealy and Anton W. T. Wei. Mining J., Ann. Review, 1965, pp. 248-250. Reports what is known of the mineral industry of mainland China in 1964.

OP 58-65. Air Pollutant Emissions From Coal-Fired Power Plants, Report No. 2, by R. W. Gerstle, S. T. Cuffe, A. A. Orning, and C. H. Schwartz. J. Air Pollution Control Assoc., v. 15, No. 2, February 1965, pp. 59-64. The Public Health Service and the Bureau of Mines are conducting a study to evaluate a number of flue-gas-stream components from coal-burning powerplants. Emissions of fly ash, sulfur oxides, nitrogen oxides, polynuclear hydrocarbons, total gaseous hydrocarbons, formaldehyde, certain metals, and carbon dioxides are determined. Includes a comparative evaluation of emissions from a tangential-fired and a turbo-fired powerplant boiler.

OP 59-65. Progress in the Application of Encapsulated Cells in a Coal Mine Subject to Coal Bursts, by James L. Gilley, Rudolph Sporcic, and Anthony Zona. Proc. 6th Symp. Rock Mechanics, University of Missouri at Rolla, October 1964, pp. 649-668. The Bureau of Mines has developed an encapsulated hydraulic cell for measuring pressure changes in coal in situ. Cooperative research and studies made in a coal mine in West Virginia have shown that the cell responds to pressure change. A brief description is given of the cell construction and operational technique. Data obtained during various stages of mining in an area of this mine subject to coal bursts are presented.

OP 60-65. Solvent Extraction and Spectrophotometric Determination of Nickel in High Purity Tungsten or Tungsten Trioxide, by Thomas E. Green. Anal. Chem., v. 37, No. 12, November 1965, pp. 1595-1596. A spectrophotometric method for determining nickel was developed in which tungsten metal samples were dissolved in hydrofluoric and nitric acids, the sample solutions are then evaporated to dryness, and the resulting tungsten trioxide is dissolved in sodium hydroxide. The method is therefore suitable for determining nickel in any physical form of tungsten metal and for determining nickel in tungsten trioxide.

OP 61-65. A Determination of the Maximum Principal Stress Direction Trhough an Analsis of In Situ Failure of Anisotropic Heterogeneous Rock, by E. W. Gresseth. Proc. 6th Symp. Rock Mechanics, University of Missouri at Rolla, October 1964, pp. 1-22. In situ occurrences of planar discontinuities on the 5900, 6100, and 6300 levels of the Star mine, Burke, Idaho, were analyzed according to their orientations, type of rupture (tensional or shear), and relative displacements. Equal area projections were used to group and classify the joint and fracture systems, and the directions of the principal stress axes were determined.

OP 62-65. Suggested Mechanism for Initiating Pressure Oscillations in Rocket Motors (letter to the editor), by Joseph Grumer. Combustion and Flame, v. 9, No. 1, March 1965, pp. 105. Discusses occurrence of pressure oscillations observed while studying the burning velocities of gases at elevated pressures.

OP 63-65. Uncontrolled Fires—Specific Burning Rates and Induced Air Velocities, by Joseph Grumer and Alexander Strasser. Fire Technol., v. 1, No. 4, November 1965, pp. 256-268. Laboratory experiments were conducted to demonstrate that a large fire area will, by virtue of its size alone, induce winds which accelerate specific burning rates into those observed in fire storms. Although the presumed correlations were not borne out by the test results, several interesting observations were made.

OP 64-65. **Oily Fibers May Increase Oxygen Tent Fire Hazard,** by Paul G. Guest. Modern Hospital, May 1965, 2 pp. Tests were made on clean and grease-contaminated tufts of textile fibers, using deliberately generated sparks in oxygen or oxygen-enriched air.

OP 65-65. **Oxygen and Oxygen Compounds,** by W. E. Haines. Anal. Chem., v. 37, No. 5, April 1965, pp. 162R-164R. Reviews the literature on oxygen and oxygen compounds published during 1963-64.

OP 66-65. **Detonability of Nitroglycerin Contained in Porous Rock,** by J. Edmund Hay and Fred H. Scott. Nature, v. 208, No. 5016, p. 1197. Reports the discovery that nitroglycerin-ethylene glycol dinitrate can be detonated when absorbed in porous sandstone in concentrations as low as 8 weight-percent. The destination velocity is higher than that which would be expected from other experience.

OP 67-65. **Variations in Permeability and Porosity of Synthetic Oil Reservoir Rock—Methods of Control,** by Larman J. Heath. SPE J., v. 5, No. 4, December 1965, pp. 329-332. Synthetic oil-reservoir rock having predictable porosity and permeability has been prepared. Variations in porosity and permeability were caused by varying the amount of blending water. Drainage-cycle relative permeability characteristics of the synthetic rock were similar to those of natural reservoir rock.

OP 68-65. **Preparation and Properties of Ultrafine High-Purity Alumina,** by Jack L. Henry and Hal J. Kelly. J. Am. Ceramic Soc., v. 48, No. 4, April 1965, pp. 217-218. Describes preparation of high-purity alumina of extremely small particle size by decomposition of ammonium alum.

OP 69-65. **The Ocean: Mining's Newest Frontier,** by H. D. Hess. Eng. and Min. J., v. 166, No. 8, August 1965, pp. 79-96. Fourth in a series of undersea mining, inventories ocean mineral resources and discusses plant and operating costs for offshore and undersea mining.

OP 70-65. **Fluidized Feeder Regulates Flow of Powders at Low Rates,** by W. R. Huff. Chem. Eng., v. 72, No. 16, Aug. 2, 1965, pp. 132-133. Describes a small fluidized feeder that can continuously inject 10 pounds per hour of powdered peat, coal, or coke into an experimental unit.

OP 71-65. **Density of Bulk Chrysotile and Massive Serpentine,** by Charles W. Huggins and H. R. Shell. Am. Mineral., v. 50, Nos. 7-8, August 1965, pp. 1058-1067. Density measurements were made on 23 bulk specimens of chrysotile and 7 massive serpentine samples. Arizona chrysotile had densities of 2.19 to 2.22 grams per cubic centimeter, whereas the Canadian had values that varied from 2.34 to 2.39 g/cm^3. Density of Arizona massive serpentine range from 2.40 to 2.44 g/cm^3. The theoretical density of chrysotile was calculated to be 2.19 g/cm^3, using published data for single-fiber measurements.

OP 72-65. **Collecting Representative Exhaust Gas Samples,** by R. W. Hurn, J. O. Chase, and R. D. Fleming. Instrument Society of America—Analysis Instrumentation—1964. Proc. 10th National Symp., June 1964. Plenum Press, New York, 1964, pp. 279-285. Automobiles operated in typical city traffic patterns discharge combustion products in erratic, highly variable fashion. Discharge rate, temperature, and composition may vary widely over time intervals less than 1 minute. The composite of such emissions is best described by information from a single sample, but collection of a representative sample from the highly variant stream requires specialized procedures. Two such procedures, one employing a servocontrol system and one employing dynamic dilution of the exhaust gas, have been used with success.

OP 73-65. **Improved Dilatometer,** by Garrett R. Hyde, Louis P. Domingues, and LeRoy R. Furlong. Rev. Sci. Instr., v. 36, No. 2, February 1965, pp. 204-205. Describes improvements in the differential-transformer-type of dilatometer.

OP 74-65. **Magnesium Damping Capacity—Causes and Effects,** by James W. Jensen. Metalscope, May 1965, pp. 7-10. A general discussion of vibration damping capacity is followed by data on the damping properties of commercial alloys. A method of assigning a useful "damping index" is described. The bulk of the data has been printed on a translucent insert for reproduction of extra copies.

OP 75-65. **Use of Coal and Fly Ash as Adsorbents for Removing Organic Contaminants From Secondary Municipal Effluents,** by Glenn E. Johnson, Louis M. Kunka, and Joseph H. Field. I&EC Process Design and Development, v. 4, No. 3, July 1965, pp. 323-327. Coals and fly ashes were tested to determine their effectiveness in removing organic contaminants from the final effluent of secondary-treated waste waters. The adsorptive capacity of fly ashes, coals of various ranks, and pretreated coals was determined and compared with activated carbon. The coals, though less active than carbon, are relatively inexpensive and can still be burned as fuel after use in waste-water treatment. Illinois No. 2 seam coal (hvcb) adsorbed about 4 percent of its weight of materials that consume oxygen (COD) in repetitive contacts with fresh sewage; activated carbon adsorbed about 10 percent of its weight COD at the same test conditions. A fly ash removed 66 percent of the COD and 76 percent of the synthetic detergents (ABS) present in a single contact period. The effectiveness of fly ash as an adsorbent improves with increasing carbon content.

OP 76-65. **Relationships of Oil Composition and Stratigraphy in the Permian Basin of West Texas and New Mexico,** by Theodore S. Jones and Harold M. Smith. Ch. in Fluids in Subsurface Environments—A Symposium, Memoir No. 4, American Association of Petroleum Geologists, 1965, pp. 101-224. The composition of crude oils, using especially the aromatic and naphthene content of the naphtha, was correlated with producing formations from Cambrian to Cretaceous.

OP 77-65. **Hydrogenation of Carbon Monoxide and Carbon Dioxide on Supported Ruthenium Catalysts at Moderate Pressures,** by F. S. Karn, J. F. Shultz, and R. B. Anderson. I&EC Product Research and Development, v. 4, No. 4, December 1965, pp. 265-269. Catalysts containing 0.5 percent ruthenium on high surface alumina are very active in hydrocarbon synthesis yielding 140 grams per cubic meter of synthesis gas.

OP 78-65. **Measuring Thermal Effects in Catalytic Reactions,** by F. S. Karn, J. F. Shultz, and R. B. Anderson. I&EC Process Design and Development, v. 4, No. 3, July 1965, pp. 266-270. A catalyst configuration has been devised for measuring catalyst temperatures in the hydrogenation of carbon monoxide on iron and nickel catalysts. The catalyst, promoted fused iron or Raney nickel, as a powder, was sprayed on the cylindrical surfaces of cylinders of copper or aluminum. Each cylinder contained a thermocouple well, and temperature differences between the central well and the Dowtherm bath were determined at corresponding positions along the length of the reactor. Data from several iron and nickel catalysts were plotted and could be represented by a single straight line, the slope of which corresponds to an overall heat-transfer coefficient of 4.79×10^{-3} cal sec^{-1} cm^{-2} ° C^{-1}. Activation energies for the synthesis on iron were determined using the observed temperature profiles and the first-order empirical rate equation that has been shown to represent the kinetics in tests where overheating is not important. An activation of 28 kcal per mole was obtained.

OP 79-65. The Analysis of Straight-Chain Aliphatics by Urea Partition Chromatography and Gas-Solid Chromatography, by Clarence Karr, Jr., and Joseph R. Comberiati. J. Chromatography, May 1965, v. 18, No. 2, pp. 394-397. C_{15} through C_{33} n-paraffins and α-olefins from a low-temperature coal tar have been analyzed by a combination of urea adduction in a highly efficient liquid-liquid partition chromatography process followed by gas-solid chromatography on alumina-coated capillary columns operated up to 400° C.

OP 80-65. Structure Determinations of Pitch Resins by Catalytic Dehydrogenation, by Clarence Karr, Jr., Kenneth B. McCaskill, and John J. Kovach. Fuel, v. 44, No. 6, November 1965, pp. 437-441. A structure determination of the benzene-soluble, ethyl ether-insoluble pitch resin from a low-temperature bituminous coal tar was made by catalytic dehydrogenation in four different pure solvents and by examination of the infrared and ultraviolet spectra of the dehydrogenates. Some of the structural features indicated for the original resin were alcoholic OH groups and naphthenic rings.

OP 81-65. Effects of Ultrasonics on Brass Plating, by Charles B. Kenahan and David Schlain. Electroplaters Soc., 51st Ann. Tech. Proc., 1964, pp. 3-10. Application of ultrasonics at a frequency of 18.5 kilocycles per second and an average acoustic intensity of 0.5 watts per square centimeter to the electrodeposition of brass from a cyanide bath resulted in changes in composition of copper-zinc alloys; produced brighter, more adherent, and finer grained deposits with a marked degree of preferred crystal orientation; and increased the corrosion protection afforded by the brass plate. In addition, high-frequency sound increased anode and cathode current efficiencies and decreased cell voltage. The relationship of these effects to current density is discussed. Electrode potential measurements showed significant depolarization effects at both electrodes as a result of ultrasonic radiation, but the decrease in cell voltage resulted chiefly from depolarization at the anode. Ultrasonics increased the limiting current density of the bath and reduced the tendency for the anode to become passive.

OP 82-65. Acoustic Velocities in Oil Reservoir Formations From Laboratory and Field Measurements, by C. A. Komar and C. I. Pierce. Producers Monthly, v. 29, No. 2, February 1965, pp. 8-12. Compares formation matrix velocities derived from laboratory acoustic velocity measurements with those obtained from acoustic velocity logs. Resulting laboratory velocity logs compare favorably with field velocity logs considering the fact that no attempts were made to simulate reservoir stresses for the laboratory specimens of reservoir rock samples.

OP 83-65. U.S. Bureau of Mines Acid Mine Drainage Control Program and Joint Interior-HEW Departments Acid Mine Drainage Control Program, by Stephen Krickovic. Proc. Symp. on Acid Mine Drainage Research, Mellon Institute, Pittsburgh, Pa., 1965, pp. 111-126. Discusses the acid mine water problem and the methods used to control or ameliorate it and describes the joint Interior-HEW demonstration program.

OP 84-65. Hot Surface Ignition Temperatures of Hydrocarbon Fuel Vapor-Air Mixtures, by J. M. Kuchta, A. Bartkowiak, and M. G. Zabetakis. J. Chem. and Eng. Data, v. 10, No. 3, July 1965, pp. 282-288. Autoignition temperatures (AIT's) and "wire" ignition temperatures of various hydrocarbon combustibles were determined as a function of heat source dimensions using stagnant or near-stagnant combustible vapor-air mixtures. The combustibles included n-hexane, n-octane, n-decane, JP-6 jet fuel, and an adipate ester aircraft engine oil MIL-L-7808).

OP 85-65. Effect of Montmorillonite on the Permeability to Gas of Water-Sensitive Reservoir Rocks, by Carlon S. Land and Oren C. Baptist. J. Petrol. Techol., v. 17, No. 10, October 1965, pp. 1213-1218. Describes laboratory research on the effect of clay hydration on the permeability to gas of water-sensitive reservoir sandstones.

OP 86-65. Freeze-Dry Technique for Making Ultra-Fine Metal Powder, by A. Landsberg and T. T. Campbell. J. Metals, v. 17, No. 8, August 1965, pp. 856-860. Ultrafine particles can be made from soluble materials by freeze-drying their solutions. Reduction of homogeneous compounds can be used to produce homogeneous alloy powders of controlled composition.

OP 87-65. Tungsten and Molybdenum Coated Nonmetallic Powders, by A. Landsberg, T. T. Campbell, and F. E. Block. J. Metals, v. 17, No. 8, August 1965, pp. 850-855. Uniform coatings of tungsten or molybdenum can be applied to several types of ceramic powders having irregular shapes. Of two processes tested, the oxide process seems more favorable.

OP 88-65. Nitrogen and Nitrogen Compounds, by D. R. Latham and W. E. Haines. Anal. Chem., v. 37, No. 5, April 1965, pp. 161R-162R. Reviews the literature on nitrogen and nitrogen compounds published in 1963-64.

OP 89-65. Nonbasic Nitrogen Compounds in Petroleum, by D. R. Latham, I. Okuno, and W. E. Haines. Hydrocarbon Analysis. ASTM Spec. Tech. Pub. 389, 1965, pp. 385-398. Reviews the status of knowledge about the nonbasic nitrogen compounds in petroleum. Pyrroles, indoles, carbazoles, benzocarbazoles, phenazines, benzenitriles, and amides have been identified in petroleum or its fractions boiling above 400°F. Nonbasic nitrogen can be divided into four subtypes by titration of the crude oil with perchloric acid in acetic anhydride before and after reduction with lithium aluminum hydride. This method requires no prior separation or concentration of the nitrogen; it provides more detailed information than previous methods.

OP 90-65. Variation of X-Ray Spectral Line Position With Ambient-Temperature Change: A Source of Error in X-Ray Spectrography, by Frederick S. Lee and William J. Campbell. Advances in X-Ray Analysis. Plenum Press, New York, v. 8, August 1965, pp. 431-442. The effect of temperature change on lithium fluoride, ammonium dihydrogen phosphate, and ethylenediamine-*d*-tartrate analyzing crystals was studied by measuring the change in intensity of a selected X-ray spectral line while maintaining a constant 2θ position on the spectrometer. A change in interplanar spacing due to thermal expansion and contraction satisfactorily account for experimentally observed line shifts for LiF and ADP. EDDT showed a large unexplained decrease in reflectivity with increasing ambient temperature. Intensity changes due to peak shift were tabulated for LiF, ADP, NaCl, silicon, germanium, quartz, calcite, fluorite, and topaz.

OP 91-65. Fracturing Oil Shales With Nuclear Explosives for In-Situ Retorting, by M. A. Lekas and H. C. Capenter. Colorado Sch. Mines Quart., v. 60, No. 3, July 1965, pp. 7-30. Reexamination of the technical and economic feasibility of fracturing oil shales with nuclear explosives preparatory to an in situ combustion-extraction process in the light of current developments indicates that the technique appears more attractive today than when it was first investigated in 1960 by the U.S. Atomic Energy Commission and the Bureau of Mines. An underground nuclear explosion creates a cylinder of extremely permeable fragmented and displaced rock, surrounded by a much larger volume of fractured rock of lesser permeability. Costs of breaking oil shale with nuclear explosives on a large scale are estimated at a few cents per ton. Recovery is estimated at 50 percent of the in-place oil. A commercial-scale operation could produce shale oil at a rate of 100,000 barrels per day at a cost of less than $1.50 per barrel. It is estimated that in the Piceance Creek basin those shales of a thickness and grade amenable to the nuclear technique contain a recoverable reserve of about 150 billion barrels.

OP 92-65. Coefficients of Thermal Linear Expansion of Fused Hafnium Carbide-Carbon Alloys, by R. Lincoln, M. Copeland, and H. Kato. U.S. Atomic Energy Commission, Topical Rept. USBM-RC-1119, 18 pp. 5 figs. Purpose of the study was to determine the thermal linear expansion coefficients of ingots of arc-melted and cast hafnium carbide and also of ingots of hafnium containing free graphite, and to compare the value with those given in the literature for the power-metallurgy product of hafnium carbide.

OP 93-65. Flame Arresters, by Elton L. Litchfield. In Electrical Safety Practices. Instrument Society of America, ISA Monograph 110, 1965, pp. 75-84. Discusses fundamentals of flame arresters. Two situations are considered, one in which the arrester has only to extinguish flame front and one where hot gases are expelled through the arrester, creating a reignition problem even though the arrester quenches the initial flame front. In the first case, Palmer's formulation of the physical picture and its agreement with experimental data are considered. In the second case, the hot gas reignition problem and the work of Wolfhard and Vanpée are discussed.

OP 94-65. Thermodynamics of Ions: Consistent Standard States for Enthalpies and Free Enthalpies, by Philip B. Lorenz and Albert Sprague Coolidge. J. Electrochem. Soc., v. 112, No. 10, October 1965, pp. 1041-1043. The requirements for accurate thermodynamic treatment of electrochemical processes are outlined and the several possible basic standards are discussed.

OP 95-65. Detonability of the System Nitrobenzene, Nitric Acid, and Water, by Charles M. Mason, Robert W. Van Dolah, and John Ribovich. J. Chem. Eng. Data, v. 10, No. 2, April 1965, pp. 173-175. The limits of detonability in 1-inch-diameter charges of the system nitrobenzene-nitric acid-water at 25° and 80° C were determined. Limited shock-sensitivity measurements were made using the card-gap technique. In general, the limit of detonability of the nitrobenzene system coincided with the region of complete miscibility in the ternary diagram.

OP 96-65. Electron Microscopy of Graphitic Crystallites in Meta-anthracite, by J. T. McCartney and S. Ergun. Nature, v. 205, No. 4975, Mar. 6, 1965, pp. 962-964. Discusses electron microscopy observations of an apparent vitrain band in a meta-anthracite from Leoben, Austria, that showed evidence of the development of three-dimensional graphite crystallinity in meta-anthracite and the ordering of the crystallites in layer planes parallel to the bedding.

OP 97-65. Optical Constants of Coal by Reflectance Measurements in the Ultra-violet and Visible Spectrum, by J. T. McCartney, J. B. Yasinsky, and E. Ergun. Fuel, v. 44, September 1965, pp. 349-354. Reflectance measurements were made on vitrinites from American coals, ranging in rank from lignite to antracite, in the ultraviolet and visible spectrum, utilizing a reflecting microscope equipped with quartz optics. The reflectance of vertically incident monochromatic light in air and water was determined with reference to a sapphire crystal. Refractive indexes, extinction coefficients, dielectric constants, and electrical conductivities were calculated from the Fresnel and Lorentz equations. The rate of change in refractive index with wavelength is largest in the ultraviolet and greater for higher rank coal. The extinction coefficients have maximums in the ultraviolet which are generally more pronounced with higher rank. The maximum for anthracite is in the visible range. Spectral variations in dielectric constants generally correspond to those of refractive index, and variations in conductivity to those of extinction coefficient.

OP 98-65. A New Potential Scrap Market—Reduction Roasting of Iron Ore, by Norwood B. Melcher. Scrap Age. February 1965, pp. 41-42; Waste Trade J. Feb. 27, 1965, pp. 61-62, 67. Discusses reduction roasting tests made with a mixture of nonmagnetic taconite and iron scrap.

OP 99-65. Degasification of Coal Mines, by William M. Merritts. Proc. 54th Convention of Mine Inspector's Inst. of America, Richmond, June 15-17, 1964, 1965, pp. 57-66. Degasification (methane drainage) tests were conducted in mines operating in the Pittsburgh and Pocahontas No. 4 coalbeds. Three basic techniques were used: (1) Drilling long horizontal holes and vertical boreholes into the coalbed in advance of mining to permit natural drainage of methane from the coal; (2) water infusion to force methane out of the coalbed; and (3) vacuum pumping of the holes drilled into the coalbed. Large quantities of methane could be drained from the coalbed through holes drilled into the coal. Infusing the holes with water further increased the amount of gas liberated from the coalbed. Water infusion had no adverse effects in the roof and floor conditions; the use of wetting agents with the infusion water appeared to reduce the amount of dust produced.

OP 100-65. Low-Temperature Thermodynamic Properties of n-Propyl, n-Butyl, and n-Decyl Substituted Cyclopentane, by J. F. Messerly, S. S. Todd, and H. L. Finke. J. Phys. Chem., v. 69, No. 2, February 1965, pp. 353-358. The heat capacities in the range 12° to 370° K, heats of fusion, triple points, and purity of n-propylcyclopentane, n-butylcyclopentane, and n-decylclopentane were measured in an adiabatic calorimeter.

OP 101-65. Low-Temperature Thermodynamic Properties of n-Propyl and n-Butylbenzene, by John F. Messerly, Samuel S. Todd, and Herman L. Finke. J. Phys. Chem., v. 69, No. 12, December 1965, pp. 4304-4311. Heat capacities from 12° to 370° K, heats of fusion, triple points, and purities of n-propylbenzene and n-butylbenzene were measured in an adiabatic calorimeter.

OP 102-65. Neutron Logs Prove Results of Water-Block Treatment, by J. S. Miller and J. L. Eakin. Oil and Gas J., v. 63, No. 5, Feb. 1, 1965, pp. 81-83. Identification of liquid-saturated gas zones and evaluation of posttreatment changes in liquid saturation are possible through neutron logging. A field test showed a 52-percent increase in gas production after water-block treatment, and the neutron log indicated a 50-percent drop in the gas zone's water saturation.

OP 103-65. Sulfur and Sulfur Compounds, by J. C. Morris and W. E. Haines. Anal. Chem., Ann. Rev., v. 37, No. 5, April 1965, pp. 160R-161R. Reviews the literature on sulfur and sulfur compounds published during 1963-64.

OP 104-65. The Energy Dilemma—Which Fuel, What Market, When? by Warren E. Morrison. SME Fall Meeting, Rocky Mountains Mineral Conference, Phoenix, Ariz., Oct. 7-9, 1965, preprint 65K302, 26 pp. Attempts to forecast the future energy economy in terms of inputs of resources and their derivatives into the major energy markets. Separate forecasts are presented for the years 1965, 1970, 1975, and 1980. The forecasts consist of energy balances derived from forward projections of the components of a series of historical balances. Predictions are made of the future demand for specific resources and levels of domestic supply and foreign trade required to meet this demand under the assumptions made for the study.

OP 105-65. Boiler Testing for Improved Economics, by Zane E. Murphy. Combustion, v. 37, No. 3, September 1965, pp. 33-40. Discusses the integral factors needed to evaluate boiler efficiency and shows what and where heat losses in boiler operation can occur.

OP 106-65. Bureau of Mines Progress in Developing the Coal-Burning Gas Turbine Power Plant, by W. M. Nabors, D. C. Strimbeck, R. W. Cargill, and Jack Smith. J. Eng. Power, v. 87, ser. A, No. 2, April 1965, pp. 215-222. Summarizes work done through mid-1964 in developing the coal-burning gas turbine. Progress has been made in developing blades resistant to coal ash erosion, and certain modifications were made in the coal-combustion, ash-separation, and coal-feeding systems prior to a 1,000-hour test to be made in the summer and fall of 1964.

OP 107-65. Deformational Behavior of Model Pillars Made From Salt, Trona, and Potash Ore, by Leonard Obert. Proc. 6th Symp. Rock Mechanics, University of Missouri at Rolla, October 1964, pp. 539-549. Objectives of investigation were to develop a model pillar that is realistically related to its prototype in the mine and to study the strength and deformational behavior of model pillars made from salt, potash, and trona. Although field data are meager, there is a general agreement between model pillar and in situ pillar measurements.

OP 108-65. Stress Conditions Under Which Core Discing Occurs, by Leonard Obert and D. E. Stephenson. Trans. SME, September 1965, pp. 227-236. Objectives of this investigation were to develop a laboratory procedure in which core disking could be produced under known (and variable) stress conditions and to study the disking characteristics of several types of rock.

OP 109-65. Type Analysis of Nitrogen in Petroleum Using Nonaqueous Potentiometric Titration and Lithium Aluminum Hydride Reduction, by I. Okuno, D. R. Latham, and W. E. Haines. Anal. Chem., v. 37, No. 1, January 1965, pp. 65-67. A procedure is described for classifying nitrogen in petroleum into five different types—strongly basic nitrogen, three types of weakly basic nitrogen, and nontitratable nitrogen. The five types of nitrogen are determined by titrating oils potentiometrically in acetic anhydride with perchloric acid before and after reduction with lithium aluminum hydride. This procedure has been applied to several crude oils and has shown wide variation in the types and distribution of nitrogen compounds in oils.

OP 110-65. Minor Products of Combustion in Large Coal-Fired Steam Generators, by A. A. Orning, Cecil H. Schwartz, and John F. Smith. Mech. Eng. (Tech. Digest), v. 87, No. 5, May 1965, p. 146. An analysis is given of the minor products of combustion from large coal-fired steam generators in relation to thermodynamic equilibria, unit design, and operating conditions. Concentrations of nitrogen oxides and the ratios of sulfur trioxide to total sulfur oxides are near equilibrium values at the furnace outlet. Significant amounts of low-molecular-weight organic acids and comparatively small amounts of polynuclear aromatic hydrocarbons are found under good combustion conditions.

OP 111-65. Appalachian Region Oilfield Reservoir Investigations, Glade Sand, Youngsville Pool, Youngsville-Sugar Grove Oilfield, Brokenstraw Township, Warren County, Pa., by William K. Overbey, Jr., and Donald M. Evans. Producers Monthly, v. 29, No. 8, August 1965, pp. 14-16. A 3½-inch-diameter diamond air-rotary core of the shallow Upper Devonian Glade sand was taken from a well in the Youngsville pool of the Youngsville-Sugar Grove oilfield, Brokenstraw Township, Warren County, Pa. Geology, development history, coring, geophysical logging operations, and well completion are discussed. Core analysis and oil-production data are presented. Attempts to orient fractures in the core well with an offset well are also discussed.

OP 112-65. Appalachian Region Oilfield Reservoir Investigations, Basal Greenbrier Limestone and Dolomite and "Keener" and Big Injun Sands, Clover-Rush Run Field, Smithfield District, Roane County, W. Va., by William K. Overbey, Jr., and Donald M. Evans. Producers Monthly, v. 29, No. 5, May 1965, pp. 22-24. The basal Greenbrier limestone and dolomite, and "Keener" and Big Injun sands were cored in a well in the Clover-Rush Run oilfield. Geology, development history of the field and lease, coring, geophysical logging operations, and well completion are discussed. Core and clay analyses and production data are presented.

OP 113-65. Sea Floor Minerals—Curios or Wealth? by John W. Padan. Preprints, 8th Nat. Symp. Soc. Aerospace Material and Process Eng., May

25-28, 1965, San Francisco, Calif., 12 pp. Discusses problems of exploiting minerals on the sea floor, including use of the hydraulic dredge, on-site mineral concentration, the new Bureau of Mines Marine Mineral Technology Center, Tiburon, Calif. (Available from the National Society of Aerospace Material and Process Engineers, P.O. Box 613, Azusa, Calif., 91702.)

OP 114-65. Methods of Reducing Emission of Oxides of Sulfur From Coal, by Harry Perry. In Symp. on the Air Pollution Problem. Proc. Am. Power Conf., v. 26, 1965, pp. 107-113. Removal of sulfur dioxide from stack gases has been accomplished by a number of processes. However, scrubbing processes which discharge a cool supersaturated gas are not acceptable at powerplants. There is much interest in processes that can be operated at higher temperatures; the more advanced of these are the Reinluft, Bureau of Mines alkalized alumina, and the Pennsylvania Electric processes. Not enough information is available to make accurate comparative cost estimates for the three methods at this time. Market studies are also needed so that proper values can be assigned to byproducts of these processes.

OP 115-65. Locality 11, Copper Bullion Mine, by Tom L. Pittman. Alaska Dept. of Natural Resources, Division of Mines and Minerals, Rept. 16, 1965, pp. 26-29. Gives results of an investigation of the Copper Bullion (Rua Cove) mine on Knight Island, Alaska.

OP 116-65. High-Pressure Hydraulic System Hazards, by S. P. Polack. Safety Newsletter, Min. Sec., September 1965, pp. 1-2. Discusses the hazards associated with high-pressure hydraulic systems and gives a list of safety precautions to be used.

OP 117-65. Book Review, by Andrew S. Prokopovitsh. "Treatise on Analytical Chemistry, Part 2: Analytical Chemistry of the Elements," ed. by I. M. Keltoff and P. J. Elwing, v. 8, J. Metals, v. 16, No. 11, November 1964, p. 148.

OP 118-65. A Procedure for Analysis of Impurities in Grade-A Helium in the Parts-Per-Billion Range, by Al Purer. J. Gas Chromatography, v. 3, No. 5, May 1965, pp. 165-169. A new procedure has been developed which combines the advantages of two existing analytical methods. Preconcentration of the impurities followed by analysis with a high-sensitivity gas chromatograph resulted in an analytical procedure which has sensitivities in the parts-per-billion range for neon, hydrogen, argon, oxygen, krypton, nitrogen, methane, and xenon.

OP 119-65. Simple Technique for the Ultrapurification by Helium, by Al Purer, L. Stroud, and T. O. Meyer. Advances in Cryogenic Engineering, v. 10, 1965, pp. 398-401. Ultrapure helium, containing less than 2 parts per billion of neon and no detectable traces of other components, may be obtained at high pressures by charcoal adsorption of the impurities at 35° K. Helium containing less than 1 part per million total impurities can be obtained by passing Grade-A helium through charcoal at liquid nitrogen temperature.

OP 120-65. Calculation of Surface Area of Anthracite From Carbon Dioxide Adsorption Data, by J. W. Ramsey. Fuel, v. 44, No. 4, July 1965, pp. 277-284. Evaluates alternate and modified forms of the BET equation, simple empirical equations, and the Langmuir equation for obtaining surface areas from carbon dioxide adsorption on anthracites. Comparison was made of the absolute specific surface values calculated by the various equations, and the monolayer volumes from each equation, calculated as normal liquid, were compared with the specific pore volumes. The effect of oxidation of the coal on the adsorption of carbon dioxide was also investigated.

OP 121-65. Solving Mine Haulage Problems by System Stimulation, by Donald E. Redmon. Colorado Sch. Mines Quart., v. 59, No. 4, Part B, 1965, pp. 887-914. Demonstrates a method that is applicable for use in mine-system analysis. Monte Carlo techniques are used to obtain data from cumulative probability distributions. The data are then applied in analyzing the system operation. The results provide information which is the basis for making decisions.

OP 122-65. Changes in Green River Oil-Shale Paraffins With Depth, by W. E. Robinson, J. J. Cummins, and G. U. Dinneen. Geochim. et Cosmochim. Acta, v. 29, No. 4, pp. 249-258. Evidence was found for differences in the composition of the paraffins in Green River shale with depth. The ratio of odd- to even-numbered *n*-paraffins (C.P.I.) decreased with depth showing a trend toward equalization of carbon numbers similar to petroleum paraffins. The distribution of the isoprenoid compounds also changed with depth. In addition, the amount of soluble bitumen changed with depth. A significant increase in the paraffin content of the bitumens from 17 to 47 percent with depth was observed. Discusses the factors or combinations of factors that may have caused the observed changes.

OP 123-65. The Transformation Temperatures of Hafnium, by P. A. Romans, O. G. Paasche, and H. Kato. J. Less-Common Metals, v. 8, March 1965, pp. 213-215. Reports a transformation temperature for pure hafnium of 1,777° C, determined by the high-temperature X-ray technique.

OP 124-65. A Comparison of Explosives by Cratering and Other Methods, by L. D. Sadwin and W. I. Duvall. Trans. SME, June 1965, pp. 110-116. Three explosives with different detonation characteristics were tested by studying their cratering ability in a granite-gneiss. The strain wave generating characteristics of these explosives were also studied in the same rock medium. Correlations between the relative performance of three explosives as evaluated by crater studies and other methods of evaluation are indicated.

OP 125-65. The Physical Phenomena Underlying the Negative and Positive Coronas in Air at High Temperatures and Pressures, by C. C. Shale. 1965 IEEE International Convention Record, v. 13, pt. 7, 1965, pp. 77-87. Electrical characteristics of the negative and positive coronas are presented for air in a 2-inch-diameter electrostatic precipitator operating under dust-free conditions at temperatures from 600° to 1,500° F and pressures from 0 to 80 psig. Experimental data show that negative corona is very erratic at high temperatures—when gas density is low, surges ocur in the flow of corona current at high field gradients and cause premature breakdown of the electrical field. These surges do not occur in the positive corona; thus, the positive corona is more stable than the negative under these conditions and thereby allows utilization of higher opearting voltages in a precipitator. The physics of each of the two corona processes is utilized to relate the electronic action in the electrode gap and to explain the causes for the relative effects of temperature and pressure on the current-voltage relationships. Existing theory, which was developed at atmospheric pressure and subatmospheric pressure, is extended and shown to apply for the corona processes over the span of temperatures and pressures investigated.

OP 126-65. Comparison of Mass Spectrometric and Gas Chromatographic Analyses of High-Boiling Oils From Coal, by A. G. Sharkey, Jr., J. L. Schultz, and R. A. Friedel. Proc. ASTM Comm. E-14 Meeting, May 1963, pp. 277-281. Naphthalene and anthracene oils from coal were analyzed by high-temperature mass spectrometry. These samples had been analyzed previously by gas chromatography at 13 European laboratories as part of a cooperative program investigating analysis of high-boiling oils from coal. Carbon number distribution data were obtained by mass spectrometry for components containing up to 24 carbon atoms. For the majority of the structural types, good agreement was shown between gas chromatographic and mass spectrometric results.

OP 127-65. Mass Spectral Studies of Heavy Residues From Pyrolysis of Several Aromatic Compounds, by A. G. Sharkey, Jr., J. L. Shultz, and R. A. Friedel. Proc. ASTM Comm. E-14 Meeting, May 1965, pp. 481-485. Mass spectra of products from the liquid-phase pyrolysis of 18 hydrocarbons having from one to four aromatic rings and molecular weights from 116 (indene) to 228 (chrysene) were investigated. By studying the pyrolyzates of several structural types found in the material extracted from Pittsburgh seam (hvab) coal with pyridine at room temperature, information related to the formation of heavy residue such as coal tar was obtained. The amount of original material remaining after pyrolysis at 450° C for 4 hours was used to estimate the extent of thermal reactivity.

OP 128-65. Computer-Oriented Research at the Denver Mining Research Center, by John F. Shaw. Colorado Sch. Mines Quart., v. 59, No. 4, part A, 1965, pp. 377-383. Discusses the usefulness of the computer in research. Over 125 computer programs have been developed at the Denver Mining Research Center. Programs in the field of engineering research proceed from mathematical statistics to mine evaluation, quality control, and economic engineering. Other programs utilize pure mathematics and physics and are used in rock mechanics and the physics of rock structures.

OP 129-65. Dust Measurement and Standards, by Earle P. Shoub. Trans. Nat. Safety Cong., v. 7, 1965, pp. 18-26. Discusses methods of measuring dust in the atmosphere of coal mines and acceptable standards of dust exposure.

OP 130-65. Observations on Dust Control and Investigations in Coal Mines by the U.S. Bureau of Mines, by Farle P. Shoub. Proc. Pennsylvania Governor's Conf. on Pneumoconiosis (Anthraco-Silicosis), Harrisburg, Pa., Nov. 30-Dec. 2, 1964, pp. 191-194. Discusses Bureau of Mines activities in connection with coal dust with particular emphasis on chest diseases. Continuous mining produces more fine coal and dust than did conventional mining and there is need for a reasonably inexpensive, simple method of dust suppression that will allay dust at the source.

OP 131-65. Analyses of Coal-Tar Pitch by Mass Spectrometry, by J. L. Shultz, R. A. Friedel, and A. G. Sharkey, Jr. Fuel, v. 44, No. 1, January 1965, pp. 55-61. Mass spectrometric analyses were obtained for three fractions of pitch from the high-temperature carbonization of coal. High-temperature and low-ionizing-voltage techniques were applied to obtain semiquantitative data (± 10 percent of the amount present) for 34 structural types, as well as carbon distribution data for alkyl derivatives. Of the 34 structural types, 24 could be associated with compounds previously identified in coal tar. Approximately 70 percent of the 80° to 85° C softening point pitch was identified. Average molecular weight for the three fractions based on mass spectrometer data is approximately 250 and the number of aromatic rings per aromatic cluster (mean structural unit) is 4-5. The aromaticity value of 0.94 calculated from these data is in excellent agreement with measurements by nuclear magnetic resonance.

OP 132-65. Proposed Paths to Products of Pyrrole Autoxidation, by Edgar B. Smith and H. B. Jensen. ACS Petroleum Division, Symp. on Organic Sulfur, Nitrogen, and Oxygen Compounds, Spring Meeting, Detroit, Mich., 1965, preprints, v. 10, No. 2, pp. C-123 through C-129. Self-initiated autoxidation of 1-methylpyrrole, 1-isopropylpyrrole, and 1-butylpyrrole at 60° C gave peroxidic polymers and carbonyl compounds thought to arise from peroxide decomposition. These carbonyl compounds were isolated from 1-methylpyrrole oxidation products, and spectral examination detected their homologs in oxidation products of the other two pyrroles. It is suggested that 1-alkylpyrroles react with oxygen by a free-radical addition process typical of dienes.

OP 133-65. Oil Shales of the Green River Formation in Wyoming, by John Ward Smith and Kenneth E. Stanfield. Wyoming Geol. Assoc. Guidebook, 1965, pp. 167-170. Summarizes what is known of oil-shale values in Wyoming. Areas where significant oil-shale deposits probably exist are pointed out.

OP 134-65. Carbon Disulfide Production by Reaction of Elemental Sulfur With Carbonized Lignite and Wood Charcoal, by Everett A. Sondreal. I&EC Process Design and Development, v. 4, No. 1, January 1965, pp. 111-117. Carbon disulfide was produced at about the same high rates, using either lignite chars or wood charcoal. Rates of production were studied relative to temperature, partial pressure of sulfur, rate of sulfur admission, and char characteristics.

OP 135-65. Some Factors in the Electrochemical Reduction of Tetralin in Ethylenediamine Solution, by Heinz W. Sternberg, Raymond E. Markby, Irving Wender, and David M. Mohilner. Symp. Ind. Electroorganic Chem., Electrochem. Soc. Meeting, San Francisco, Calif., May 6-13, 1965, pp. 16-19. Electrochemical reduction of tetralin in ethylenediamine in an undivided cell yields hexalin and octalin. The effect of certain operating variables on currency efficiency and product distribution was investigated. Cathode material, type of electrolyte, and temperature had a marked effect on current efficiency and product distribution. Product distribution also differed widely depending on whether a cell with or without a divider was used. A possible mechanism of the electrochemical reduction in ethylenediamine based on current-voltage curves is discussed.

OP 136-65. Coal-Burning Turbine With Water Injection Can Increase Peaking Power, by Donald C. Strimbeck, Jack Smith, and J. P. McGee. Power Eng., v. 69, No. 2, February 1965, pp. 43-44. Describes a proposed system for peak load generation in which water is injected into the combustor of the gas turbine to supply a large mass of working fluid for the turbine. The system would reduce capital costs, but would be useful only to carry peak loads for a total of about 1,000 hours yer year.

OP 137-65. Electrorefining Vanadium, by T. A. Sullivan. J. Metals, v. 17, No. 1, January 1965, pp. 45-48. Describes the application of molten-salt electrorefining techniques to the production of high-purity vanadium and also to the refining of lower purity vanadium to ductile-grade metal.

OP 138-65. Recent Calorimetric Studies of Beryllium Fluoride, by A. R. Taylor, Jr. Chem. Propulsion Information Agency, Interagency Chem. Rocket Propulsion Group, Working Group on Thermochem., Proc. 2d Meeting, June 3-4, 1964, CPIA Pub. 54 U, pp. 85-86. Describes additional calorimetric studies of an alpha quartz type BeF_2, using the ice calorimeter.

OP 139-65. Identification of Some Cyclic Sulfides in A Wasson, Texas, Crude Oil Distillate Boiling from 110° to 150° C, by C. J. Thompson, H. J. Coleman, R. L. Hopkins, and H. T. Rall. J. Chem. and Eng. Data, v. 10, No. 3, July 1965, pp. 279-282. Discusses a procedure for isolation and identification of cyclic sulfides in petroleum and reports identification of 17 cyclic sulfides in a 110° to 150° C boiling range distillate.

OP 140-65. Structure Characterization by Microhydrogenation, by C. J. Thompson, H. J. Coleman, R. L. Hopkins, and H. T. Rall. Anal. Chem., v. 37, No. 8, July 1965, pp. 1042-1044. Structure characterization by vapor-phase catalytic hydrogenolysis has been amplified and extended. The basic technique, with improvements discussed, permits structure characterization that would be difficult or impossible by any other technique.

OP 141-65. Sulfur Compounds in Petroleum, by C. J. Thompson, H. J. Coleman, R. L. Hopkins, and H. T. Rall. In Hydrocarbon Analysis. ASTM Special Tech. Pub. 389, 1965, pp. 329-360. Paper presents methods used in the isolation and identification of sulfur compounds and lists, by class, the 141 individual compounds identified in petroleum by the Bureau of Mines-API Research Project 48.

OP 143-65. Physical Structure of Green River Oil Shale, by P. R. Tisot and W. I. R. Murphy. Chem. Eng. Progress, Symposium Series, A.I.Ch.E., v. 61, No. 54, 1965, pp. 25-32. Presents information concerning particle size and particle-size distribution of the inorganic constituents in oil shale; surface area, pore structure, and pore volume of both oil shale and its inorganic constituents; the manner in which the organic matter is distributed within oil shale; and an estimate of the amount of organic matter in direct contact with the surface of the mineral constituents. Photomicrographs show the geometric form of some of the inorganic particles.

OP 144-65. Mineral Potential of Eastern Montana—A Basis for Future Growth, by U.S. Geological Survey and U.S. Bureau of Mines. Prepared at the request of Senator Mike Mansfield of Montana. 89th Congr., 1st sess., S. Doc. 12, Feb. 2, 1965, 77 pp. Report indicates what mineral resources are present, where they occur and in what amounts, what use is now being made of them, and points out potential uses that might be developed. Mineral resources investigated are coal, petroleum and natural gas, bentonite, clay and shale, gem stones, gypsum and anhydrite, potash, salt, sand and gravel, sodium sulfate, stone, and uranium.

OP 145-65. Evaluating Ingredient Hazards, by Robert W. Van Dolah. Bull. 21st Interagency Solid Propulsion Meeting, June 9-11, 1965, San Francisco, Calif., v. 2, Chem. Prop. Inf. Agency Pub. 71A, 1965, pp. 457-459. Methods for evaluating the sensitivity of explosive material are reviewed briefly. These methods range from elementary heating and impact tests to highly instrumented versions of the card-gap test. The essentially thermal character of all these methods is indicated. The nature of the initiation reaction and the conditions of its growth to detonation are discussed.

OP 146-65. Book Review, by Robert W. Van Dolah. "Energetics of Propellant Chemistry," by B. Siegel and L. Scheiler. Science, v. 147, No. 3664, Mar. 19, 1965, pp. 1435-1436.

OP 147-65. Shock Sensitivity and Its Evaluation, by Robert W. Van Dolah. Safety and Accident Prevention in Chemical Operations, ed. by H. Fawcett and W. Wood. Interscience Publishers, Inc., New York, 1965, pp. 319-329. Describes the card-gap test as a means to determine the sensitivity of condensed-phase materials to initiation of high-velocity detonation.

OP 148-65. Inelastic Deformation of Rock Under a Hemispherical Drill Bit, by James Paone and Sathit Tandanand. Proc. 7th Symp. Rock Mechanics, 1965, Pennsylvania State University, June 14-16, 1965, pp. 149-174 (preprint). Results of triaxial strength tests on rock samples and static and dynamic indentation of the rock surface by a hemispherical bit were used to study the inelastic behavior of rock. Theoretical analysis and experimental results together provide a better understanding of the relations among the triaxial stress conditions, permanent set, yield strength, and the energy per unit volume involved in crater formation under a drill bit.

OP 149-65. Heavy Liquid Cyclone Concentration of New Mexico Potash Ores, by R. B. Tippin and James S. Browning. SME Fall Meeting, Rocky Mountains Mineral Conf., Phoenix, Ariz., Oct. 7-9, 1965, Preprint 65B312, 17 pp. Excellent specific gravity separations of three different types of potash ores were made with two-stage heavy liquid cyclones. The cyclone overflow contained over 93 percent float product while the amount of misplaced float material reporting with the cyclone underflow was less than 4 percent. However, an effective separation of sylvite from halite to produce a commercial-grade concentrate with a high potash recovery depended upon the mineralogical composition of the ore. With an ore containing only sylvite and halite, a 57.5-percent K_2O concentrate was made at a 93.3-percent recovery. The presence of carnallite in another ore downgraded the sylvite concentrate to 51.1 percent K_2O but the recovery was approximately 88.5 percent. In a third ore, the halite tailings contained kainite which, because of its potassium values, lowered the potash recovery to 65.4 percent although the concentrate grade was 58.7 percent K_2O. Results compare favorably with commercial brine flotation, which usually requires additional water leaching to meet specifications. Investigation into effect of feed pressure and heavy liquid viscosity on the grade and recovery showed that increasing pressures only slightly enhanced the grade, but a pronounced improvement in the separation was effected by lowering the liquid viscosity.

OP 150-65. Some Problem Areas in Hydrogen Safety, by Robin Van Meter. Supplement to Fifty-First and Fifty-Second Annual Reports 1963-1964, Nos. 51 and 52, Compressed Gas Association, New York, pp. 20-24. Discusses methods of achieving better levels of safety in operations involving the use of liquid hydrogen. The problem areas in hydrogen safety include hydrogen leak detection, hydrogen flame detection, explosion damage prevention, hydrogen disposal, lightning protection, and quantity-distance criteria.

OP 151-65. Pattern of Energy Consumption in the United States, by William A. Vogely. American Chemical Society Meeting, Detroit, Mich., April 1965, v. 9, No. 2, pp. 205-221 (preprints). Examines the patterns of energy consumption in the period 1947-62. Within this decade and a half there were factors that created a very different set of energy flows for 1962 from that of 1947. Changes are examined, hypotheses concerning them are presented, and projections to 1980 of the patterns are made. Energy resource consumption is tabulated by consuming sector by sources and by consuming sector by function. Concluding section presents a tentative hypothesis concerning competition among energy sources and energy trends.

OP 152-65. A Shift Analysis of Production, Employment and Income in the Mining Industries, by William A. Vogely. Min. Eng., v. 17, No. 4, April 1965, pp. 72-74. Presents a technique by which the various forces that have been acting on the market for a mineral commodity may be sorted out and by which the extent of the impact of technological change in use as well as the technological change in production can be measured.

OP 153-65. Basic Minerals, by William A. Vogely and Robert E. Johnson. Chem. and Eng. News, v. 43, No. 36, Sept. 6, 1965, pp. 82-87. Presents forecast of refined minerals production for the year 1965, based on actual data for the first quarter of the year and on a general forecast of industrial and business activity for the year as a whole.

OP 154-65. Instrumentation for Rock Mechanics as Used in a Mine, and Its Possible Application to Other Engineering Problems, by Galen C. Waddell. Proc. 3d Ann. Eng. Geol. and Soils Eng. Symp., Apr. 6-7, 1965, Boise, Idaho, pp. 91-117. Expansion and contraction of the rock surrounding horizontal access openings of a deep mine (Star mine, Burke, Idaho) were analyzed during stope advance to determine what type of measurements, made with inexpensive instrumentation, would best reflect the rock behavior. Detailed descriptions are given of down-the-hole extensometers, floating rockbolt clusters, and other measuring techniques. Several useful relationships were found between the rock deformation rate and the stoping process. Information was produced on the elastic state of rock around an underground opening, effectiveness of stope support, rheology of rock, zone of influence around stopes, effectiveness of rockbolts, direction of maximum principal stress, and other phenomena.

OP 155-65. The U.S. Minerals Attaché Program, by K. P. Wang, and Virgil L. Barr. International Science Notes, U.S. Department of State, No. 11, October 1965, pp. 14-17. Describes briefly the U.S. Minerals Attaché Program, which is directed jointly by the Department of State and of the Interior.

OP 156-65. Preshot and Postshot Safety Survey of Oil and Gas Facilities—Baxterville Field, Mississippi (Final Report), by Don C. Ward. U.S. Atomic Energy Commission, Project Dribble, Salmon Event, VUF 1022, 1965, 73 pp. Oil and gas wells and related facilities of the Baxterville field were surveyed to document any physical changes resulting from the Salmon nuclear test event. All such structures within a 5-mile radius of ground zero were examined and photographed in detail. In addition, all wells and major facilities between the 5- and 6-mile radii, as well as other selected wells and facilities with a 10-mile radius of ground zero, were examined and photographed. No damage was observed at any of the oil or gas wells or related facilities.

OP 157-65. Concentrations, by P. A. Wasson. Min. Eng., v. 17, No. 2, February 1965, pp. 106-108. Continued progress was noted in all fields of mineral concentration throughout 1964. Development and expansion continued at an advanced rate with the construction of several new plants and the enlargement of facilities in existing plants. Research on gravity, magnetic, and flotation concentration has shown considerable progress at both academic and industrial levels.

OP 158-65. Improving Effectiveness of Backfill, by William R. Wayment and David E. Nicholson. Min. Cong. J., v. 51, No. 8, August 1965, pp. 28-32. Hydraulic backfill research has centered around methods of improving the cohesive and frictional properties of these granular materials. The grain-size distributions of backfill classified by hydrocyclones, from typical mill tailings, is extremely important to both the frictional properties and water percolation properties of these materials. Most backfills are presently placed as loose granular structures and a significant increase in the bearing strength of hydraulic backfill can be obtained by compaction of these materials (increase the frictional properties) into more dense grain structures. Cohesive strengths can be improved by the modest addition of portland cement or other types of cementing agents.

OP 159-65. Fluid Dynamics, by Murray Weintraub. Ind. and Eng. Chem., v. 57, No. 6, June 1965, pp. 41-46. Presents a review of the literature published during 1963 and early 1964 that describes recent developments in the manifold aspects of fluid flow.

OP 160-65. Progress in Preventing Coal Mine Disasters, by James Westfield. Proc. Rocky Mountain Coal Min. Inst., 61st Meeting, June 27-30, 1965, pp. 59-63. Discusses progress in preventing coal mine disasters and reports the three common factors that set the stage for coal mine disasters and how to eliminate them. The factors are inadequate face ventilation, inadequate testing of the face atmosphere for gas, and inadequate cleanup and rock dusting between the loading point and the working faces.

OP 161-65. West Virginia Mine Safety Association, by James Westfield. Coal, v. 19, No. 10, October 1965, pp. 31-33. Describes the organization, operation, and objectives of the West Virginia Mine Safety Association, founded in 1964 to improve the safety of coal mines in the State.

OP 162-65. Appalachian Region Oilfield Reservir Investigations, Gordon Stray, Gordon, and "Fourth" Sands, Smithfield Field, Grant District, Wetzel County, W. Va., by Charles E. Whieldon, Jr., and William K. Overbey, Jr. Producers Monthly, v. 29, No. 9, September 1965, pp. 16-19. The Bureau of Mines obtained oil-reservoir samples of the Gordon Stray, Gordon and

"Fourth" formations by rotary, mud coring Wolf's Head Oil Refining Company's I. D. Morgan well W-1 in the Smithfield field, Grant district, Wetzel County, W. Va. Well logs were taken to supplement core information. Core analysis, well logs, geology, field development, and production history are presented.

OP 163-65. Appalachian Region Oilfield Reservoir Investigations, Mitchell and Berea Sands, Lower Newport Field, Newport Township, Washington County, Ohio, by Charles E. Whieldon, Jr., and William K. Overbey, Jr. Producers Monthly, v. 29, No. 11, November 1965, pp. 8-11. The Mitchell and Berea sands were cored, and well logs were run in a well in the Lower Newport field. This work was done to evaluate the possibilities of increasing ultimate oil recovery by secondary-recovery methods. Geology, lease history, geophysical logs, coring and logging operations, and results of core analysis are presented.

OP 164-65. Storage Stability of High Temperature Fuels, by Marvin L. Whisman and C. C. Ward. Air Force Aero Propulsion Laboratory, Research and Technology Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, AFAPL-TR-65-13, pt. 1, 1965, 80 pp. Modifications of a 5-milliliter bomb test equipment and method have shown promise of permitting precise measurement of labeled fuel components that contribute to deposits during thermal stressing. Three test methods were developed and evaluated for the separation and measurement of radioactivity contributed to deposits and gums by selected fuel constituents. One of these techniques used the principle of liquid-solid chromatography followed by liquid scintillation counting of the radioactive reaction products. The other two test methods employed gas-liquid chromatography for separation and both ionization chamber counters and liquid scintillation radioassay techniques. An evaluation of these latter procedures showed the chromatographic separation procedures were adequate but quantitative recoveries of gum from the apparatus were dependent upon the radioisotope and fuel system. This incomplete recovery of material indicated other separation techniques might hold more promise. The migratory nature of tritium under conditions of severe thermal stress was investigated with the hope of broadening the selection of isotopes available to these investigations in the future.

OP 165-65. Mining and Milling of Possolan for Glen Canyon Dam, Arizona, by Frank E. Williams and Andrew J. Zinkl. Rock Products, v. 68, No. 3, March 1965, pp. 97-98. Describes the open-pit mining and dry-milling processing of rhyolitic sand used as possolanic material in the construction of the Glen Canyon Dam, Arizona. This is one of the major applications of natural pozzolans in the United States. Approximately 210,000 tons of material was supplied to the U.S. Bureau of Reclamation project.

OP 166-65. Blast Furnace Operations With Very Low Slag Rates, by P. L. Woolf. 26th Ann. Min. Symp., University of Minnesota, Duluth, Minn., Jan. 11-13, 1965, pp. 81-87. The Bureau of Mines experimental blast furnace was successfully operated with extremely low slag volumes. The minimum slag volume achieved was 245 pounds per ton of hot metal; this was 90 pounds less than the lowest recorded slag volume. The coke rate saving and increase in productivity resulting from lowered slag volumes are discussed as well as the factors limiting a low slag practice.

OP 167-65. Transmittance of Single Crystals of Graphite in the Infrared Spectrum, by J. B. Yazinsky and E. Ergun. Carbon, v. 2, 1965, pp. 355-358. Measurements have been made of transmission of infrared radiation through ultrathin single crystal flakes of grapite. Transmission spectra for flakes of different thickness show peaks near 0.82 eV. This frequency values is interpreted as equivalent to twice Y_1, a band energy parameter which accounts for the main splitting of the singly degenerate bands along the zone edge. The value of Y_1 obtained here lends support to McClure's overlap model for the band energies of graphite.

OP 168-65. Mining: Metals and Minerals, by Paul F. Yopes. Britannica Book of the Year, 1965. Reviews briefly developments in mining of metals and minerals in 1964.

OP 169-65. 1964 Sales: Coal-Mining and Cleaning Equipment, by W. H. Young and R. L. Anderson. Coal Age, v. 70, No. 2, February 1965, pp. 86-88; Coal Min. and Processing, v. 2, No. 2, February 1965, pp. 29-32. Shipments of mechanical loading equipment for underground use in all coal mines, in terms of capacity, increased 13 percent in 1964. The capacity of mechanical cleaning equipment sold for use at bituminous coal mines decreased 28 percent during the same period. Of the total capacity of mechanical equipment sold in 1964, 84 percent was placed in operation during that year; the remaining 16 percent will be installed later. Tabulates production of coal by methods of mining, cleaning, and loading.

OP 170-65. Need for an Intermediate A-C Voltage for Underground Mining, by L. H. Harrison. Min. Cong. J., v. 51, No. 4, April 1965, pp. 60-62. Discusses the need for a standard voltage of some intermediate value between 600 and 2,400 volts for mining equipment. It is suggested that this could best be accomplished by providing a standard transformer winding suitable for wye connection on a 3-phase, 2,400-volt system. This would provide a neutral point for resistance grounding on 2,400-volt systems and a voltage of 1,388 phase-to-neutral.

OP 171-65. Thermal Fragmentation of Rock, by R. L. Marovelli, T. S. Chen, and K. F. Veith. Proc. 7th Symp. Rock Mechanics, 1965, Pennsylvania State University, June 14-16, 1965, v. 2, 1965, pp. 253-280 (preprint). Presents results of analytic and experimental work on stress in rock undergoing a controlled thermal shock. The important physical parameters are discussed.

OP 1-66. Changing Conditions Compel New Concepts of Mineral Engineering, by Paul T. Allsman. Trans. SME, June 1966, pp. 217-224. Comments on the relationships between the mining industry, mineral engineering as a profession, and Government and the economic, technologic, political, and social changes that dictate their relationships. Suggests remedies for certain mineral engineering problems.

OP 2-66. The Shifting Pattern of Lime Usage, by Paul L. Allsman. Min. Eng., v. 18, No. 6, June 1966, pp. 65-66. Advancements in mineral technology and a significant growth in new applications have had a marked result in the shifting pattern of lime use. Summarizes lime uses in agriculture, construction, water and sewage, and metallurgy.

OP 3-66. Recent Advances in Radioisotope Applications for Exploitation of Petroleum and Natural-Gas Reservoirs, by F. E. Armstrong and W. D. Howell. Isotopes and Radiation Tech., v. 3, No. 2, Winter 1965-1966, pp. 102-114. This paper reports some of the more important recent advances in the application of radioisotopes to the exploitation of petroleum and natural-gas reservoirs. No attempt was made to summarize all work in the field. Most references were published during the past 5 years, although in a few isolated instances earlier work was included for the sake of continuity and clarity. The uses of radioisotopes in injection and production-profile work, well logging, and well-to-well tracers for reservoir evaluation and secondary recovery operations are discussed. Some applications of activation analysis are also reviewed.

OP 4-66. Thermodynamic Properties of a van der Waals Fluid, Particularly Near the Critical Point, by Robert E. Barieau. Phys. Rev. Letters, v. 16, No. 8, Feb. 21, 1966, pp. 297-300. Gives equations for the thermodynamic functions of a van der Waals fluid.

OP 5-66. Spotlight on Roof Control, by Anthony J. Barry and John A. McCormick. Coal Min. and Processing, v. 3, No. 2, February 1966, pp. 18-22. This article describes studies currently being conducted by the Roof Control Research Group in the field of roof control in underground coal mines. The roof control-related studies include roof bolting, sonic testing of mine roof, measurement of roof gas and/or water pressure in mine roof, and coal bursts.

OP 6-66. Instruments and Apparatus Supplement on Leak Detection and Leakage Measurement, by A. A. Berk. Mech. Eng., v. 88, No. 4, April 1966, p. 110. Summarizes part 21 on Methods of Leak Detection and Leakage Measurement (PTC 19.21-1965) of the Supplements on Instruments and Apparatus to the ASME Power Test Codes. Part 21 revises an earlier 1952 publication.

OP 7-66. Formation of Oxides of Nitrogen in Pulverized Coal Combustion, by Daniel Bienstock, R. L. Amsler, and E. R. Bauer, Jr. Air Pollution Control Assoc. J., v. 16, No. 8, August 1966, pp. 442-445. A reduction of 62 percent of the nitrogen oxides in pulverized-coal combustion can be effected by admitting 105 percent of the stoichiometric air to the flame and 17 percent beyond the flame front.

OP 8-66. An Experimental Study of Convective Heat Transfer to a Solid-in-Gas Suspension, by Dean Edward Blauman. Ph.D. thesis, West Virginia University, Morgantown, W. Va., 1966, 77 pp., 19 figs. A recirculating system for the study of convective heat transfer from solid-in-gas suspensions was designed and instrumented. A centrifugal compressor circulated a mixture of 30-micron glass beads through a heating section, a test-section cooler, and a meter which was developed for this application. The meter contained an orifice followed by a cantilevered target, and the pressure drop across the orifice and the drag force on the target were correlated to provide simultaneous measurement of gas flow rate and solids-to-gas mass ratio. Convective heat transfer coefficients of the gas were not increased when up to 0.7 pound of solids were added per pound of gas. This occurred when the suspension was being cooled with several hundred degrees temperature difference between the walls and the fluid. The direction of the temperature gradient has no effect for the range of variables tested, so the usual equations found in the literature for calculation of convective coefficients to or from gases may be used for suspensions up to approximately 1 pound of solids per pound of gas.

OP 9-66. Determination of the Particle Velocity in Detonating Gases by a Magnetohydrodynamic Principle, by M. L. Bowser, J. N. Murphy, J. E. Hay, and F. C. Gibson. J. Appl. Phys., v. 37, No. 6, May 1966, pp. 2273-2275. A technique using the magnetohydrodynamic generator principle for experimentally determining the hydrodynamic particle velocity in gaseous detonations is described and application is made to hydrogen-oxygen mixtures.

OP 10-66. Fast-Neutron Activation Analysis in Molten Salt Electrometallurgical Research, by K. G. Broadhead, D. E. Shanks, and H. H. Heady. Proc. 1965 Internat. Conf., Modern Trends in Activation Analysis, College Station, Tex., May 1966, pp. 39-43. Fast-neutron activation-direct instrumental-analysis techniques have proven to be very successful in analyzing major and minor constituents in complex halide electrolytes used in electrowinning tungsten, molybdenum, and the rare-earth metals. Several trace elements have also been determined in the electrowon metals and related materials. Because of the inherent speed these techniques are being used to supplement or replace other analytical procedures.

OP 11-66. Comprehensive Computer Program for Electron Probe Microanalysis, by James D. Brown. Anal. Chem., v. 38, No. 7, June 1966, pp. 890-894. A computer program for calculating composition from X-ray data measured with an electron-probe microanalyzer is described. This program can be used with several calculation procedures, including absorption corrections due to Philibert and as modified by Duncumb and Shields, fluorescence corrections of Castaing and Wittry, and Thomas' atomic number correction. The program facilitates the comparison of calculation procedures as well as the evaluation of errors associated with uncertainties in the parameters used.

OP 12-66. A Computer Program for Quantitative Electron Probe Microanalysis, by James D. Brown. Ch. in the Electron Microprobe, ed. by McKinley, Heinrich, and Wittry. John Wiley & Sons, Inc., New York, 1966, pp. 189-198. A computer program has been written in FORTRAN for calculating composition from measured X-ray intensities in electron-probe microanalysis. The measured intensities are corrected for instrumental drift, dead time, and background. Philibert's absorption and Castaing's fluorescence functions are used to relate the corrected X-ray intensities to composition. The program should be adaptable for use with data from any electron-probe microanalyzer for a wide variety of samples. An example of the use of the program is given.

OP 13-66. Selective Flotation of Mica From Pegmatites, by James S. Browning and Ralph B. Adair. Trans. SME, September 1966, pp. 277-280. The laboratory batch and continuous flotation pilot plant tests demonstrated the technical feasibility of recovering high-grade mica concentrates from weathered mica pegmatite ores of Alabama and Georgia. The research indicated that combinations of anionic and cationic collectors may be used effectively for flotation of fine-size mica from weathered pegmatite ores. In continuous tests, concentrates containing 98.5 percent mica were obtained from the Georgia pegmatite ore; the Alabama pegmatite ore concentrates contained 98.4 percent mica. The recoveries were 91 and 89 percent, respectively.

OP 14-66. Pulse Amplitude Shifts in Gas Proportional X-Ray Detectors, by P. G. Burkhalter, J. D. Brown, and R. L. Myklebust. Rev. Sci. Inst., v. 37, No. 9, September 1966, pp. 1266-1267. The pulse amplitude dependence on X-ray intensity (peak shift) has been measured in both sealed and flow gas proportional X-ray detectors. Larger peak shifts were found in gas flow detectors. The peak shifts, which increase with increasing anode potential, were independent of X-ray energy above 1,800 volts.

OP 15-66. Multiple Tracers Aid Evaluation of a Pilot Waterflood, by Edward L. Burwell. Proc. 25th Conf. on Petrol. Production, The Pennsylvania State University, University Park, Pa., Oct. 19-21, 1966, College of Earth and Min. Sci. Experiment Station Circ. 71, pp. 305-316. Many materials have been used to trace fluid flow in underground reservoirs. This report describes the use of five different tracers to help define the orientation and liquid flow capacity of a fracture system believed to be present in a reservoir during a pilot waterflood project on the Fords Brook Drilling Co. lease, Kane oilfield, Elk County, Pa. The presence and orientation of the fractures were established, the preferential flow direction was indicated from observation of the directional flow of tracers, and the approximate volume of injected water being produced through the fracture system was measured.

OP 16-66. Multiple Tracers Establish Waterflood Flow Behavior, by Edward L. Burwell. Oil and Gas J., v. 64, No. 48, Nov. 28, 1966, pp. 76-79. Describes the use of five different tracers that were successfully used over a 2-year period to define the orientation and liquid flow of a reservoir fracture system.

OP 17-66. Metallothermic Reduction of Beryllium Oxide, by T. T. Campbell, R. E. Mussler, and F. E. Block. Trans. SME, October 1966, pp. 1456-1461. An exploratory study was made to determine the feasibility of preparing beryllium by the metallothermic reduction of beryllium oxide. The procedure involved heating a relatively nonvolatile metal reductant in contact with beryllium oxide in a vacuum. Beryllium vapors formed in the reaction were condensed as a coherent deposit on a heated surface. Reductants tested included lanthanum, yttrium, thorium, Th-Mg, and Zr-Ti alloys, and the hydrides of lanthanum, yttrium, and zirconium. Test temperatures ranged from 1,350° to 1,750° C, and reaction times ranged from 30 to 100 hours. In most cases metal recoveries were low, although yields close to 90 percent of theoretical were obtained with lanthanum, yttrium, and zirconium reductants. In most cases metal deposits were contaminated by beryllides, usually of the $Be_{13}M$ or $Be_{13}M$ type.

OP 18-66. Micro and Trace Analysis by a Combination of Ion Exchange Resin-Loaded Papers and X-Ray Spectrography, by W. J. Campbell, E. F. Spano, and T. E. Green. Anal. Chem., v. 38, No. 8, July 1966, pp. 987-996. Ion exchange resin-loaded papers were used to collect microgram quantities of cations and anions and present the collected ions to a fluorescent X-ray spectrograph. High sensitivities and low matrix effects make this a preferred procedure for trace analysis. Chemical and X-ray characteristics of cation and anion resin-loaded papers were investigated.

OP 19-66. Fly Ash Utilization, by J. P. Capp. Combustion, v. 37, No. 8, February 1966, pp. 36-40. Reviews the present situation with respect to fly ash utilization and discusses recent advances and current programs in utilization technology. Present uses for fly ash include lightweight aggregate, highway construction, and bituminous concrete and asphalt. Research is being conducted on using fly ash for bricks, soil conditioner, concrete block, and water treatment.

OP 20-66. Pipeline Gas by Hydrogasification, by H. C. Carpenter and P. L. Cottingham. Chem. Eng. Prog., v. 62, No. 8, August 1966, pp. 68-70. Study shows that high yields of pipeline gas may be produced from shale oil by several different hydrogasification processes. Yields of gas obtained by use of a catalyst were greater than those obtained in thermal hydrogasification. Further studying using a wider range of conditions would be needed to select the most desirable operating conditions.

OP 21-66. Hollow Chrysotile Fibers, by R. A. Clifton, Jr., C. W. Higgins, and H. R. Shell. Am. Mineral, v. 51, March-April, 1966, pp. 508-511. Electron microscopy shows that the ultimate microstructure of single fibers of chrysotile is a "hollow tube" or in some cases a partially filled "hollow tube." This offers the possibility of altering certain properties of the mineral.

OP 22-66. Here's How Producers Can Turn Brine Disposal Into Profit, by A. Gene Collins. Oil and Gas J., v. 64, No. 27, July 4, 1966, pp. 112-113. The mineral content of oilfield brine disposed of each year is worth more than $3 billion. Recovery of these minerals would ease the burden of brine disposal.

OP 23-66. The Solubilities of Barium and Strontium Sulfates in Oilfield Brines, by A. Gene Collins and William P. Zelinski. Division of Water, Air, and Waste Chemistry, 151st National American Chemical Society Meeting, Mar. 22-31, 1966, Pittsburgh, Pa., Preprints, v. 6, No. 1, March 1966, pp. 7-13. Information concerning the solubilities of barium and strontium sulfates in subsurface brines is necessary in petroleum engineering problems, geochemical exploration research, and ground water hydrology research. The solubilities of barium and strontium sulfates in synthetic and natural oilfield brines were determined using the radioactive isotope sulfur 35. The results indicate excellent applicability of a radioactive isotope technique plus new basic solubility data.

OP 24-66. Measurement of Soluble Calcium in Iron Flotation Pulps, by Arthur F. Colombo. Proc. Technicon Symposium on Automation in Analytical Chemistry, New York, v. 2, November 1966, pp. 153-157. An analytical method was developed for determining calcium ion level in iron-ore pulps undergoing anionic flotation of activated silica. The problems associated with the application of the technique are discussed.

OP 25-66. The Role of Vaporization in High Percentage Oil Recovery by Pressure Maintenance, by Alton B. Cook, F. S. Johnson, G. B. Spencer, and Abdo F. Bayazeed. California Regional Meeting Soc. Petrol. Eng. AIME, Santa Barbara, Calif., Nov. 17-18, 1966, Preprint SPE 1646, 7 pp. A limited number of laboratory experiments have been performed with a rotating model oil reservoir that simulates gas cycling operations and allows a separation of the oil from the free gas flowing into the laboratory wellbore at reservoir conditions, thus revealing which is displaced oil and which is vaporized oil. In these experiments recovery by vaporization ranged from 15.3 to 73.6 percent of the immobile oil.

OP 26-66. Flexible Linings for Ground Support, by Ernest L. Corp. Eng. and Min. J., v. 167, No. 4, April 1966, pp. 80-84. Flexible linings for underground mine supports offer certain advantages not inherent in other more common types of support. They can deform without rupture, they can shed or redistribute a portion of the load acting on an opening, and they have the ability to carry the remaining loads in a more efficient manner. Possible applications include drift supports and passageways in cut and fill stopes.

OP 27-66. Two Aids to Extrusion of High-Temperature Refractories, by J. G. Croeni and J. S. Howe, Jr. Tool and Manufacturing Eng., v. 56, No. 4, April 1966, p. 59. Describes the use of zirconia dies and molybdenum inserts in the extrusion of high-temperature refractories.

OP 28-66. Inverse Gas-Liquid Chromatography. A New Approach for Studying Petroleum Asphalts, by T. C. Davis, J. C. Petersen, and W. E. Haines. Anal. Chem., v. 38, No. 2, February 1966, pp. 241-243. A new approach to the characterization of asphalt is described in which the asphalt serves as the liquid substrate in an unusual application of gas-liquid chromatography (GLC). The term "inverse GLC" has been applied to differentiate this technique from conventional GLC. In this technique, the asphalt on the column is characterized by measuring the corrected retention volumes of a series of selected test compounds with different functional groups. The retention data are quantified by referencing to the behavior of *n*-paraffins on the asphalt column. The retention behavior of each test compound depends on interactions with functionality in the asphalt and thus is related to the chemical composition of the asphalt. The new technique was found to be useful in showing differences among asphalts and holds promise as a method of studying asphalt composition and showing chemical changes which occur on oxidation and weathering.

OP 29-66. Automatic Analytical X-Ray Methods, by C. W. Dwiggins, Jr. In Encyclopedia of Chemistry, ed. by G. L. Clark. Reinhold Pub. Corp., New York, 2d ed., 1966, pp. 115-116. The application of automated X-ray methods to research and development analyses is described. The emphasis is on the determination of trace elements, carbon, and hydrogen in petroleum-related materials.

OP 30-66. Foams Purge Well Bore and Formation Waters, by J. L. Eakin and W. E. Eckard. Part 1, Petrol. Eng., v. 38, No. 7, July 1966, pp. 71-84; Part 2, No. 9, August 1966, pp. 81-93. Where the productivity of natural-gas and gas-storage wells is impaired by the accumulation of liquids in the wellbore, the condition can be corrected through the use of foaming agents. Similar productivity impairment resulting from waterblocks can be relieved by a recently developed alcohol-surfactant treatment.

OP 31-66. The Isotopic Abundance of Neon From Helium-Bearing Natural Gases, by D. E. Emerson, L. Stroud, and T. O. Meyer. Geochim. Cosmochim. Acta, v. 30, No. 9, September 1966, pp. 847-854. This paper is the first presentation of data for the isotopic composition of neon from natural gas. The Ne^{21} isotopic content was found to be much greater than in the atmosphere. The concurrent generation of Ne^{21} and He^{4} from radioactive sources is postulated.

OP 32-66. Quantitative Ultraviolet Determination of C_{10}-C_{15} Naphthalenes in Hydrocarbon Oils, by Patricia A. Estep, Edward E. Childers, John J. Kovach, and Clarence Karr, Jr. Anal. Chem., v. 38, No. 13, December 1966, pp. 1847-1851. Alkylnaphthalenes in coal-tar neutral oils where separated by liquid chromatography according to the number of alkyl groups and their amounts determined by ultraviolet spectrophotometry.

OP 33-66. Bureau of Mines Respirator Approval Schedules: New and Revised, by B. I. Ferber. Amer. Indus. Hygiene Assoc. J., v. 27, No. 2, March-April 1966, pp. 110-114. The Bureau of Mines tests and approves respiratory protective devices according to performance requirements set forth in pertinent approval schedules. Changes in industrial technology and respirator application require review and revision of these performance requirements. Revisions are accomplished through cooperative efforts of the Bureau of Mines, the manufacturers, and the users of respiratory protective devices. The requirements of recently revised Schedule 21B for dust, fume, and mist respirators are discussed, as well as requirements proposed for inclusion in revisions of approval schedules for other types of respiratory protective devices.

OP 34-66. Oxygen Functional Groups in Green River Oil-Shale Kerogen and Trona Acids, by J. I. Fester and W. E. Robinson. In Coal Science. Advances in Chem. Ser. 55, 1966, pp. 22-31. Carboxyl, ester, amide, hydroxyl, aldehyde, and ketone groups were estimated for oil-shale kerogen and kerogen-derived trona acids from the Green River Formation. Ether groups were estimated by difference. Carboxyl, ester, and ether groups were found to account for the major portion of the oxygen in both the kerogen and trona acid samples. Minor amounts of amide, hydroxyl, aldehyde, and ketone groups were indicated. The reactive oxygen groups, carboxyl and ester, account for about one-half of the total oxygen in kerogen and two-thirds of the total oxygen in trona acids while the unreactive ether group accounts for the other half of the total oxygen in kerogen and one-third of the total oxygen in trona aicds.

OP 35-66. Experimental Production of Prereduced Pellets From Natural and Synthetic Magnetites, by M. M. Fine and N. Bernstein. Proc. 23d Ironmaking Conf. AIME, Pittsburgh, Pa., Apr. 13-15, 1964. Gordon and Breach Science Publishers, Inc., New York, v. 23, 1966, pp. 229-245. Green (moist) pellets rolled from natural and synthetic magnetites containing 66 and 68 percent iron, respectively, were reduced and indurated simultaneously in a 36-foot rotary kiln at 1,130° C with lignite, and in other tests at 1,150° C with anthracite. All four procedures resulted in physically competent upgraded pellets containing 80 to 90 percent iron with as much as 90-percent metallization. Lignite-produced pellets were capable of resisting from 200 to 300 pounds compression, and those produced with anthracite resisted 300 to 500 pounds. Both types were highly resistant to abrasion. Material balances of the product showed that from 91 to 96 percent of the iron units reported as plus ¼-inch pellets and much of the remainder was suitable for immediate blast furnace consumption or recycling.

OP 36-66. Preparation of Trimethylsilyl Ethers of Tertiary Alcohols, by Sidney Friedman and Marvin L. Kaufman. Anal. Chem., v. 38, No. 1, January 1966, pp. 144-145. Trimethylsilyl ethers of tertiary alcohols can be prepared by reacting the alcohol with hexamethyldisilazane in either dimethylformamide or dimethylsulfoxide. The method is applicable to other alcohols.

OP 37-66. Coking Coal Behavior in Gas-Producer Tests, by R. L. Gall and J. D. Spencer. Coal Age, v. 71, No. 2, February 1966, pp. 128-130. Describes the design and operation of a simple atmospheric pressure unit that was built to make comparative tests on two high-volatile highly caking coals. Both coals were from West Virginia, one from the Cedar Grove seam in the southern part of the State and one from the Pittsburgh seam in the northern fields. These tests were part of a program to develop a gas producer for the efficient production of industrial fuel gas from highly caking bituminous coal.

OP 38-66. Selective Plugging of Water Injection Wells, by Thomas M. Garland. J. Petrol. Technol., v. 18, No. 12, December 1966, pp. 1550-1560. A field study was made to determine the feasibility of changing the injection profile of water-input wells after water breakthrough at producing oil wells. Secondary objectives were to study the particle size and quantity of plugging materials required to change the input profile and methods of applying these materials. Fifty-three injection wells were treated with various amounts and types of commercial plugging materials; the injection profile was definitely changed in most of the wells treated. Increased efficiency of water injection after treatment was indicated by commercial tracer surveys and injection-well performance. There were some indications that the rate of water production was reduced and the rate of oil production was increased as a result of selective-plugging treatments, but it was found that an immediate change in the rate of oil and water production did not normally occur.

OP 39-66. Fiber Optic and Strain Probe Mass-Flux Meters for Gas-Solids Suspensions, by Harry G. Gilson, H. A. Dwyer, R. L. Peskin, and John D. Spencer. ASME Paper 66-FE-22, 1966, 6 pp. Describes two instruments developed for measuring the mass flux and mean properties of solid particles in gas-solids suspensions. One is a fiber-optic probe that derives signals from the attenuation of light by particles crossing the gap between the optic fibers. These signals are relayed to an oscilloscope giving a trace that is proportional to the local mass flux. The other device consists of a circular target attached to a rod at the end of a cantilevered metal strip. Solid particles and gas strike the target, deflecting the strip, and strain gages attached to the strip detect this strain and relay it to a recorder. Both instruments are shown to respond to individual solid particles and measure local mass flux.

OP 40-66. The Enthalpies of Combustion and Formation of the 1-Alkanethiols. The Methylene Increment to the Enthalpy of Formation, by W. D. Good and B. L. DePrater. J. Phys. Chem., v. 70, No. 11, November 1966, pp. 3606-3609. Enthalpies of formation of 1-hexanethiol, 1-heptanethiol, and 1-decanethiol were derived from rotating-bomb calorimetry. Earlier enthalphy of formation studies of short-chain 1-alkanethiols were revised to conform to present values of atomic weights and enthalpies of formation of combustion products. Methylene increments to the enthalpy of formation of 1-alkanethiols were computed.

OP 41-66. The Thermochemistry of Boron and Some of Its Compounds. The Enthalpies of Formation of Orthoboric Acid, Trimethylamineborone, and Diammonium-decaborane, by W. D. Good and M. Mansson. J. Phys. Chem., v. 70, No. 1, January 1966, pp. 97-104. The enthalpies of combustion of crystalline boron, trimethylamineborane, and diammonium decaborane were determined. The enthalpies of formation of trimethylamineborane, diammonium decaborane, and orthoboric acid were derived.

OP 42-66. Co-op Effort Pioneers Undersea Mining, by J. Leslie Goodier. Undersea Technol., v. 7, No. 1, January 1966, pp. 61-62. Outlines the program of the Marine Mineral Technology Center at Tiburon, Calif.

OP 43-66. Reactions of Coal in a Plasma Jet, by R. D. Graves, Walter Kawa, and R. W. Hiteshue. I&EC Process Design and Development, v. 5, No. 1, January 1966, pp. 59-62. Pulverized coal fed by entrainment into argon plasma jets was converted to a solid residue and gases. A maximum acetylene yield of 15 weight-percent of moisture- and ash-free coal was obtained.

OP 44-66. Gases: Thermodynamic Properties, by Roland H. Harrison. Ch. in Encyclopedia of Physics, ed. by M. Besancon, Reinhold Publishing Corp., Dayton, Ohio, 1966, pp. 291-293. Some fundamental principles relating to the thermodynamic properties of gases are explained. Methods are outlined for evaluating the thermodynamic properties of both ideal and real gases and also gas mixtures.

OP 45-66. Tetrafluoromethane: The Thermodynamic Properties of the Real Gas, by R. H. Harrison and D. R. Douslin. J. Chem. and Eng. Data, v. 11, No. 3, July 1966, pp. 383-388. The thermodynamic properties, $H—H^{\circ}$, $S—S^{\circ}$, and $C—C^{\circ}$, of tetrafluoromethane were determined as functions of temperature (0° to 350° C) and molal density (0.75 to 11.0 g-mole/liter) over a pressure range of 0 to 400 atm.

OP 46-66. Solvent Enhancement of Emissions Lines for Plasma Arc Determination of Vanadium in Petroleum Fractions, by Raymond J. Heemstra and Norman G. Foster. Anal. Chem., v. 38, No. 3, March 1966, pp. 492-493. A method is presented for increasing the sensitivity for the plasma arc determination of vanadium in petroleum fractions through the use of highly chlorinated solvents.

OP 47-66. A High-Temperature Electrowinning Cell for Rare Earths, by T. A. Henrie and E. Morrice. J. Metals, v. 18, No. 11, November 1966, pp. 1207-1208. An electrolytic cell for winning high-melting point rare-earth metals in the liquid state has been designed and operated. Gadolinium, dysprosium, and yttrium metals were prepared.

OP 48-66. An Optically Active Triterpane, Gammacerane in Green River, Colorado, Oil Shale Bitumen, by I. R. Hills, E. V. Whitehead, D. E. Anders, J. J. Cummins, and W. E. Robinson. Chem. Communications, v. 20, 1966, pp. 752-754. An optically active hydrocarbon separated from a Green River oil-shale bitumen was identified as gammacerane.

OP 49-66. Dithizone Extraction and X-Ray Spectrographic Determination of Trace Metals in High-Purity Tungsten or Tungsten Trioxide, by Grant L. Hubbard and Thomas E. Green. Anal. Chem., v. 38, No. 3, March 1966, pp. 428-432. Trace quantities of copper, nickel, lead, and zinc are extracted into chloroform solution of dithizone from alkaline tartrate solution containing up to 5 grams of tungsten. Dithizone in the organic extract is then oxidized with benzoyl peroxide and the trace metals are back-extracted into dilute hydrochloric acid. The separated trace metals are collected on ion exchange resin-loaded paper disks and determined by fluorescent X-ray spectrography. Copper, nickel, and zinc from 0.3 to 20 ppm and lead from 1.0 to 20 ppm are determined to within 0.3 ppm or with a relative standard deviation of 8 percent, whichever is greater. Cobalt can be estimated in the 0.1 to 1.0-ppm range.

OP 50-66. Air Pollutant Inventory—Enter the Diesel, by R. W. Hurn and D. E. Seizinger. Proc. API, v. 45, No. 3, 1965, pp. 127-132. Exhaust gases from truck-type diesel engines tested on a dynamometer stand were shown to involve hydrocarbons, oxides of nitrogen, and formaldehyde in significant quantities.

OP 51-66. Evaluation of Low-Temperature Coal Tars by A Rapid, Detailed Assay Based on Chromatography, by Clarence A. Karr, Jr., Joseph R. Comberiati, Kenneth B. McCaskill, and Patricia A. Estep. J. Applied Chem., v. 16, No. 1, January 1966, pp. 22-27. An assay, based largely on both liquid and gas chromatography, was developed for the determination of about 100 compounds of commercial interest in low-temperature coal tars.

OP 52-66. Removing Sulfur Dioxide From Flue Gases, by Sidney Katell. Chem. Eng. Prog., v. 62, No. 10, October 1966, pp. 67-73. Estimated capital investment and operating costs for three dry processes for removing sulfur dioxide from powerplant flue gas are projected for an 800-Mw plant burning 3-percent-sulfur coal.

OP 53-66. Bureau of Mines Research on Mine Safety, by D. S. Kingery. Proc. 55th Convention, Mine Inspectors' Institute of America, 1965, pp. 163-167. Summarizes the Bureau of Mines' work in research on mining safety; it covers work of roof-control research and reviews the recent developments in roof bonding and its application. Other discussions involve new developments in the field of rock mechanics. Ventilation research is discussed, pointing out the common ventilating methods that are used in coal mines and how such methods could be improved to improve face ventilation. In the session on mine explosions, flame spread on conveyor belts, the possible dust hazards in coal storage silos, and float dust transport are discussed.

OP 54-66. Reduce Your Drilling Cost With Visual Training Aids, by G. M. Kintz and F. C. Hill. World Oil, v. 163, No. 4, September 1966, pp. 89-92. The article describes visual aids and their effectiveness in training employees in the oil industry to recognize job hazards and avoid accidents.

OP 55-66. Acid Mine Drainage Pollution Control—Approach to Solution, by Stephen Krickovic. Min. J., v. 52, No. 12, December 1966, pp. 64-68. Describes the type of mines involved in the acid mine drainage problem and methods of reducing or eliminating acid mine drainage.

OP 56-66. Cyclopentane: Molecular Vibrational Analysis, by F. H. Kruse and D. W. Scott. J. Molecular Spectroscopy, v. 20, No. 3, July 1966, pp. 276-281. Normal coordinate calculations for cyclopentane were made with force constants transferred from *n*-paraffins. The vibrational assignment based thereon differs somewhat from any proposed previously but is consistent with calorimetric data.

OP 57-66. Ignition of Tank Atmospheres During Fuel Loading, by I. Liebman, I. Spolan, J. M. Kuchta, and M. G. Zabetakis. Proc. API, v. 45, sec. 3, 1965, pp. 217-230. An investigation was made to determine the formation, persistence, and ignition energy requirements of flammable zones which occur in the vapor space of fuel tanks during fuel loading. These flammability studies were made using JP-4, gasoline, and kerosine fuels which were loaded into a 2.4-cu ft cylindrical tank or a 22.5-cu ft simulated aircraft wing tank. The extent and duration of flammable zones was found to be dependent on fuel vapor pressure, temperature, flow rate, fuel inlet, and tank dimensions.

OP 58-66. The Stability of High Road Bank Slopes in Rock—Some Design Concepts and Tools, by A. E. Long, R. H. Merrill, and D. W. Wisecarver. Highway Res. Record, No. 135, 1966, pp. 10-26. The instruments and data analysis procedures used by the Bureau of Mines in a continuing study of predicting the steepness of the angle and height at which a rock slope will safely stand are described and discussed. The instruments and procedures represent the beginning of a scientific effort to quantify experimentally the engineering and general significance of the attitude of rock joints, bedding planes, and faults; the character of gravity and tectonic induced stresses in rock slopes with and without berms; slope geometry; ground water; and overblasting as they affect the stability of a rock slope. Also discussed is the use of the presplitting technique of blasting to form a smooth and tight slope face relatively free of rock falls.

OP 59-66. Thermal Fragmentation of Rock, by R. I. Marovelli, T. S. Chen, and V. F. Keith. Trans. SME, March 1966, pp. 1-15. An analytical study is made of thermal stress distribution in a thin circular disk subjected to a peripheral thermal shock at various rates of heat transfer. The problem is of importance in predicting thermal shock response of a rock body of finite size. The theoretical analysis is based on radial heat flow by combustion in the disk and heat exchange by convection between the disk and surroundings. The case of constant properties and plane stress is treated. Solutions of the stress distributions are presented for both cooling and heating shocks and an average stress theory is formulated. Preliminary experimental verification was obtained from the results of shock tests on thin rock disks insulated on both flat end faces so that heat exchange took place through the exposed peripheral surface.

OP 60-66. Prereduced Iron-Ore Pellets, State of the Art, by N. B. Melcher and M. M. Fine. J. Metals, v. 18, July 1966, pp. 795-802; Skillings' Mining Review (pt. 1), v. 55, No. 28, July 9, 1966, pp. 3-6; (pt. 2) No. 29, July 16, 1966, pp. 8-9, 23. Discusses methods of producing prereduced iron-ore pellets, costs of production, and the future of the pelletizing industry.

OP 61-66. A Study of Shale Oil for Pipe Line Gas Production, by H. C. Carpenter and P. L. Cottingham. Pipe Line Industry, v. 25, No. 1, July 1966, pp. 19-20. Shale oil could be a satisfactory raw material for production of pipeline gas should there be a need for supplementing the supply of natural gas.

OP 62-66. Strategic Minerals, by Charles W. Merrill. Min. Cong. J., v. 52, No. 2, February 1966, pp. 178-181. Discusses the eight most important strategic minerals—antimony, chromite, cobalt, columbium, manganese, mercury, tin, and tungsten. These are excess stocks of strategic-grade material in every commodity except refractory-grade chromite.

OP 63-66. U.S. Self-Sufficiency in Selected Metals and Minerals, by Charles W. Merrill. Eng. and Min. J., v. 167, No. 2, February 1966, pp. 77-79. The degree of U.S. self-sufficiency for 49 important minerals is graphically compared for six significant periods.

OP 64-66. Low-Temperature Thermodynamic Properties of *n*-Propyl and *n*-Butylbenzene, by John F. Messerly, Samuel S. Todd, and Herman L. Finke. J. Phys. Chem., v. 69, No. 12, December 1965, pp. 4304-4311. The heat capacities from 12° to 370° K, heats of fusion, triple points, and purities of *n*-propylbenzene and *n*-butylbenzene were measured in an adiabatic calorimeter. Both compounds exhibited monotropism with the metastable crystals melting 2.02° below the stable crystals in the case of *n*-propylbenzene and 0.16° below the stable crystals in the case of *n*-butylbenzene. From the calorimetrically measured data the thermodynamic functions $(G_s - H^\circ_0)/T$, $(H_s - H^\circ_0)/T$, $H_s - H^\circ_0$, S_s, and C_s were calculated at selected temperatures for each compound for both the metastable and stable crystals and the liquid phase. For each compound, the entropies at 298.15° K in the liquid state calculated by metastable and by stable paths agreed within experimental error, providing another check of the third law of thermodynamics. The entropy increment obtained between *n*-propylbenzene and *n*-butylbenzene is about 0.25 eu greater than the constant entropy increment for the normal paraffins from C_5 to C[illegible] in both the liquid and ideal gas states. This slightly larger increment from *n*-propyl to *n*-butyl substitution has been noticed earlier in monoalkyl-substituted cyclopentanes and cyclohexanes. From incomplete measurements on *n*-decylbenzene, values of the heat of melting and triple point temperature were obtained. Estimates of the entropies of *n*-decylbenzene at 298.15° K in the liquid and ideal gas states were made.

OP 65-66. Air Sealing as a Means of Abating Acid Mine Drainage Pollution, by Noel N. Moebs. 151st National Meeting, American Chemical Society, Pittsburgh, Pa., Mar. 22-31, 1966, Preprints, v. 10, No. 1, March 1966, pp. 93-100. Both field and laboratory tests indicate that if oxygen can be excluded from an abandoned coal mine, the oxidation of pyrite will be prevented and the acidity of the mine discharge reduced. A small abandoned mine with a highly acid discharge has been selected, and it is planned to seal it to prevent air from entering it. A study of the geologic and hydrologic environment of the mine is expected to serve as a basis for comparing the quality of the mine discharge before and after sealing.

OP 66-66. Comparison of Porphyrins From Shale Oil, Oil Shale, and Petroleum by Absorption and Mass Spectroscopy, by J. R. Morandi and H. B. Jensen. J. Chem. and Eng. Data, v. 11, No. 1, January 1966, pp. 81-88. Mass and absorption spectroscopy were used to characterize porphyrins extracted by a hydrogen bromide-acetic acid solution from an oil shale, a shale oil, and a petroleum. The porphyrins in oil shale and petroleum were shown to be similar and to consist of at least two homologous series. These porphyrins were alkylsubstituted and contain from 7 to 13 methylene substituents per molecule, and most of the molecules also contained a carboalkoxy group. Their average molecular weights were 508 for the shale porphyrins and 494 for the petroleum porphyrins; their visible spectra were of the phyllo type. The porphyrins in shale oil are a complex mixture of etio-type porphyrins. They have a molecular weight range of 366 to 522. There is evidence for the lack of an isocyclic ring and for the presence of both one and two carboalkoxy groups per molecule.

OP 67-66. A New Look at the Cause of Fuming, by J. P. Morris, J. P. Riott, and E. G. Illig. J. Metals, v. 18, No. 7, July 1966, pp. 803-810. The mechanics of fuming of iron-carbon melts during top-blowing with oxygen was investigated. Melts weighing 45 lb were prepared in an induction furnace and blown with oxygen by means of water-cooled lances. The rate of fuming was measured and correlated with the operating variables. The data showed that the primary cause of fuming was a boil at the bath surface in the impingement zone of the jet. Nucleation of the carbon monoxide bubbles producing the boil was brought about by the precipitation of an oxide phase. The actual fuming mechanism apparently involved oxidation, vaporization, and mechanical disintegration of bubble films and fine metal spray generated by the bursting of the bubbles. The rate of fuming was found to be proportional to the carbon content of the metal, the concentration of oxygen in the jet, and the bath temperature, provided that a continuous boil occurred. In the absence of a boil, very little fume was produced.

OP 68-66. The Energy Dilemma—Which Fuel, What Market, When? by Warren E. Morrison. SME Fall Meeting, Rocky Mountains Min. Conf., Oct. 7-9, 1965, Preprint 65 K 302, 26 pp. Reasonably accurate predictions of total energy consumption can be made for periods up to 15 years by relating energy to projections of economic indicators. However, forecasting by component parts of the energy economy results in the dilemma that the sum of the projected parts frequently exceeds the whole. Experience shows that unilateral forecasting of a single source of energy results in a high degree of expected variation since this does not reflect the multiple interrelationships among energy resources and their markets. This paper attempts to overcome some of these deficiencies by projecting the demand for energy resources within the context of total energy balances. The paper forecasts U.S. demand for coal, natural gas, petroleum products, hydropower, and nuclear power for the period 1963-80. Separate energy balances are presented for the years 1965, 1970, 1975, and 1980. Each balance is made up of interrelated projections of energy demand by source and consuming sector. The balances are based on Bureau of Mines data for a recent historical period, and have been subjected to assumptions and techniques of forecasting outlined in the paper. Estimates are also made of levels of domestic production that would be required to meet projected consumption of energy resources during the forecast years.

OP 69-66. Vapor Pressure Relations of 36 Sulfur Compounds Present in Petroleum, by Ann G. Osborn and Donald R. Douslin. J. Chem. Eng., v. 11, No. 4, October 1966, pp. 502-508. Compilations of vapor pressures measured by static and ebulliometric methods, covering more than five orders of magnitude in pressure, are given for "key" members of classes of alkane thiols, alkane sulfides, alkane disulfides, and cyclic sulfides which were selected for a comprehensive study of their thermodynamic properties.

OP 70-66. Inelastic Deformation of Rock Under a Hemispherical Drill Bit, by J. Paone and S. Tandanand. Trans. SME, June 1966, pp. 113-124. This paper studies the behavior of rock at the initial state of crater formation resulting from stresses created under a drill bit. The maximum yield strength or hardness of rock were considered from the Mohr-Coulomb criterion from which the surface of failure was constructed.

OP 71-66. Front-end Loader Accidents, by R. O. Pynnonen. Canadian Pit and Quarry, v. 7, No. 9, September 1966, pp. 38-39; Min. Cong. J., v. 52, No.

11, November 1966, pp. 60-62. Discusses the causes of 44 fatal accidents with front-end loaders.

OP 72-66. Electro-Osmotic and Electrophoretic Dewatering as Applied to Solid-Liquid Separation, by Carl Rampacek. In Solid-Liquid Separation: A Review and a Bibliography, by J. B. Poole and D. Doyle. Ministry of Technology. H. M. Stationery Office, London, 1966, pp. 100-108. Reviews the literature on electrophoretic and electro-osmotic dewatering of clays and other fine mineral particles. Discusses present and potential uses of electrophoresis and electro-osmosis in the mineral industry, including methods for dewatering clays, soils, or silts in situ.

OP 73-66. Problems Facing the North American Iron Ore Industry, by Horace T. Reno and Francis E. Brantley. Skillings' Min. Rev., v. 55, No. 6, Feb. 5, 1966, pp. 6-7, 22-23. Discusses the problems of the North American iron ore industry—foreign competition, grade of ore, beneficiation, stocks, and markets.

OP 74-66. Composition and Crystallographic Data for the Highest Boride of Tungsten, by P. A. Romans and M. P. Krug. Acta Crystall., v. 20, pt. 2, February 1966, pp. 313-314. Gives results of a study of WB_4, the highest boride of tungsten, which found the unit cell to be hexagonal with $a_0 = 5.200$ A and $c_0 = 6.340$ A. Evidence was found that while the ideal formula is WB_4, the compound studied may contain more than stoichiometric amounts of boron.

OP 75-66. Mining on the Moon, by Clifford W. Schultz. New Scientist, v. 31, No. 503, July 7, 1966, p. 33. Research on using lunar resources, in particular theoretical and experimental studies of possible mining and mineral processing techniques applicable on the Moon, can prepare for the day when decisions have to be taken about the feasibility of manned lunar bases.

OP 76-66. Chromatographic Analysis of Gas Streams Associated With Helium Production, by C. A. Seitz, Al Purer, and C. L. Klingman. Gas, v. 42, No. 9, September 1966, pp. 56-65. Details are given for the chromatographic analysis of seven gas streams associated with helium production. Only one stream at a time may be monitored.

OP 77-66. Food From Coal-Derived Materials by Microbial Synthesis, by Melvin P. Silverman, Joan N. Gordon, and Irving Wender. Nature, v. 211, No. 5050, Aug. 13, 1966, pp. 735-736. Results of an evaluation of a variety of coal-derived materials as growth substrates for microorganisms are reported. Coal is a potential source of immense quantities of high-protein food.

OP 78-66. Estimation of Solubility of Bismuth Compounds in Liquid Ammonia, by Annie G. Smelley, Francis E. Brantley, and Arthur F. Findeis. Anal. Chem., v. 38, No. 3, March 1966, pp. 449-451. The solubilities of the triiodide, trichloride, tribromide, nitrate, sulfate, and lactate of bismuth in liquid were determined polarographically.

OP 79-66. Conversion Constants for Mahogany-Zone Oil Shale, by John Ward Smith. Bull. Amer. Assoc. Petrol. Geol., v. 50, No. 1, January 1966, pp. 167-170. Describes the Bureau of Mines method for accurately determining the organic content of oil-shale samples and the elemental composition of this organic matter.

OP 80-66. Dawsonite in the Green River Formation of Colorado, by John Ward Smith and Charles Milton. Econ. Geol., v. 61, No. 6, 1966, pp. 1029-1042. Widespread occurrence of dawsonite, an unusual sodium aluminum carbonate potentially an economic source of aluminum, in oil shales of Colorado's Piceance Creek basin is described.

OP 81-66. Ankerite in the Green River Formation's Mahogany Zone, by John Ward Smith and William A. Robb. J. Sedimentary Petrol., v. 36, No. 2, June 1966, pp. 486-490. Ankerite, a dolomite altered by isomorphous cation substitution, is the primary carbonate mineral in Mahogany zone oil shales of the Green River Formation in Colorado and Utah. X-ray diffraction spacings determined on 10 composite samples representing the zone over a broad geographic area are shifted from those of unsubstituted dolomite to spacings very similar to an ankerite. Substitution of Fe^{++} for Mg^{++} in these samples was insufficient to account for the large shifts detected. Isomorphous substitution of Sr^{++} for Ca^{++}, suggested as contributing to the shift in spacing, was strongly supported by correlation significant to more than 99 percent between d_{104} spacing shift and the proportions of substitution of Fe^{++} for Mg^{++} and Sr^{++} for Ca^{++} in these samples.

OP 82-66. In Situ Oil Shale Retorting, by H. W. Sohns and H. C. Carpenter. Chem. Eng. Prog., v. 62, No. 8, August 1966, pp. 75-78. In situ techniques that have been successfully employed in petroleum recovery can probably be used for recovery of oil from shale. Field tests should provide solutions to most of the problems.

OP 83-66. Determination of Metallic Impurities in Molybdenum by a Combined Ion Exchange-X-Ray Spectrographic Method, by Ernest F. Spano and Thomas E. Green. Anal. Chem., v. 38, No. 10, August 1966, pp. 1341-1345. Trace quantities of cobalt, copper, iron, lead, manganese, nickel, and zinc are separated from molybdenum by ion exchange. The separated trace metals are collected on ion-exchange resin-loaded paper disks and determined by X-ray fluorescence with a precision of ±10 percent of the amount present.

OP 84-66. Instant Tips for Authors, by John D. Spencer. STWP Rev., v. 13, No. 3, July 1966, p. 18. Describes a series of technical writing aids. The "tip" is a single-page treatment of some aspect of technical writing, usually done in a humorous style.

OP 85-66. Electrochemical Reduction of Aromatic Hydrocarbons in Ethylenediamine, by Heinz W. Sternberg, Raymond E. Markby, Irving Wender, and David M. Mohilner. J. Electrochem. Soc., v. 113, No. 10, October 1966, pp. 1060-1062. In a solution of ethylenediamine containing lithium chloride, polycyclic aromatic hydrocarbons are reduced by direct electron transfer from cathode to substrate provided a platinum electrode free of surface oxides is used. Evidence is presented that in this system benzene is reduced with lithium cation acting as an electron transfer agent.

OP 86-66. Clean Gas From Coal May Be Economical Fuel for Gas Turbines, by Donald C. Strimbeck and John H. Faber. Power Eng., v. 70, No. 7, July 1966, pp. 52-53. A gas producer can be integrated into combined cycle, to generate clean gas that will minimize compressor erosion and air pollution.

OP 87-66. High Pressure Mass Spectrometry for Analysis of Trace Impurities in Helium, by Elmer T. Suttle, David E. Emerson, and Diana W. Burfield. Anal.

Chem., v. 38, No. 1, January 1966, pp. 51-53. Trace impurities in helium in the parts per million range have been analyzed with a conventional mass spectrometer. To increase the sensitivity, the inlet sample pressure was increased from the micron to the millimeter range and the ionizing current to 100 microamperes.

OP 88-66. A Flame Spectrophotometric Method for Sodium, Potassium, and Calcium in Fuel Oil, by Rex D. Thomas. Anal. Chem., v. 38, No. 6, May 1966, pp. 785-786. A flame spectrophotometric method using a standard-addition technique was developed for the determination of 0.1 to 10 milligrams per liter of sodium, potassium, and calcium in distillate fuel oils. The method is rapid, sensitive, and relatively unaffected by interferences.

OP 89-66. Identification of Naturally Occurring Cyclic Sulfides in a Wilmington, Calif., Crude Oil Distillate Boiling From 111° to 150° by Use of a Series of Gas-Liquid Stationary Phases, by H. L. Coleman, C. J. Thompson, R. L. Hopkins, and H. T. Rall. J. Chromatography, v. 25, 1966, pp. 34-47. Describes the positive identification of 18 cyclic sulfides in a Wilmington, Calif., 111° to 150° C distillate and the systematic separation and identification procedures employed.

OP 90-66. Sulfur Compound Characterization Studies on High-Boiling Petroleum Fractions, by C. J. Thompson, H. J. Coleman, H. T. Rall, and N. G. Foster. Preprints, American Chemical Society, Division of Petroleum Chemistry, v. 11, No. 2, March 1966, pp. 85-93. Paper describes the preparation of sulfur compound concentrates boiling from 225° to 400° C and reports the sulfur types present as suggested by low-voltage mass spectrometry. The procedures described should be generally applicable.

OP 91-66. Heavy Liquid Cyclone Concentration of New Mexico Potash Ores, by R. B. Tippin and J. S. Browning. Trans. SME, December 1966, pp. 360-366. The Bureau of Mines has conducted research to develop processes for heavy-liquid concentration of potash ores. This method of concentration is discussed, and results of tests made on potash ores from New Mexico are presented. The tests demonstrated the technical feasibility of producing near commercial-grade potash concentrates, with a high recovery of the contained sylvite.

OP 92-66. Project Gasbuggy—A Nuclear Fracturing Experiment, by Don C. Ward, Charles H. Atkinson, and J. Wade Watkins. J. Petrol. Technol., v. 18, No. 2, February 1966, pp. 139-145. Project Gasbuggy was instituted to design, conduct, and evaluate a nuclear fracturing experiment and it is a joint undertaking by the U.S. Atomic Energy Commission, the Bureau of Mines, the Lawrence Radiation Laboratory, and the El Paso Natural Gas Co. The experiment is designed for the detonation of a 10-kiloton fission explosive at a depth of 4,150 feet to evaluate th stimulative effect on gas production from the Pictured Cliffs Formation in the San Juan Basin of New Mexico.

OP 93-66. Appalachian Region Oilfield Reservoir Investigations, Keener and Big Injun Sands, Wingett Run Field, Ludlow Township, Washington County, Ohio, by C. E. Whieldon, Jr., and D. M. Evans. Producers Monthly, v. 30, No. 8, August 1966, pp. 10-12. The Bureau of Mines obtained oil-reservoir samples of the Keener and Big Injun sands by coring the Oxford Oil Co. K. M. Day well 1 in the Wingett Run field, section 27, Ludlow township, Washington County, Ohio. Geophysical well logs, core analysis, geology, and oilfield development are presented. This work is part of a broader effort to evaluate the potential oil recovery of this area by secondary-recovery operations.

OP 94-66. Appalachian Region Oilfield Reservoir Investigations, Venango Group, First, Lytle, and Second Sands, Walnut Bend Pool, Cornplanter Twp., Venango County, Pa., by Charles E. Whieldon, Jr., and William K. Overbey, Jr. Producers Monthly, v. 30, No. 6, June 1966, pp. 2-5. The Bureau of Mines obtained oil-reservoir samples of the Venango First, Lytle (Red Valley), and Venango Second sands by rotary air coring a well in the Walnut Bend pool, Cornplanter township, Venango County, Pa. Core analysis, well logs, and well-completion data are presented.

OP 95-66. Anodic Electropolishing of Stainless Steel Apparatus, by M. L. Whisman. Materials Res. and Standards, v. 6, No. 1, January 1966, pp. 24-25. Describes an anodic electropolishing method for removing deposits of varnish and lacquer or residual radioactivity from stainless steel containers used in small-scale thermal stability tests. A mixture of glycolic acid, phosphoric acid, and sulfuric acid was used for the electrolyte and a copper wire or rod as the cathode. A similar procedure can be used for electropolishing aluminum using fluoboric acid as the electrolyte.

OP 96-66. Storage Stability of High Temperature Fuels, Part 2, by Marvin L. Whisman and C. C. Ward. Air Force Aero Propulsion Laboratory, Research and Technology Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, AFAPL-TR-65-13, February 1966, 168 pp. This report covers the second year's work by the Bureau of Mines, working under a 3-year Air Force contract, on an investigation of the influence of fuel constituents on thermal stability during storage of Spec MIL-J-25656B type (JP-6) and other high-temperature fuels. These investigations are contingent upon the successful development of several methods utilizing radiotracers to determine the causes of thermal instability as well as predicting thermal stability of high-temperature fuels during storage. Ninety-four test blends representing 12 fuels and 9 radioactive fuel components were prepared, tested, and stored at 130° F in the evaluation of a microscale thermal stability procedure developed for the purpose of determining the contribution of selected fuel components to thermally induced deposits. Sixty-four of these test blends reached 26 weeks storage interval and were retested to determine the effect of storage upon deposit-forming tendencies. A study of several variables associated with a dynamic microhydrogenation method using tritium as the index of reactivity was completed. Final investigation with a series of test fuels and pure hydrocarbons concluded the application of the technique. An alternate static system of hydrogenation utilizing active metal catalysts prepared by the in situ treatment of the metal salt with sodium borohydride and the in situ generation of hydrogen from sodium borohydride was completed. A revised procedure employing tritium-labeled borohydride was likewise developed and evaluated. The third modification of a proportional counting device designed to accept the preheater tube from either research or standard cokers was successfully tested and shown to represent an improvement over previous designs.

OP 97-66. Suppression of Selective Volatilization in a Method for the Spectrographic Analysis of Lanthanum, by A. B. Whitehead, B. C. Piper, and H. H. Heady.

Appl. Spectroscopy, v. 20, No. 2, April 1966, pp. 107-112. The effects of electrode type, arc, current, and the Stallwood Jet on selective distillation of impurities other than rare earths in La_2O_3 are evaluated. Selective volatilization is reduced by use of a 20-A dc arc with a ⅛-inch-diameter electrode. An analytical method incorporating these operating conditions is presented for 19 impurity elements in La_2O_3 prepared from the lanthanum metal sample. The overall precision is about ±14 percent relative standard deviation over the concentration range of 30 to 1,000 ppm.

OP 98-66. Constant Low-Voltage Drop Rotating Electrode Assembly, by Charlie Wyche and Frank X. McCawley. Electrochem. Technol., v. 4, No. 7-8, July-August 1966, p. 144. Describes an efficient low-voltage drop electrode rotating mechanism developed at the College Park Metallurgy Research Center.

OP 99-66. Synthesis of Ethylmethylphenols, by R. W. Youngs and W. W. Fowkes. Proc. North Dakota Acad. Science, v. 19, April 1966, pp. 100-103. The synthesis of 2-ethyl-3-methylphenol and a simpler route to the preparation of 3-ethyl-4-methylphenol are described. Physical constants and infrared spectra are reported.

OP 100-66. X-Ray Absorption and Emission, by William J. Campbell, James D. Brown, and John W. Thatcher. Anal. Chem., Ann. Rev., v. 38, No. 4, April 1966, pp. 416R-439R. Surveys the literature on fundamental developments and gives tabular summaries of applications of X-ray spectrography and electron-probe microanalysis. Most of the references cited were published in 1964 and 1965.

OP 101-66. Equilibrium Sorption Studies of Methane on Pittsburgh Seam and Pocahontas No. 3 Seam Coal, by R. B. Anderson, J. Bayer, and L. J. E. Hofer. Coal Science, Advances in Chem., Ser. 55, Paper 24, 1966, pp. 386-399. Methane is adsorbed at atmospheric pressure and 30° C, 2.89 cc (STP)/gram (lvb) and 1.97 cc (STP)/gram (hvab). Pore volumes are 0.136 cc/gram (lvb) and 0.020 cc/gram (hvab).

OP 102-66. How Nuclear Explosions Can Boost Gas-Storage Capacity, by Charles H. Atkinson and D. C. Ward. Oil and Gas J., v. 64, No. 34, Aug. 22, 1966, pp. 102-105. The need for gas-storage capacity near metropolitan areas opens new fields of study as part of the Plowshare program. Results show that cost of storing gas in cavities formed by nuclear explosives will be less than for liquefied natural gas or mined cavity storage. Under current study are problems which may arise from radioactivity and seismic shock and the feasibility of a field test.

OP 103-66. A Survey of the Sulfur Reduction in Northern Appalachian Region Coal by Stage Crushing, by A. F. Baker, A. W. Deurbrouck, and E. R. Palowitch. Annual Meeting, AIME, New York, Feb. 27-Mar. 3, 1966, Preprint 66F26, 17 pp. The effect of crushing on the release of sulfur impurities in five of the most important northern Appalachian region coals has indicated that the Upper and Lower Freeport and Upper Kittanning beds show significan sulfur reduction when crushed to 14-mesh top size. Samples of the Pittsburgh and the Lower Kittanning beds did not show significant sulfur reduction when crushed to finer sizes.

OP 104-66. Centrifugal Casting of Tungsten, by E. D. Calvert and R. A. Beall. J. Metals, v. 18, No. 1, January 1966, pp. 39-46. Describes the design and operation of a skull-casting furnace specifically designed for tungsten casting. Technique is sufficiently advanced that hollow and solid billets can be prepared. In general grain size is smaller than that normally obtained in arc-melted ingots, and the castings can be further worked by a variety of processes.

OP 106-66. Why a Fire Flood Project Failed, by G. G. Campbell, E. L. Burwell, T. E. Sterner, and L. L. Core. World Oil, v. 162, No. 2, Feb. 1, 1966, pp. 46-50. The Bureau of Mines has completed evaluation of a pilot underground combustion project conducted in a shallow, high-gravity, paraffin-base crude oil reservoir in northwestern Pennsylvania. Although the project failed to increase production, it provided valuable information on the applicability of the combustion process to similar reservoirs containing low-viscosity oil. The article describes performance of the combustion test, cites reasons for its failure, and recommends procedures which should solve the problems encountered.

OP 107-66. Analysis of Beryllium Metal and Its Compounds by Optical Emission Spectrography, by L. Carpenter, R. W. Lewis, and K. A. Hazen. Appl. Spectroscopy, v. 20, No. 1, January/February, 1966, pp. 44-46. Eighteen elements were determined in beryllium from 5 to 1,000 ppm by a dc-arc method. Samples were dissolved in hydrochloric acid, converted thermally to beryllium oxide, then mixed with graphite and barium carbonate for determining calcium, mixed with cupric oxide for determining boron and molybdenum, and mixed with graphite and germanium oxide for determining the other 15 elements. Spectral transmittances of analytical and internal lines were converted to relative-intensity ratios which were plotted against concentrations of standards to form curves from which concentrations of impurities were read.

OP 108-66. High-Temperature, Low-Rate Hydrocarbons Compressor, by R. P. Csamer and James P. McGee. Chem. Eng., v. 73, No. 24, Nov. 21, 1966, pp. 154, 156. Describes a piston-type short-stroke compressor that is leakproof and satisfactorily recycles about 1 cubic foot per minute of hydrocarbon gas at 1,000° F and atmospheric pressure.

OP 109-66. Bureau of Mines Updates Respirator Criteria, by B. I. Ferber. Nat. Safety News, v. 94, No. 5, November 1966, pp. 54-55. Requirements recently included in revised respirator approval schedules are discussed. Provisions to be included with other revisions are also discussed.

OP 110-66. Effect of Additives on Phase Diagrams: Normal Butane Added to Condensate-Natural Gas System, by Byron A. Baker and C. Kenneth Eilerts. Proc. 25th Tech. Conf. Petrol. Production, Pennsylvania State University, October 19-21, 1966, College of Earth and Min. Sci. Experiment Station Circ. 71, pp. 317-352. The effect on phase-boundary pressures of a related series of condensate mixtures of additions of normal butane was determined with a windowed PVT cell. The investigation was conducted at pressures up to 5,000 psia and at temperatures in the range 70° to 310° F. Relationship of the critical state to changing compositions was evaluated. The fluids were a mixture of intermediate hydrocarbons and selected distillation cuts from a field condensate combined with mole fractions of natural gas in the range 0.800 to 0.933. The data were subjected to statistical analysis using a computing program that provided a polynomial for interpreting the results. The polynomial yields phase-boundary pressure, and independent variables are temperature, natural gas content, and mole fractions of normal butane additive. A method is described for approximating such a polynomial before measurements are complete, using a mathematical model that requires more measurements than are available.

OP 111-66. Separation by Ultrasonic Elutriation and Analysis of the Fine Particles in Sandstone, by Jerry B. F. Champlin and Rex D. Thomas. J. Sedimentary Petrol., v. 36, No. 4, December 1966, pp. 1152-1156. Apparatus and technique for quantitative removal of fine particles from crushed sandstones are described. Chemical and X-ray mineralogical analyses of the fine portion of natural sediments are enhanced.

OP 112-66. Removal of Water Blocks From Gas-Producing Formations, by J. L. Eakin, J. S. Miller, and W. E. Eckard. API Drilling and Production Practices, 1965, pp. 26-39. A method was developed in the laboratory and in the field to relieve capillary waterblocks in gas wells. Impaired gas permeability was improved by this inexpensive chemical treatment which lowers the surface tension of the water held in the capillaries of the formation. Effectiveness of the alcohol-surfactant treatment was tested with a variety of chemicals and with standstone cores cut from rocks having relatively low permeability. Field tests on 20 gas-producing and storage wells demonstrated the effectiveness and limitations of the method. The productive capacity of some wells was doubled by the treatment. The final test was evaluated by the neutron logging technique for measuring changes in apparent liquid saturation. Maximum apparent liquid saturation was reduced by 52 percent; gas production rate increased from 2.3 to 3.5 million cubic feet per day.

OP 113-66. Sintering of Yttrium Oxide, by LeRoy R. Furlong and Louis P. Domingues. Am. Ceram. Soc. Bull., v. 45, No. 12, December 1966, pp. 1051-1054. Yttrium oxide compacts of density exceeding 97 percent of theoretical were obtained by sintering at the relatively low temperature and short soak time of 1,600° C and 1 hour. Distributions of particle size of powder and of pore size of green compact were found to affect the sinterability of yttrium oxide to a great degree. Variation in powder properties was obtained by decomposing six salts of yttrium.

OP 114-66. A Study of Lattice Dilation in Finely Divided MgO, by Ronald C. Garvie. Materials Res. Bull., v. 1, No. 3, November 1966, pp. 161-171. The lattice parameter of MgO is an important parameter in its characterization and may usually be regarded as a constant of the material. However, the lattice parameter of this solid, in a finely divided state, is a variable, becoming larger as the crystallite size becomes smaller. In this paper, using published data for MgO, a theoretical interpretation of this phenomenon is given, based on the fundamental cohesive forces which hold the crystal together.

OP 115-66. Pneumatic Coal Transport: Difficult But Promising, by L. J. Kane and J. D. Spencer. Power Eng., v. 70, No. 8, August 1966, pp. 58-69. Discusses the 22 technical papers presented at the symposium on the pneumatic transportation of solids sponsored by the Institute of Gas Technology and the Bureau of Mines.

OP 116-66. Subsolidus Equilibria in the System MgO-GeO_2-MgF_2, by George Robert McCormick. J. Am. Ceram. Soc., v. 49, No. 11, November 1966, pp. 618-620. Four MgO-GeO_2-MgF_2 compounds, analogous to the humite minerals, were synthesized by solid-state reaction by substituting germanium for silicon. The 43 selected compositions were sintered at 800° to 1,200° C. Solid-state compatibility relations were established from petrographic and X-ray diffraction analyses. The optical properties and characteristic X-ray diffraction data for the four MgO-GeO_2-MgF_2 compounds were determined and $2MgO \cdot GeO_2 \cdot MgF_2$, $4MgO \cdot 2GeO_2 \cdot MgF_2$, and $6MgO \cdot 3GeO_2$ MgF_2 were indexed by Ito's method.

OP 117-66. Pressurized Gas Producer, by James P. McGee, George M. Hamilton, and J. H. Faber. Gas Turbine Catalog, v. 7, No. 6, November-December 1966, pp. 30-31. Describes the design and operation of a fixed-bed producer to process highly caking coal into a pressurized gas.

OP 118-66. The Role of Microstructure in the Physical Properties of Rock, by J. R. McWilliams. In Testing Techniques for Rock Mechanics, ASTM Special Tech. Pub. 402, 1966, pp. 175-189. Presents an experimental technique relating rock microstructure to sonic and mechanical properties. Data are presented for three orthogonal directions to introduce the concept of anisotropy.

OP 119-66. Shape of the Coexistence Curve of an Analytical Fluid in the Critical Region, by Robert E. Barieau. J. Chem. Phys., v. 45, No. 9, November 1966, pp. 3175-3177. For an analytical fluid it is shown that the relationship between coexisting phases is given by $a_3 = -a_1(1+Ma_1)$, where $a_3 = (\rho_{liq}/\rho_c)-1$, $a_1 = (\rho_{gas}/\rho_c)-1$, $M = -4/15 - \frac{1}{3}\ (p_{aal}/p_{al}) + (p_{aaaa}/p_{aaa})$, $p = P/P_c - 1$, and p with subscripts indicates partial derivatives of p evaluated at the critical point. Coexisting phase as a function of temperature are given by $a_1 = (3Mp_{al}t/p_{aaa}) - (-6p_{al}t/p_{aaa})^{1/2}$, $a_3 = (3Mp_{al}t/p_{aaa}) + (-6p_{al}t/p_{aaa}{}^{1/2}$, wtere $t = (T/T_c) - 1$. The reduced rectilinear diameter is given by $[(a_3+a_1(/2]+1 = 1 + (3Mp_{al}t/p_{aaa})$. The reduced slope of the reduced rectilinear diameter is given by $\frac{1}{2}[d(a_1+a_3)/dt] = 3Mp_{al}/p_{aaa}$.

OP 120-66. Improve Your Ventilation and Save, by John Nagy and Edward M. Kawenski. Coal Min. and Processing, v. 3, No. 9, September 1966, p. 28. Recent research at the Bureau of Mines Experimental Coal Mine demonstrates that proper construction and repair of stoppings and overcasts improve face ventilation without costly changes in fan installation.

OP 121-66. Latest Developments in the Bureau of Mines Research Related to Damage Criterion. Presplitting and Short Delay Blasting, by Leonard Obert. Pit and Quarry, v. 58, No. 7, January 1966, pp. 162-165, 192. Discusses the Bureau of Mines research on vibrations produced by quarry blasting. The recommended basis for a safe blasting vibration criterion for surface structures is particle velocity; the recommended limiting value is 2.0 inches per second; and a safety factor of 2 is recommended.

OP 122-66. Lithologies, Environments, and Reservoirs of the Middle Mississippian Greenbrier Group in West Virginia, by William K. Overby, Jr. Proc. Symp. Petrolum Geology of the Appalachian Basin, 25th Tech. Conf. on Petroleum Production, Pennsylvania State University, October 1966, pp. 39-74. Comparison of lithologies observed in subsurface cores with outcrop samples of the basal members of the Greenbrier Group of the middle Mississippian in West Virginia indicate that oil and gas reservoirs found within this interval are the result of several slightly different but related depositional environments. These environments and the resulting lithologies are (1) moderate to high energy environment above or near wavebase producing an oolitic limestone or a slightly sandy, oolitic limestone; (2) moderate to high energy beach and near-shore environment producing a sandy limestone-limy sand facies; and (3) moderate to high energy environment at or near wavebase producing a skeletal, biohermal limestone. In the subsurface, all of the above lithologies were modified to some extent by subsequent dolomitization which produced reservoirs controlled primarily by the areal extent of dolomitization. Methods of investigation to determine lithologies and environments are discussed and possible methods of exploration for these primarily stratigraphic-type reservoirs are presented.

OP 123-66. Appalachian Region Oilfield Reservoir Investigations, Basal Greenbrier Group, Dolomite Zone ("Big Injun"), Sycamore Field, Sherman District, Calhoun County, W. Va., by William K. Overbey, Jr., and Charles E. Whieldon, Jr. Producers Monthly, v. 30, No. 4, April 1966, pp. 16-19. The lower portion of the Mississippian Basal Greenbrier limestone, including the dolomite zone, was diamond-rotary cored in a well in the Sycamore field, Sherman district, Calhoun County, W. Va. Well logs were run to supplement core analysis data. Geology, lease development history, and well completion data are presented.

OP 124-66. Theoretical and Field Waterflood Performance, Kane Oilfield, Elk County, Pa., by Leo A. Schrider, John R. Duda, and Harry R. Johnson. 25th Tech. Conf. on Petroleum Production, Oct. 21-26, 1966, Pennsylvania State University, University Park, Pa., Experiment Station Circ. 71, 1966, pp. 287-304. A prediction for oil recovery from a pilot waterflood in the Kane oilfield was made and compared with actual field performance. The calculated behavior of the pilot waterflood was predicted using a modified Craig, Geffen, and Morse calculation technique. Maximum recovery from this low-permeability, preferentially oil-wet formation was predicted to be about 25,000 barrels of oil after 300,000 barrels of water had been injected into the pilot area. After additional field data were collected, it became necessary to reevaluate the pilot flood area. The gas saturation prior to the flood was estimated to have been 20 percent, based on an assumption regarding the required volume of water injected to initiate oil production. In view of the actual field performance, a gas saturation of 13 percent is indicated. When this gas saturation and the method originally proposed by Craig and coworkers are used, the predicted results are more representative. In December 1965 field performance was further analyzed using a hyperbolic decline curve as presented by Arps. Based upon this evaluation method, the pilot waterflood in the Kane sand should produce 37,000 to 42,000 barrels of oil with the injection of 300,000 barrels of water or 129 to 142 barrels per acre-foot from 36.5 acres.

OP 125-66. Review of Some of the Fundamentals of Hydrocarbon Storage Stability, by F. G. Schwartz and C. C. Ward. Trans. SAE, v. 74, 1966, pp. 983-992. This paper summarizes the results of storage stability tests on distillate fuels and gasolines. A general equation for fuel deterioration curves is presented.

OP 126-66. Microbial Synthesis of Food From Coal-Derived Material, by Melvin P. Silverman, Joan N. Gordon, and Irving Wender. In World Protein Resources. Advances in Chem. Ser. 57, 1966, pp. 269-279. Yeasts grown on certain coal-derived materials give protein in as high yield as can be obtained from the best petroleum substrates. Fischer-Tropsch synthetic fuel fractions are excellent substrates for food production; a low-temperature tar may also be used.

OP 127-66. Bureau of Mines Progress in Developing Open and Closed-Cycle Coal-Burning Gas Turbine Power Plants, by J. Smith, D. C. Strimbeck, N. H. Coates, and J. P. McGee. Trans. ASME, v. 88A, No. 4, October 1966, pp. 313-322. Closed-cycle developments include tests of a turbocompressor with hydrodynamic gas bearings. The working fluid is inert gas, with turbine inlet temperatures to 1,600° F. A refractory-metal turbine for tests at 1,950° F is described. Open-cycle operations for 1,963 hours with turbine blades specially designed to resist erosion by coal ash particles are described. Estimated life of the rotor and stator blading was 20,000 and 5,000 hours, respectively. Efforts to increase blade life by reducing the amount of ash entering the turbine through improvements in combustion and ash separation systems are described.

OP 128-66. Electrochemical Reductions in Ethylenediamine, by H. W. Sternberg, C. L. Delle Donne, R. E. Markby, and I. Wender. Coal Science. Advances in Chem. Ser. 55, 1966, pp. 516-520. The effect of operating variables on the electrochemical reduction of tetralin used as a model compound for the hydrogenation of coal is described.

OP 129-66. Appalachian Region Oilfield Reservoir Investigations, Clinton Sandstone, Carbon Hill West Pool, Green Township, Hocking County, Ohio, by Charles E. Whieldon, Jr. Producers Monthly, v. 30, No. 12, December 1966, pp. 6, 7, 26. Clinton sandstone was cored and well logs were run in the R. L. Conner well 3, Carbon Hill West Pool, Hocking County. This work is part of a broader effort to evaluate the possibilities of increasing the ultimate oil recovery from Appalachian area reservoirs by secondary-recovery methods. Geologic data, lease development history, geophysical logs, coring information, and the results of core and log analyses are presented.

OP 130-66. Blast Furnace Operation with Prereduced Burdens, by P. L. Woolf. J. Metals, v. 18, No. 2, February 1966, pp. 243-247. The Bureau of Mines smelted prereduced pellets in its experimental blast furnace in 1962. Very low coke rates were obtained and productivity increased as much as 55 percent. Considerable interest was generated throughout the industry and additional test work was warranted. Consequently, tests with prereduced materials were included as part of an extensive program of blast furnace research conducted under a cooperative agreement between the Bureau of Mines and Blast Furnace Research, Inc.

OP 131-66. The Electrochemical Reduction of a Low Volatile Bituminous Coal—Nature of the Reducer Material, by H. W. Sternberg, C. L. Delle Donne, R. E. Markby, and I. Wender. Fuel, v. 45, No. 6, November 1966, pp. 469-482. A low-volatile bituminous coal was reduced electrochemically and the nature of the reduced material was investigated.

OP 132-66. Avoiding Damage to Residences from Blasting Vibrations, by James F. Devine. Highway Res. Record, No. 135, 1966, pp. 35-42. Presents some basic procedures for avoiding vibration damage to residences when blasting. Particle velocity of the ground near the residence is presented as the most suitable criterion for associating ground vibration with building damage. Two inches per second particle velocity is recommended as a safe vibration level.

OP 133-66. Research on Western Coals: Present Program of the Federal Bureau of Mines, by Charles C. Boley and Wayne R. Kube. Proc. Rocky Mountain Coal Min. Inst., 62d Ann. Meeting, June 26-29, 1966, pp. 53-62. Bureau of Mines research on Western coals is centered at the Grand Forks Coal Research Laboratory and consists of seven major project areas: Ash characteristics and behavior in combustion, drying, carbonization, gasification, pulverization, storage, and nonfuel uses.

OP 134-66. Evaluation of the Martinsburg Shale and Two Younger Formations as Sources of Lightweight Aggregate in the Delaware River Area, Pennsylvania-New Jersey, by Avery Ala Drake, Jr., M. V. Denny, and Howard P. Hamlin. Geol. Survey Prof. Paper 525-D, pp. D-156 through D-162. Five samples of slate from different stratigraphic intervals within the Martinsburg Shale and one sample each from the New Scotland Limestone and the Esopus Shale were tested as potentials for production of bloated rotary-kiln-fired lightweight aggregate. The expanded products that formed in the muffle-kiln and rotary-kiln firing tests of the Martinsburg material were found to compare favorably with selected commercial lightweight aggregates. Muffle-kiln firing of shale from the New Scotland Limestone and the Esopus Shale, however, failed to cause it to expand notably and consequently resulted in products too heavy to be usable as lightweight aggregate.

OP 135-66. Integration of Partial Differential Equation for Transient Linear Flow of Gas-Condensate Fluids in Porous Structures, by C. Kenneth Eilerts. Soc. Petrol. Eng. J., v. 4, No. 4, December 1964, pp. 291-305. Finite difference equations were programed and used to integrate the second-order, second-degree, partial differential equation with variable coefficients that represent the transient linear flow of gas-condensate fluids. Effect was given to the change with pressure of the compressibility factor, the viscosity, and the effective permeability and to change of the absolute permeability with distance. Integrations used as illustrations include recovery of fluid from a reservoir at a constant production rate followed by recovery at a declining rate calculated to maintain a constant pressure at the producing boundary. The time required to attain such limiting pressure and the fraction of the reserve recovered in that time vary markedly with properties of the fluid represented by the coefficients. Fluid also is returned to the reservoir at a constant rate, until initial formation pressure is attained at the input boundary, and then at a calculated rate that will maintain but not exceed the limiting pressure. The computing programs were used to calculate the results that would be obtained in a series of back-pressure tests made at selected intervals of reservoir depletion. If effect is given to the variations in properties of the fluid that actually occur, then a series of back-pressure curves—one for each stage of the depletion—is required to indicate open-flow capacity and related flow characteristics dependably. The isochronal performance method for determining flow characteristics of a well was simulated by computation.

OP 136-66. Refinement of the Hematite Structure, by R. L. Blake, R. E. Hessevick, Tibor Zoltai, and Larry W. Finger. Am. Mineral., v. 51, Nos. 1 and 2, pp. 123-129. Three-dimensional diffraction intensities were collected on a spherical single crystal of hematite with a Buerger single-crystal diffractometer. The structure has been refined with a least-squares program and the final structure gave an R factor of 7.16 percent. The structure model of Pauling and Hendricks has been confirmed with essentially no change in the iron and approximately 4 percent change in the oxygen coordinates. The interatomic distances and the bond angles were also calculated.

OP 137-66. Identification of Thiaindans in Crude Oil by Gas-Liquid Chromatography, Desulfurization, and Spectral Techniques, by C. J. Thompson, H. J. Coleman, R. L. Hopkins, and H. T. Rall. Anal. Chem., v. 38, No. 11, October 1966, pp. 1562-1566. Knowledge of the sulfur components in petroleum is of both theoretical interest and practical value to the petroleum industry. The apparent absence of thiaindins in petroleum has been of interest to sulfur and petroleum chemists for many years. Recently the authors have identified 1-thiaindan and 17 alkylthiaindans in Wasson, Texas, crude oil by a combination of gas-liquid chromatography, desulfurization, and spectral techniques. This represents the first known identification of this class of sulfur compound in petroleum. These identifications and the techniques employed are described.

OP 138-66. Appalachian Region Oilfield Reservoir Investigations, Glade, Clarendon, and Gartland Sands, Morrison Run Field, Mead Township, Warren Co., Pa., by Charles E. Whieldon, Jr. Producers Monthly, v. 30, No. 9, September 1966, pp. 9-11. The Glade, Clarendon, and Gartland Sands were cored and logged in Blain M. Mead well 26, lot 460, Morrison Run field. This work was done to evaluate the possibilities of increasing ultimate oil recovery from the Morrison Run field by secondary-recovery methods. Geology, oilfield history, geophysical well logs, and core analysis are presented.

OP 139-66. A Large Spherical Vessel for Combustion Research, by Alphone Bartkowiak and Joseph M. Kuchta. I&EC Process Design and Development, v. 5, No. 4, October 1966, pp. 436-439. Design and construction features are given for a 12-foot-diameter spherical steel vessel which has been added to the Bureau of Mines facility at Bruceton, Pa., for use in combustion research. The maximum design of the vessel is 300 psig. The relatively large size of the vessel makes its particularly suitable for ignition, flammability, and detonability studies with minimum wall effects. It can be used for experiments with solid explosives as well as vapors and gases.

OP 1-67. Explosives Research To Improve Flow Through Low Permeability Rock, by J. L. Eakin and J. S. Miller. 3d Conf. on Drilling and Rock Mechanics, Soc. Petrol. Eng., AIME, Austin, Tex., January

1967, Preprint SPE 1715, 10 pp. Small-scale surface tests were conducted to determine the feasibility of using a nitroglycerin-base explosive for rock fracture creation. A 50-quart charge of nitroglycerin was displaced into a permeable zone at a depth of 42 feet in Green River oil shale. Fracture improvement ratios on eight test holes ranged from 2.3 to 19.1 and averaged 8.0.

OP 2-67. Permeability Alteration of Sandstone Using a High-Energy Liquid Compound, by Larman J. Heath and Ray V. Huff. 96th Ann. AIME Meeting, Los Angeles, Calif., Feb. 19-23, 1967, Preprint SPE 1719, 8 pp. A proprietary liquid monopropellant was burned in several sandstone cores to effect an increase in permeability. This report summarizes the results of preliminary tests.

OP 3-67. Quenching Face Ignitions, by E. M. Murphy, D. W. Mitchell, and E. M. Kawenski. Coal Age, v. 72, No. 1, January 1967, pp. 80-82. A research report on quenching face ignitions. Split-second sensing of methane ignitions at the face initiates dispersal of flame-quencing chemicals from trays mounted on the mining machines.

OP 4-67. Electrolytic Generation of Solvated Electrons and Reduction of the Benzene Ring in Ethanol Containing Hexamethylphosphoramide, by Heinz W. Sternberg, Raymond E. Markby, Irving Wender, and David M. Mohilner. J. Am. Chem. Soc., v. 89, No. 1, Jan. 4, 1967, pp. 186-187. Reduction of the benzene ring was achieved by electrolytic generation of solvated electrons in ethanol containing hexamethylphosphoramide.

OP 5-67. Manganese Recovery as Chloride From Ores and Slags, by A. A. Cochran and W. L. Falke. Min. Eng., v. 19, No. 3, March 1967, pp. 72-76; J. Metals, v. 19, No. 4, April 1967, pp. 28-32. Difficulties in treating low-grade domestic manganese ores are analyzed, and a one-step chlorination separation operation is proposed and tested. The operation is technically feasible for nine out of 10 domestic ores, and a complete, integrated process is proposed.

OP 6-67. A Performance Study of Dense-Medium Vessels in Cleaning Coarse Coal, by J. Hudy, Jr. SME Fall Meeting, AIME, Tampa, Fla., Oct. 13-15, 1966, Preprint 66F325, 13 pp. The performance of five dense-medium washers was evaluated in four preparation plants. Three of the plants were making a two-product separation that produced a clean coal and a refuse; one plant employed dense-medium vessels in series to effect a primary and a secondary separation.

OP 7-67. Quality Control of Coal: Testing of the Cendrex X-Ray Ash Meter, by J. Hudy, Jr. 96th Ann. AIME Meeting, Los Angeles, Calif., Feb. 19-23, 1967, Preprint 67F79, 21 pp. An investigation has been made to determine the applicability of the Cendrex X-ray instrument for the monitoring of the ash contents of washed bituminous coal products. The results obtained for selected products from five preparation plants in the northern Appalachian region are described.

OP 8-67. Bibliography on Incineration of Refuse and Waste, by Richard C. Corey, Herbert C. Johnson, and Hazel C. Anderson. Air Pollution Control Association, Pittsburgh, Pa., March 1967, 273 pp. Bibliography, with abstracts, on incineration research and practices, covering the period 1960 through 1966. Includes reference to incineration of residential, commercial, community, and salvage wastes; radioactively contaminated wastes; methods of testing incinerator performance; and incinerator design. Contains author and subject indexes.

OP 9-67. Storage Stability of High Temperature Fuels. Part 3, by Marvin L. Whisman and C. C. Ward. Air Force Aero Propulsion Laboratory, Research and Technology Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, AFAPL-TR-65-13, pt. 3, February 1967, 83 pp. Report covers work from February 1966 to February 1967 on the storage stability of high-temperature fuels. Ninety-four test blends of 12 fuels and nine radioactive fuel components were prepared and tested in the evaluation of a microscale thermal stability procedure developed for the purpose of determining the contribution of selected fuel components to thermally induced deposits. Eighty-eight of these test blends were retested after 26 weeks' storage at 130° F to determine the effect of storage upon deposit-forming tendencies. Analysis of the data obtained in this study resulted in a further study of thermal decomposition of a fuel antioxidant additive. An investigation of several variables associated with an in situ hydrogenation method using tritium as the index of reactivity was completed as an effort to develop a sensitive and accurate analytical technique for very low concentrations of olefins in hydrocarbon fuels. In addition initial steps were taken toward obtaining or synthesizing radioactive materials and reference standards essential to a continuation of this program along a similar line of approach.

OP 10-67. Conjugation of Soybean Oil by Decomposition of Its Iron Tricarbonyl Complex With Carbon Monoxide, by E. N. Frankel and S. Metlin. J. Am. Oil Chem. Soc., v. 44, No. 1, January 1967, pp. 37-39. Nonconjugated vegetable oils have been converted into the more valuable conjugated isomers by their reaction with CO and $Fe(CO)_5$ and subsequent decomposition of the resulting complexes.

OP 11-67. Operating Practices Required To Optimize Blast Furnace Performance, by K. H. Gee, W. M. Mahan, and E. J. Ostrowski. J. Metals, v. 19, No. 2, February 1967, pp. 46-47; AIME Ironmaking Proc., v. 25, 1967, pp. 154-155. The balance between reducing gas and hearth temperature requirements in an experimental blast furnace is achieved by varying coke and blast moisture to find the minimum rates which would provide control of iron sulfur. The new practice for adjusting slag chemistry combines the use of iron temperature and optimum magnesia contents for minimizing liquidus temperatures.

OP 12-67. Method for Rapid Transfer of GLC Fractions Into Infrared Cavity Cells, by R. F. Kendall. Appl. Spectroscopy, v. 21, No. 1, January 1967, pp. 31-32. A rapid transfer procedure is described, which permits the qualitative infrared analysis of microliter samples collected from gas-liquid chromatographic instruments.

OP 13-67. Use of High Top Pressures and Wind Rate With Sinter and Pellet Burdens, by N. B. Melcher, W. E. Marshall, and P. L. Woolf. J. Metals, v. 19, No. 2, February 1967, pp. 41-45; AIME Ironmaking Proc., v. 25, 1967, pp. 83-87. High top pressures in an experimental blast furnace are beneficial to both productivity and coke rate at high wind rates. Closely sized sinter results in lower coke rates and in higher production than will acid pellets of higher quality.

OP 14-67. Cyclohexanethiol and 2,4-Dimethyl-3-Thiapentane: Molecular Vibrations, Conformational Analyses, and Chemical Thermodynamic Properties, by D. W. Scott and G. A. Crowder. J. Chem. Phys., v. 46, No. 3, February 1967, pp. 1054-1062. Statistical thermodynamic treatments were made of the conformational energetics of the cyclohexanethiol and 2,4-dimethyl-3-thiapentane molecules. Tables of the chemical thermodynamic properties were compiled.

OP 15-67. Nuclear Measurement of Carbon in Bulk Materials, by Robert F. Stewart. Proc. 17th Nat. ISA Conf. on Instrumentation for the Iron and Steel Industry, Pittsburgh, Pa., Mar. 15-16, 1967, pp. 2-1 through 2-14. A method is described for continuous measurement of carbon in granular materials by counting the 4.43-mev gamma rays produced from carbon atoms by the inelastic scatter of neutrons. Carbon in iron-ore sinter mix and in fly ashes containing 2 to 16 percent carbon was determined within 0.5 percent, and repeated tests on one sample of sinter mix showed a precision of 0.2 percent carbon. Tests on coal samples as large as 4,000 pounds show the possibility of adapting the method to continuous process control of materials at high tonnage flow rates. Considerations of nuclear design, instrumentation, and material handling are discussed for commercial use of a continuous carbon meter for process control.

OP 16-67. Thermal Fragmentation of Rock. A Five-Year Study, by Robert L. Marovelli. Trans. 1966 Nat. Safety Cong., Mining, v. 16, October 1966, pp. 48-53. This report describes rock thermal fragmentation work at the Twin Cities Mining Research Center of the Bureau of Mines. The safety problems associated with thermal methods are discussed.

OP 17-67. Emission Spectrometric Determination of Barium, Boron, Iron, Manganese, and Strontium in Oilfield Waters Using a Plasma Arc, by A. Gene Collins. Appl. Spectroscopy, v. 21, No. 1, January/February 1967, pp. 16-19. Studies of the concentration and distribution of the mineral content in subsurface oilfield waters aid in locating water-pollution sources, determining water compatibilities, determining the origin and distribution of oilfield waters and petroleum, and exploring for petroleum and other minerals. An emission-spectrographic method using a plasma arc to determine B, Ba, Fe, Mn, and Sr in oilfield waters was developed. Variations in brine composition were reduced by use of a synthetic brine solution. Less than 1 mg/liter of each ion can be detected. Synthetic and natural oilfield waters containing the subject ions were mixed with various organic solvents and the internal standard. Relative intensities of their emission lines were determined using each of 10 solvent systems.

OP 18-67. Bromide and Iodide in Oilfield Brines in Some Tertiary and Cretaceous Formations in Mississippi and Alabama, by A. Gene Collins, William P. Zelinski, and Cynthia A. Pearson. 153d Nat. Meeting Am. Chem. Soc., Division of Water, Air, and Waste Chem., v. 7, No. 1, April 1967, pp. 166-173. The iodide and bromide content of 280 oilfield brine samples was determined. These data together with the sodium, calcium, magnesium, bicarbonate, and sulfate content of the samples were analyzed using a digital-computer factor analysis program. A correlation of bromide to calcium was found for these waters.

OP 19-67. Hydrocracking Prehydrogenated Shale Oil, by Philip L. Cottingham and Harry C. Carpenter. I&EC Process Design and Development, v. 6, April 1967, pp. 212-217. Shale oils with lowered carbon residue and metals contents were prepared by prehydrogenating crude gas-combustion shale oil at 1,000 pounds pressure and 600° to 660° F. The prehydrogenated oils were once-through hydrocracked at 1,000 or 1,500 pounds with temperatures from 800° to 900° F. At a given conversion, naphtha yields were about the same at both pressures, but sulfur and nitrogen percentages were lower at 1,500 than at 1,000 pounds. At 900° F, naphthas obtained at 1,000 pounds averaged below 0.10 percent nitrogen and those obtained at 1,500 pounds averaged 0.02 percent. These percentages were reduced to below 0.01 percent when the tar bases were removed. A 66-hour recycle hydrocracking run at 1,000 pounds and 907° F produced 80.6 and 106.4 volume-percent of conversion as, respectively, C_5^+ and C_4^+ naphthas.

OP 20-67. An Adaptation of Inverse Gas-Liquid Chromatography to Asphalt Oxidation Studies, by T. C. Davis and J. C. Petersen. Anal. Chem., v. 38, No. 13, December 1966, pp. 1938-1940. Describes a study of the oxidation characteristics of asphalts by direct oxidation within the gas-liquid chromatography column followed by inverse gas-liquid chromatographic analysis. This technique may be useful in predicting asphalt durability.

OP 21-67. Determination of Nitrogen Oxides in Auto Exhaust, by Basil Dimitriades. J. Air Pollution Control Assoc., v. 17, No. 4, April 1967, pp. 238-243. A new procedure for determining nitrogen oxides in automobile exhaust gas has been developed. The new procedure was included in a Bureau of Mines comparative study that aimed at evaluating four widely used methods for determining NO_2 in auto exhaust. The principal objective of this study was to generate experimental evidence that would lead to defining an optimum procedure for converting NO, present in exhaust gas, into NO_2; this conversion was desired so that the total of $NO + NO_2$ can be determined quantitatively in the form of NO_2. The results indicated that all four methods are subject to error, the extent of which depends on the conditions employed. The Bureau's own method was superior from the standpoint of accuracy because it was less affected by interferences due to hydrocarbon-NO_x reactions.

OP 22-67. Infrared in Coal Structure Research, by R. A. Friedel. Ch. in Applied Infrared Spectroscopy, ed. by D. N. Kendall. Reinhold Publishing Corp., New York, 1966, pp. 312-343. Discusses studies of coal structure by infrared spectroscopy and the information on coal structure to be obtained from investigation of coal, coal derivatives, and similar carbonaceous materials. Special techniques that are required are discussed in detail.

OP 23-67. Infra-red Luminescence (Fluorescence) and Reflectance of Coals, Coal Derivatives, and Graphite, by R. A. Friedel and H. Lou Gibson. Nature, v. 211, No. 5,047, July 23, 1966, pp. 404-405. Gives results of an investigation of the infrared luminescence and reflectance of coal, coal derivatives, and graphite. In general the highest infrared reflectances are observed for the weakest luminescing samples, and the strongest infrared luminescence is found for the weakest reflectors.

OP 24-67. Quantitative Application of C^{13} Nuclear Magnetic Resonance: C^{13} N.M.R. Signals in Coal Derivatives and Petroleum, by R. A. Friedel and H. L. Retcofsky. Chem. and Ind., Mar. 12, 1966, pp. 455-456. A recent investigation of the quantitative aspects of carbon-13 nuclear magnetic resonance spectrometry suggests that the detection and quantitative determination of aromatic carbon atoms by this direct method is feasible.

OP 25-67. Similar Compositions of Alkanes From Coal, Petroleum, Natural Gas, and Fischer-Tropsch Product, by R. A. Friedel and A. G. Sharkey, Jr. Coal Science. Adv. in Chem. Ser. 55, 1966, pp. 32-42. Possible interrelationships of natural substances are important. Similarities of the low-molecular-weight alkane isomers from crude oil and Fischer-Tropsch synthesis product have been reported. A similar composition for high-temperature composition has been found. The C_4 to C_7 alkane isomers from these sources can be calculated quantitatively with equations developed for Fischer-Tropsch products. A reversal of the concentrations of the monomethyl isomers from C_6 (2 Me>3 Me) to C_7 (3Me>2 Me) occurs in all three products; comparisons at higher carbon numbers indicate some dissimilarities. Naphthene isomers for crude oil and high-temperature coal carbonization also have similar composition. Aliphatic hydrocarbons from low-temperature coal processes are considerably different. The C^{13} isotopic composition of pure compounds from the various sources are being compared in order to provide information on their origin.

OP 26-67. Effect of Saturation on Mobility of Low Liquid-Vapor Ratio Fluids, by Jerry D. Ham and C. Kenneth Ellerts. Soc. Petrol. Eng. J., v. 7, No. 1, March 1967, pp. 11-19. The effects of pressure, apparent velocity, flowing liquid-vapor volume ratio, and other related parameters on the mobility-saturation relationships for condensate-type fluids are described in this paper.

OP 27-67. Distribution of Gaseous Products From Laser Pyrolysis of Coals of Various Ranks, by F. S. Karn, R. A. Friedel, and A. G. Sharkey, Jr. Carbon, v. 5, 1967, pp. 25-32. Gaseous products from the laser irradiation of coals of various ranks were analyzed by mass spectrometry. Total gas yield varied inversely with coal rank, showing a fourfold increase between anthracite and lignite. The atomic C-H ratio for the gases was lower than for the corresponding coal. Yields of acetylene, hydrogen, carbon monoxide, and carbon dioxide generally increased between anthracite and lignite. Changes were most pronounced between anthracite and low-volatile bituminous coal. Liquid products were not detected. The infrared spectrum of the solid residue showed few of the characteristic coal bands.

OP 28-67. Infrared Analysis of Minerals in Coal Using the 650 to 200 cm^{-1} Region, by Clarence Karr, Jr., Patricia A. Estep, and John J. Kovach. Chem. and Ind., v. 9, Mar. 4, 1967, pp. 356-357. A new approach to the identification of minerals in coal samples, namely, infrared analysis in the 650 to 200 cm^{-1} (15 to 20 micron) region, has been found to have considerable usefulness as a rapid method of analysis.

OP 29-67. Orientation Dependence of Dislocation Damping in Magnesium Single Crystals, by R. R. Nothdurft and A. E. Schwaneke. J. Applied Physics, v. 38, No. 2, February 1967, pp. 894-895. The dislocation damping was measured in six single crystals of magnesium having angular orientations ranging from 10° to 84°. The results are in agreement with the Granato-Lücke theory of dislocation damping.

OP 30-67. Materials Handling and Environmental Control Research, by Eugene R. Palowitch. Min. Cong. J., v. 53, No. 4, April 1967, pp. 42-47. Discusses the Bureau of Mines research projects in materials handling and environmental control, including methane control, mine water control, and bulk materials transport.

OP 31-67. Carbon-13 Magnetic Resonance of Diene-Iron Tricarbonyl Complexes, by H. L. Retcofsky, E. N. Frankel, and H. S. Gutowsky. J. Am. Chem. Soc., v. 88, June 1966, pp. 2710-2712. The C^{13} nuclear magnetic resonance spectra of butadiene-iron tricarbonyl and methyl octadecadienate-iron tricarbonyl were obtained to elucidate the structure of these complexes. The C^{13} coupling constants indicate that all of the C-H bonds in the butadiene complex are essentially sp^2 hybrids. This observation, the C^{13} and proton chemical shifts, the H-H coupling constants, and other data are consistent with a structure in which the bonding of Fe at $C_{2,3}$ in the diene complexes is very similar to that in ferrocene, but in which the terminal CH_2 and CHR groups are rotated about the C_1-C_2 and C_3-C_4 bonds of the ligand. This steric distortion of the ligand from planarity makes the bonding of the Fe at $C_{1,4}$ differ somewhat from that at $C_{2,3}$, but both instances involve π orbitals on the carbons.

OP 32-67. Proton and Carbon-13 NMR of Coal Derivatives and Other Carbonaceous Materials, by H. L. Retcofsky and R. A. Friedel. Coal Science. Adv. in Chem. Ser. 55, 1966, pp. 503-515. Complementary use of proton and carbon-13 nuclear magnetic resonance technique has been applied to studying the mean structural units present in coal derivatives and other carbonaceous materials. The method requires using quantitative data from both proton and C^{13} spectra. Although PMR intensity measuresments are known to be reliable, corresponding C^{13} measurements have been explored very little. Intensity-concentration calibration curves for a series of alkyl aromatics and hydro aromatic compounds suggest that quantitative C^{13} data can be used with reasonable assurance of accuracy. The technique has been applied to several coal derivatives and chemically reduced coal derivatives.

OP 33-67. 4-Indenol and 7-Indenol Structure Determination, by H. L. Retcofsky, J. Queiser, and R. A. Friedel. Chem. and Ind., Feb. 19, 1966, p. 340. Gives mass spectrometric and nuclear magnetic resonance data for 4- and 7-indenol.

OP 34-67. Gases From Flash and Laser Irradiation of Coal, by A. G. Sharkey, Jr., J. L. Shultz, and R. A. Friedel. Coal Science. Adv. in Chem. Ser. 55, 1966, pp. 643-649. Gases from the flash and laser irradiation of Pittsburgh seam (hvab) coal were investigated to determine the action of high temperatures on coal. Temperatures in excess of 1,000° C were reached with both types of irradiation. Craters about 300 microns in diameter were produced in the coal with millisecond pulses from the laser unit rated at 1.7 joules output. Gaseous products from the laser and flash irradiations showed 21 and 8 percent acetylene, respectively. Diacetylene, vinylacetylene, and other products to molecular weight 130 were indicated in the mass spectrum of the gas from the laser study. The results indicated that the distributions of products obtained from the flash and laser irradiation of coal were different from that produced in high-temperature carbonization.

OP 35-67. Mass Spectra of Pyrolyzates of Several Aromatic Structures Identified in Coal Extracts, by A. G. Sharkey, Jr., J. L. Shultz, and R. A. Friedel. Carbon, v. 4, 1966, pp. 365-374. Mass spectra of products from the liquid phase pyrolysis of 20 hydrocarbons having from one to four aromatic rings and molecular weights from 116 to 228 were investigated. By studying the pyrolyzates of several structural types found in the material extracted from Pittsburgh seam (hvab) coal with pyridine at room temperature, information related to the formation of heavy residues such as coal tar was obtained. The amount of original material remaining after pyrolysis at 450° C for 4 hours was used to estimate the extent of thermal reactivity. Many of the molecular weights appearing in the mass spectra of the residues could be correlated with structures resulting from the recombination of radicals. The highest mass peaks in the spectra of the pyrolyzates of naphthalene, phenanthrene, and pyrene were 254, 354, and 402, respectively, corresponding to dehydrogenation dimers of these compounds. Thermal treatment of binary mixtures indicated extensive interaction of species derived from the original structures. The residue from the liquid-phase pyrolysis of a 1:1 mixture, by weight, of 9,10-dihydroanthracene and acenaphthylene indicated extensive interaction of species having three aromatic rings to produce species having up to seven condensed rings. Mass spectrometric and other data have indicated that the major components in the liquid and solid product from the low-temperature carbonization of coal have molecular weights below about 400. This can be explained if, on pyrolysis, most of the major structural types in the room-temperature extract of coal produce components resulting from the recombination of radicals.

OP 36-67. Gases From Laser Irradiation of Coal: Effect of Argon, Nitrogen, and Other Atmospheres, by J. L. Shultz and A. G. Sharkey, Jr. Carbon, v. 5, 1967, pp. 57-59. The distribution of gaseous products from the laser irradiation of Pittsburgh seam (hvab) coal in various atmospheres was studied by mass spectrometry. The acetylene content of the gas was increased by the presence of argon and nitrogen and reduced by the presence of helium. The acetylene content of the gas reached a maximum at argon pressures of 80 to 400 torr.

OP 37-67. Project Gasbuggy, by Sam Smith and C. H. Atkinson. Midwest Eng., v. 19, No. 8, April 1967, pp. 9-11. Gives a brief history and review of the technical aspects of a project involving the firing of a 20-kiloton nuclear explosive underground to shatter natural gas-bearing rock to increase recovery.

OP 38-67. Vapor Pressures of Liquid Titanium and Liquid Iron, by R. K. Koch, W. E. Anable, E. D. Calvert, and R. A. Beall. Trans. Vacuum Met. Conf., Am. Vacuum Soc., Boston, Mass., June 27-29, 1966, pp. 1-14. The Bureau of Mines determined the vapor pressures of liquid iron and liquid titanium by the Langmuir method of free evaporation. An electron-beam furnace with a water-cooled copper hearth was used for melting, and a two-color ratio pyrometer was employed to measure melt temperatures. The vapor pressure of liquid titanium for the range 1,953° to 2,193° K can be approximated by the equation

$$\log p \text{ (atm)} = 5.131 - \frac{19,860}{T}$$

and the vapor pressure of liquid iron in the range of 1,813° to 1,973° K can be represented by

$$\log p \text{ (atm)} = 4.878 - \frac{16,780}{T}.$$

Third law determinations of heats of sublimation at 298.15° K gave mean values of 111.85 ± 1.72 kcal/mole and 99.23 ± 1.66 kcal/mole for titanium and iron, respectively. These values are in reasonable agreement with previous determinations at lower temperatures for both metals.

OP 39-67. Vacuum-Induction Melting of Reactive Metals in Water-Cooled Crucibles, by P. G. Clites. Trans. Vacuum Met. Conf., Am. Vacuum Soc., Boston, Mass., June 27-29, 1966, pp. 183-194. A technique for induction melting of reactive metals in water-cooled copper crucibles is described. This technique differs from other cold-mold induction-melting techniques in that the crucible is not segmented. Ingots are formed by drip melting of a feed rod or by vibrating loose material into a molten pool at the top surface of the ingot. This molten pool is maintained by exposing the upper surface of the ingot to the intense field of a current concentrator. Titanium ingots 2 inches in diameter and zirconium ingots 1½ inches in diameter have been successfully produced. In addition buttons of a variety of reactive metals have been melted. The most encouragng aspect of the work has been the improvement in ingot quality with increased ingot diameter up to the limit imposed by the 30-kilowatt radio frequency power supply used.

OP 40-67. Solid and Gaseous Fuels, by R. F. Abernethy and J. G. Walters. Anal. Chem., Ann. Rev., v. 39, No. 5, April 1967, pp. 248R-260R. This two-part report is a technical literature survey of the improved and new methods of sampling and analyzing coal and coke and methods used for testing blast-furnace top, carbureted water, coal, coke-oven, liquefied petroleum, sludge, manufactured, natural, producer, synthesis, and water gases.

OP 41-67. An X-Ray Study of Carbon Blacks Produced From Coals, by James Bayer and Sabri Ergun. Carbon, v. 5, 1966, pp. 107-111. X-ray diffraction patterns of eight carbon blacks produced from coals have been studied. Layer diameters, L_a, obtained from the (100) and (110) reflections ranged from 6 to 17 A, and the stack heights, L_c, derived from the (002) reflections, ranged from 12 to 14 A. The above values compare with 20 A and 14 A, respectively, obtained from the diffraction patterns of a commercial black (Pelletex). It appears that coal blacks are structurally similar to well-known commercial blacks.

OP 42-67. Nomograph for the Density of Powder Compacts, by Robert Blickensderfer. Am Ceram. Soc. Bull., v. 46, No. 5, May 1967, p. 1. Presents a nomograph that gives relations among the cross sectional area, density, mass, length, and percent density of a powder compact. It is especially useful for relating the length of a compact to its percent density during the progress of hot pressing.

OP 43-67. Water Use in the Mineral Industry, by Alvin Kaufman. Trans. SME, March 1967, pp. 83-90. More than 3 trillion gallons of water are used annually by the mineral industry. Of this, approximately 2.5 trillion gallons are recirculated, the rest constituting intake water. The major users are natural gas processing plants and phosphate rock, sand and gravel, and iron ore producers. Water was used by the mineral industry for mining (6 percent), processing (64 percent), cooling and condensing (27 percent), and miscellaneous uses such as boiler feed and sanitary purposes (3 percent). Whereas total water use is dependent on the quantity of material processed and on the particular requirements of an industry, recirculation is dependent on processing, as well as cooling and condensing requirements, quality of new water intake, and the necessity for treating new and discharged water. Consumed water, on the other hand, is dependent on the quantity of water recirculated, and temperature and humidity in the area. Based on this analysis, an increase in water use by the mineral industry of 2.5 times by 1985 is forecast. Water intake, however, will rise only 62 percent, because of a substantial increase in recirculation.

OP 44-67. Let's Not Overlook Salvage, by C. B. Kenahan and P. M. Sullivan. APWA Reporter, v. 34, No. 3, March 1967, pp. 5-8. Gives data on the compositions of the residues from five incinerators in metropolitan Washington, D.C.

OP 45-67. Hydrogenolysis—An Identification Tool, by C. J. Thompson, H. J. Coleman, R. L. Hopkins, and H. T. Rall. J. Gas Chromatography, v. 5, January 1967, pp. 1-10. The development of equipment and techniques that permit application of Sabatier's classical discoveries in vapor-phase hydrogenation to micro samples was accomplished 6 years ago in the Bureau of Mines laboratories. Since then many improvements in the procedure have been made, and identifications of sulfur compounds in petroleum, previously thought impossible with the quantities of materials available, are now being made routinely. This technique rapidly and quantitatively removes the sulfur atom from organic sulfur compounds to produce paraffins or cycloparaffins. Identification of the produced hydrocarbon identifies or contributes to the identification of the precursor. The technique is direct, applicable to extremely small samples (5×10^{-8} ml), and requires no costly apparatus. The method also has been applied successfully to halogen-, oxygen-, nitrogen-containing compounds. In addition it has been applied, with success, to the removal of other hetero atoms such as phosphorus, silicon, and metals. Only a few anomalies have been found, principally in the deoxygenation reaction. The basic technique, with recent improvements, permits structure characterization that would be difficult or impossible by any other procedure.

OP 46-67. The Role of Vaporization in High Percentage Oil Recovery by Pressure Maintenance, by Alton B. Cook, F. Sam Johnson, George B. Spencer, and Abdo F. Bayazeed. J. Petrol. Technol., v. 19, No. 2, February 1967, pp. 245-250. A limited number of laboratory experiments have been performed with a rotating model oil reservoir that simulates gas cycling operations and allows a separation of the oil from the free gas flowing into the laboratory well-bore at reservoir conditions, thus revealing which is displaced and which is vaporized oil. In these experiments recovery by vaporization ranged from 15.3 to 73.6 percent of the immobile oil. (Presented at California Regional Meeting Soc. Pet. Eng. AIME, Santa Barbara, Calif., Nov. 17-18, 1966, Preprint SPE 1646.)

OP 47-67. Chromium, Molybdenum, Nickel, and Tungsten as Automotive Metals, by Charles W. Merrill. Auto Eng. Congr., Detroit, Mich., Jan. 9-13, 1967, SAE Preprint 670121, 4 pp. These four metals, so important to automotive manufacture, currently are in ample supply. Their availability is well supported by world resources and reserves. There are some hazards from hostilities denying access to remote sources or from political factors hindering efficient mining and transport from some producing countries. Future demand can be expected to grow with an increase in the number of motor vehicles produced, but this trend should be countered by their more efficient use. Chromium, molybdenum, nickel, and tungsten are among the more expensive raw materials consumed in automobile manufacture and as such will be a target for redesign by automotive engineers. On the other hand, greater quantities may be needed with refinement in vehicle design.

OP 48-67. Flyash: New Hope for Strip Spoil, by Carl F. Engle and John P. Capp. Science, West Virginia University Agricultural Experiment Station Bull. 544, Winter 1967, pp. 1-4. Describes studies in the use of fly ash as a soil additive and conditioner for reclaiming acid surface mined areas. Only a small portion of the fly ash produced is utilized at present, so that reclamation of spoil areas with fly ash would provide a way for the landowner, surface mine operator, and coal-burning powerplant operator to cooperate in waste disposal and land beautification to the benefit of all.

OP 49-67. Project Gasbuggy, by Harry Gevertz, R. F. Lemon, W. T. Hollis, M. A. Lekas, Don C. Ward, Charles H. Atkinson, and Norman Bonner. El Paso Natural Gas Co., May 14, 1965, 57 pp. A report on the feasibility of using nuclear explosives for the stimulation of a natural gas reservoir by generating extensive fracturing within the producing formation. The report describes the beneficial effects of such a nuclear explosion as (1) a network of radiating fractures that will permit more effective drainage; (2) an expanded wellbore allowing higher rates of production; and (3) an effective storage volume for short-term high deliverability.

OP 50-67. Line Brattice Ventilation, by R. W. Dalzell. Proc. 54th Convention, Mine Inspection Institute of America, June 15-17, 1964, pp. 78-84. This paper reviews the important factors in operation of line brattice constructed with common jute cloth. The line brattice system of ventilation, properly constructed and applied, is an efficient and economic method of delivering adequate air to the face area.

OP 51-67. Ultrafine Structures in Coal Components as Revealed by Electron Microscopy, by J. T. McCartney, H. J. O'Donnell, and S. Ergun. Coal Science. Adv. in Chem. Ser. 55, 1966, pp. 261-273. Electron microscopic studies have been made of several petrologic components of coals of different ranks. The ultrathin specimens utilized, from 500 to 2,000 A thick, have been cut on microtome with diamond knives. Structures in various size ranges have been observed. Some that have been resolved with optical microscopes have been more clearly and definitely characterized using the electron microscope. Ultrafine structures not resolvable optically have been revealed in electron micrographs. There appear to be two general ranges of these ultrafine structures in a numbers of components, one of the order of hundreds of angstroms, the other less than 100 angstroms. Particles having the general form of spheroids, curved cylinders, and round and polygonal platelets have been observed.

OP 52-67. Reactions of Carbon With Carbon Dioxide and Steam, by Sabri Ergun and Morris Mentser. Chemistry and Physics of Carbon, ed. by P. L.

Walker, Jr. Marcel Dekker, Inc., New York, 1965, pp. 203-263. The studies reported here primarily concern the derivation of reaction sequences when carbons are gasified with steam or carbon dioxide. Based on the reaction sequences, rate equations were developed so that the postulated sequences could be more critically examined under a wide range of experimental conditions. The reacation sequence outlined accounts well for the reactions of carbon and coke with carbon dioxide and of coke with steam under diverse experimental conditions.

OP 53-67. Evaluation of a Demountable X-Ray Tube Vacuum Spectrograph for the Determination of Low-Atomic-Number Elements, by John W. Thatcher and William J. Campbell. Advances in X-Ray Analysis, v. 7, 1964, pp. 512-522. The fluorescent excitation of long-wavelength X-ray spectra is reviewed with respect to X-ray tube target element, inherent filtration, and optimum kilovoltage. A demountable X-ray tube vacuum spectrograph designed for the determination of the light elements is described. Operation of this instrument with both secondary and combined primary-secondary excitation is evaluated. Examples from the literature are cited to show the feasibility of direct electron excitation of long-wavelength spectra.

OP 54-67. Fire and Explosion Hazards at Temperature and Pressure Extremes, by Michael G. Zabetakis. Proc. Symp. on Chemical Engineering Under Extreme Conditions. AIChH-Inst. Chem. Eng. Meeting, London, 1965, v. 2, pp. 2:99-2:104. A number of general trends are reviewed and specific data are given on the effects of temperature and pressure on the ignition energy requirements and on the limits of flammability of various flammable materials. Specific data are given on the effect of pressure on the minimum oxygen requirements for flame propagation through paraffin hydrocarbons in nitrogen-air atmospheres and on the minimum autoignition temperature of various fuels and lubricants. These data and others are used to develop a number of empirical rules that have been found useful in predicting the behavior of flammable gases and vapors over a wide range of temperatures and pressures.

OP 55-67. A Cost Comparison: Production of Prereduced Versus Iron Ore Pellets, by N. Bernstein, J. L. Reuss, and P. L. Woolf. J. Metals, v. 18, No. 5, May 1966, pp. 652-656. Gives a projection of cost estimates of the production and smelting of prereduced pellets, regular iron ore pellets, and a mixture of the two. Full commercial-size prereduced pellet production and smelting facilities were extrapolated, in part, from experimental data, the pellet plant being designed to yield 2 million long tons of product annually. The blast furnaces are considered as existing facilities that yield approximately 1 million net tons of hot metal each from an oxide pellet burden. Estimates and assumptions are considered reasonable for the Mesabi range and lower Lake steel centers, but it must be emphasized that each situation in practice would differ as to raw materials, transportation, desired production capacities, and individual operational features.

OP 56-67. Ignition of Tank Atmospheres During Fuel Loading, by Israel Liebman, Irving Spolan, J. M. Kuchta, and M. G. Zabetakis. Proc. API, v. 45 (III), 1965, pp. 217-230. An investigation was made to determine the formation, persistence, and ignition energy requirements of flammable zones which occur in the vapor space of fuel tanks during fuel loading. These flammability studies were made using JP-4, gasoline, and kerosine fuels which were loaded into a 2.4-cubic-foot cylindrical tank or a 22.5-cubic-foot simulated aircraft wing tank. The extent and duration of flammable zones was found to be dependent on fuel vapor pressure, temperature, flow rate, fuel inlet, and tank dimensions.

OP 57-67. Considerations of Solvent Extraction Processing of U.S. Beryllium Ores, by J. B. Rosenbaum, R. O. Dannenberg, and D'Arcy R. George. In Solvent Extractions Chemistry of Metals, Proc. Internat. Conf., UKAEA, 1965, pp. 315-325. Report deals with laboratory studies on the selection and adjustment of parameters for organophosphate solvent extraction of beryllium from leach liquors of widely varying beryllium concentration. The liquors are prepared by sulfuric acid leaching of ore from Spor Mountain, Utah, or of a lime sinter of flotation concentrates from Mount Wheeler, Nev., ores. Feed solutions differ markedly in beryllium concentration with a consequent variation in the ratio of beryllium to other components such as chloride, fluoride, magnesium, aluminum, iron, zinc, and manganese. Operating parameters and peripheral procedures for rejecting various contaminating elements are described. Modifications required to attain high beryllium extraction from 1 *M* beryllium sulfate solutions as opposed to 0.1 *M* solutions are also described. Applications of the results of preliminary investigations to countercurrent extraction is shown to result in 98-percent extraction of the beryllium as a beryllia product which assays over 98 percent BeO.

OP 58-67. Space Age Metals, by J. B. Rosenbaum and J. H. Bilbrey, Jr. Mining Cong. J., v. 52, No. 2, February 1966, pp. 153-159. Discovery of new uses for familiar metals has been greatly accelerated by requirements of the space age. This has also brought about development of new metals and alloys, expanded our resource base, and resulted in better processing methods. Properties of some metals and alloys are reviewed, including maraging steel, aluminum, titanium, beryllium, and refractory metals.

OP 59-67. The Occurrence of Germanium in Willemite, by Herman W. Sheffer. Cheochim. et Cosmochim. Acta, v. 30, No. 8, August 1966, pp. 837-838. Appreciable quantities of germanium, ranging from 47 to 350 ppm, have been found in crystals of willemite from several localities in New Mexico and Utah.

OP 60-67. **See OP 129-67.**

OP 61-67. The Role of Urethane Foam in Mines, by Donald W. Mitchell and Edwin M. Murphy. Proc. Coal Min. Inst. of America, Pittsburgh, Pa., Dec. 10, 1965, pp. 126-130; Coal Age, v. 71, No. 3, March 1966, pp. 72-74. Experiences in operating mines with urethane foam are described. Precautions to be taken in the use of foam in underground mines are reviewed. These precautionary measures are based on full-scale tests conducted in the Bureau of Mines Experimental Coal Mine.

OP 62-67. Coking Practice in the United States Compared With Some Western European Practices, by J. D. Doherty and J. A. DeCarlo. Internat. Cong., Coke in Iron and Steel Ind., Charleroi, Belgium, v. 1, September 1966, pp. 185-200. The operations of coke plants in the United States are reviewed briefly and compared with coke-plant practice in certain countries of Western Europe.

OP 63-67. High-BTU Gas Via Fluid-Bed Gasification of Caking Coal and Catalytic Methanation, by J. H. Field and A. J. Forney. Proc. Synthetic Pipeline Gas

Symp., November 1966, pp. 83-94. A combined free-fall, fluid-bed gasifier is described which will operate with caking coals. The gases from this gasifier, after purification, are sent to either a hot-gas-recycle or a tube-wall methanator to produce high-Btu gas which is interchangeable with natural gas.

OP 64-67. Problems in Evaluating Marine Mineral Resources, by Thomas E. Howard and John W. Padan. Min. Eng., v. 18, No. 6, June 1966, pp. 57-61. Discusses the problems that would be encountered in determining mineral content and distribution of marine deposits, in designing equipment for marine mining systems, and in estimating operating costs of equipment. Research is still required on every aspect of undersea mining.

OP 65-67. Experience With Roof Bolts Anchored With a Resin Cartridge, by John A. McCormick. Proc. Coal Mining Inst. of Am., 79th Annual Rept., 1965, pp. 120-126. The Bureau of Mines is currently testing resin-type grouts for anchoring roof bolts. Although there is relatively little difference between the anchorages obtained with the resin cartridges and conventional expansion shells in firm shale roof, there was a marked difference when the roof was composed of soft shale and/or coal. The loads supported by the resin anchorages ranged from 24,600 pounds to at least 32,000 pounds with negligible bolt displacement, whereas the conventional anchorges were erratic and in many cases were not capable of supporting loads up to the 14,000-pound yield point of the ⅝-inch-diameter bolts. Resin-anchored bolts probably would be of help in maintaining roof stability in many mines.

OP 66-67. Problems Facing the North American Iron Ore Industry, by Horace T. Reno and Francis E. Brantley. Proc. 27th Mining Symp. and 39th Ann. Meeting Minnesota Sec. AIME, Jan. 10-12, 1966, pp. 1-7; Skillings' Min. Rev., v. 55, No. 6, Feb. 5, 1966, pp. 6-7, 22-23; Northern Miner, No. 5, Apr. 28, 1966, pp. 20-28. The iron mining industry of North America is faced with three general types of problems. These involve operations, administration, and competition. Of these, competition is perhaps of greatest concern to most companies. Free trade in iron ore has resulted in intense exploration in all geographical areas and in increased activity by the iron ore producing countries to take their share of present and future world trade. In addition technological developments involving all phases of iron ore production and transportation have brought about sweeping changes during the past decade. Vast resources and proven reserves of high-grade iron deposits in South America, Australia, and Africa are expected to make an impact on the world iron market in the next few years. Problems of adjusting to these changes and the necessity of constantly seeing methods of increasing the quality of the lower grade ores at minimum cost must be met by the iron ore industry on this continent.

Operations, as such, are not discussed, but some of the administrative problems peculiar to management are outlined. In particular, problems relating to inventories, seasonal production, fluctuations in ore demand, tariff barriers, taxes, and labor problems are mentioned in relation to their individual effect on the industry.

OP 67-67. Nuclear Blasting and Its Potential for Stripping Overburden, by Paul L. Russell. Proc. 27th Mining Symp. and 39th Ann. Meeting Minnesota Sec. AIME, Jan. 10-12, 1966, pp. 145-151. Nuclear cratering experiments have demonstrated the ability of nuclear explosives to move vast volumes of earth and rock. Their compact size for very high energy yields permits emplacement at less cost than equal energy yields of chemical explosives. Phenomenology of nuclear cratering and possible application to overburden removal for open-pit mining are discussed. Limitations and hazards are considered. All cratering explosions result in the release of radioactivity to the atmosphere; however, this release is generally small compared with that of above-ground explosions of similar yield. Most of this radioactivity falls out locally and, unlike above-ground detonations, only a very small quantity is believed to enter the worldwide fallout system. Extensive research on reduction in radioactive contamination indicates that current technology is such that cratering tests in selected areas should not significantly raise radiation levels beyond our borders and therefore should present no danger.

OP 68-67. Electrorefining Vanadium, by T. A. Sullivan. J. Metals, v. 17, January 1965, pp. 45-48. High-purity metal containing over 99.95 percent vanadium was prepared by electrorefining commercial calcium-reduced vanadium in both molten bromide and chloride electrolytes. The technical feasibility of refining vanadium products containing as low as 80 percent V to produce ductile metal was demonstrated. Laboratory production tests were successful in preparing ductile 99.6 percent V by refining 90-percent-grade vanadium in molten-salt electrolytes. These tests indicate substantial advantages in the preparation of vanadium by (1) lowering the cost of ductile vanadium and (2) controlling the quality of the metal.

OP 69-67. Electrolytic Preparation of Metal Phosphides, by Don H. Baker, Jr. Trans. Met Soc. AIME, May 1967, pp. 755-756. Describes the molten-salt electrolytic preparation of manganese phosphide, titanium phosphide, and chromium phosphide. Some physical-chemical properties for these compounds, such as melting point, specific gravity, and resistivity, are reported.

OP 70-67. The Application of 2.8-MeV (D,d) Neutrons to Activation Analysis, by K. G. Broadhead and D. E. Shanks. Internat. J. Appl. Radiation and Isotopes, v. 18, 1967, pp. 279-283. The application of 2.8-MeV neutrons produced by the $H^2(d, n)He^3$ reaction in a neutron generator is presented. These neutrons, though not energetic enough to produce the usual fast neutron reactions, do induce usable $(n, n' \gamma)$ reactions. Cross sections are presented for thirteen elements most amenable to this reaction. Examples are given of the analysis of bromine, yttrium, and barium in complex matrices to illustrate potential uses in activation analysis.

OP 71-67. A Probability Model for the Random Component in Bulk Sampling, by Robert M. Becker. Seminar on Sampling of Bulk Materials, Tokyo, Japan, Nov. 15-18, 1965, pp. 53-95. The development of a probability model for the random component in bulk sampling is outlined and is shown to be acceptable experimentally. The model is based on the probabilities of equally likely items and is applicable to the sampling of a well-mixed aggregate. It is not valid when the probability of selection of items is a function of, say, position or time as well as random variables. Thus, it is applicable only to the random component in the bulk sampling of a segregated product. The probability functions for sampling to some number of equally likely items per sample (the binomial, hypergeometric, multinomial, and generalized hypergeometric functions) are reviewed. Their distributions are generalized to include some attribute or measured characteristic of the items. Several moments and moment relationships are also reviewed. The development of probability functions for sampling to some amount (i.e., weight) of equally likely items per sample (those here called the compound binomial and compound multinomial functions) is outlined. Their distribution may also be generalized to include some measured characteristic of the items, and distribution moments and moment relationships have been developed. Particle mixtures were sampled in the laboratory to determine whether the probability functions developed for bulk sampling were in agreement with experimental results. The complete agreement between model and experiment seems to confirm the application of the compound multinomial function to bulk sampling.

OP 72-67. New Devices Subjugate Evasive Methane Gas, by C. L. Brown. Coal Min. and Processing, v. 3, No. 11, November 1966, pp. 20-24. Mechanization of coal mining has created new problems in face ventilation and methane detection. The higher rates of coal extraction expose gas-liberating surfaces more rapidly, and continuous mining machines have increased in size, thereby reducing the available space for the flow of ventilating air to the working face. The article describes the progress of the Bureau of Mines methane-monitoring research and development program.

OP 73-67. Technology and Economics of Fly Ash Utilization, by John P. Capp and John H. Faber. Ann. Meeting AIME, Feb. 27-Mar. 3, 1966, New York, Preprint 66F81, 19 pp. Fly ash was converted into a lightweight aggregate suitable for concrete blocks and masonry products that meet ASTM standards. The Bureau of Mines also investigated the use of fly ash as a soil conditioner and source of trace nutrients, such as boron, for plants. Sintered fly ash was being studied for this application because sintering eliminates certain objectionable characteristics of raw fly ash. Raw fly ash was tested as a soil neutralizer for highly acid spoils.

OP 74-67. Effect of Temperature on Upper Flammability Limits of Hydrocarbon Fuel Vapors in Air, by R. J. Cato, W. H. Gilbert, and J. M. Kuchta. Fire Technol., v. 3, No. 1, February 1967, pp. 14-19. Data are given on the effect of temperature on the upper flammability limits of fuel vapor-air mixtures of various members of the paraffin hydrocarbon series and for a hydrocarbon jet fuel, JP-6.

OP 75-67. Iodide Abundance in Oilfield Brines in Oklahoma, by A. Gene Collins and G. C. Egleson. Science, v. 156, No. 3777, May 19, 1967, pp. 934-935. Samples of subsurface water, oil, and rock from strata of Mississippian and Pennsylvanian age in the Northern Oklahoma Platform area were analyzed. Several of the water samples contained iodide at more than 500 parts per million. Analyses of the brines and rock indicated that the iodide originated organically.

OP 76-67. Inverse GLC—An Extension of the Technique to the Study of the Oxidation of Asphalts, by T. C. Lavis and J. C. Peterson. Highway Res. Record, No. 134, 1966, pp. 1-7. An extension of the inverse gas liquid chromatography (GLC) technique to the study of the oxidation of asphalts is reported. An asphalt, serving as the liquid substrate in a gas liquid chromatographic column, is oxidized directly within the chromatograph. The retention behavior of a group of selected test compounds possessing different functional groups is determined before and after oxidation. Because the retention behavior is dependent on interactions between the functional groups of the test compound and chemical functionalities in the asphalt, the changes occurring in the asphalt on oxidation are reflected as changes in retention behavior. Inverse GLC was found to be a sensitive means of detecting changes that take place on oxidation and holds promise as a method of predicting asphalt durability.

OP 77-67. Bureau of Mines Blasting Research, by Dennis V. D'Andrea. Proc. 27th Ann. Min. Symp., University of Minnesota, January 1966, p. 171. Bureau of Mines blasting research projects are summarized.

OP 78-67. Cesium Extractive Metallurgy—Ore to Metal, by K. C. Dean, I. L. Nichols, and B. H. Clemons. J. Metals, v. 19, No. 11, November 1966, pp. 1198-1202. A general synopsis of the Bureau of Mines cesium research is provided, including the development of a field test for cesium and rubidium, ore beneficiation, ore dissolution, purification of leach liquors to produce pure salts, and metallothermic reduction of ores and pure salts. Cost evaluations of selected methods were made.

OP 79-67. A Brief Résumé: The U.S. Helium Conservation Program, by William M. Deaton. Proc. Gas Conditioning Conf., University of Oklahoma, April 1966, pp. G-1 through G-6; Cryogenic Eng. News, v. 1, No. 9, July 1966, pp. 20-22. This article presents a brief history of the Helium Act, examines program facilities, and looks at the current status of the helium conservation program.

OP 80-67. A Modified Redlich-Kwong Equation for Helium from 30° to 1,473° K, by J. M. Estes and P. C. Tully. AIChE J., v. 13, No. 1, January 1967, pp. 192-194. The original Redlich-Kwong equation is modified for helium by setting $B = 0.06372T_c/P_cT$ for $30° \leq T \leq 1{,}173°$ K. This modified equation represents the compressibility factors of each of 76 isotherms tested in this temperature range to less than 1-percent average deviation.

OP 81-67. Reservoir Investigations, Cooper Sand, Fork Run Area, Ludlow Field, Wetmore Township, McKean County, Pa., by Donald M. Evans. Producers Monthly, v. 31, No. 5, May 1967, pp. 18-20. A 3½-inch-diameter rotary core of the Cooper sand was obtained by the Bureau of Mines from the Pennsylvania Gas Co. well 16, located in Allegheny National Forest Tract 432, Ludlow oilfield, Wetmore Township, McKean County, Pa. Well logs were run to supplement the core information. Geology, lease history, geophysical logs, coring and logging data, and core analysis are presented.

OP 82-67. Phase Relations in the ZrO_2-MgO System, by Clark F. Grain. J. Am. Ceram. Soc., v. 50, No. 6, June 1967, pp. 288-290. Phase relations were studied in the system ZrO_2-MgO with emphasis on the range 1,350° to 1,600° C. A phase relation was determined from samples, using precision lattice parameters, X-ray diffraction line intensities, and petrographic observations of the phases present during high-temperature X-ray diffraction techniques. Limits were established for the solubility of MgO in tetragonal ZrO_2 and for the range of the cubic solid solution. The phase relations below 1,240° C were complicated by hysteresis in the monoclinic to tetragonal inversion of ZrO_2.

OP 83-67. Gas Chromatographic Separations of Benzenecarboxylic Acids Derived From Coal, by Marvin L. Kaufman, Sidney Friedman, and Irving Wender. Anal. Chem., v. 39, No. 8, July 1967, pp. 1011-1014. A procedure for analyzing benzene polycarboxylic acids by gas chromatography of their trimethsilyl ethers has been developed. It has been applied to mixtures obtained by partial decarboxylation of acids obtained by oxidation of coal.

OP 84-67. Iron Ore Flotation: Practice, Problems, and Prospects, by Donald W. Frommer. J. Am. Oil Chem. Soc., v. 44, No. 4, October 1966, pp. 270-274. Iron ore flotation is examined in context of present commercial practices and of factors tending to restrict application. Prospects for growth in flotation processing of iron ores is shown to be related to increasing demand for higher grade concentrates.

OP 85-67. Mainland China, by Edgar J. Gealy and Anton W. T. Wei. Min. J. Mining, Ann. Rev., 1967, pp. 270-273. Mainland China's mineral industry apparently made considerable progress in 1966 in spite of internal political problems. Increases in production were registered at least in such major mineral commodities as iron and steel, coal, petroleum, chemical fertilizers, and construction materials.

OP 86-67. Recovery of Uranium From Uranium Mine Waters and Copper Ore Leaching Solutions, by D. R. George and J. R. Ross. Proc. Panel on Processing of Low-Grade Uranium Ores, Vienna, June 27-July 1, 1966. International Atomic Energy Agency, Vienna, Austria, 1967, pp. 227-234. Waters pumped from uranium mines in New Mexico are processed by ion exchange to recover uranium. Production is approximately 200 pounds per day of U_3O_8 from waters containing 5 to 15 parts per million of U_3O_8. Recoveries range from 80 to 90 percent. Processing plants are described. Uranium has been found in the solutions resulting from the leaching of copper-bearing waste rock at most of the major copper mines in the Western United States. These solutions, which are processed on a very large scale for the recovery of copper, contain 2 to 12 ppm U_3O_8. Currently, uranium is not being recovered, but a potential production of up to 6,000 pounds per day is indicated. Ion exchange and solvent extraction research studies are indicated.

OP 87-67. Comparison of Ash Fouling Tendencies of High- and Low-Sodium Lignite From a North Dakota Mine, by G. H. Gronhovd, R. J. Wagner, and A. J. Wittmaier. Proc. Am. Power Conf., v. 28, 1966, pp. 632-644. This report describes the results of a series of tests performed to study the effect of sodium content of the lignite on boiler fouling. The rate of fouling, as determined both by boiler performance and by probe tests, is much greater when burning lignite having 8 to 10 percent sodium oxide in the ash compared with burning lignite having less than 2 percent sodium oxide in the ash.

OP 88-67. [The Promise and Challenge for Mineral Industries in Urban America], by Walter R. Hibbard, Jr. Pit and Quarry, v. 59, No. 4, October 1966, pp. 274-275. Approximately two-thirds of the value of U.S. nonfuel mineral production are represented by nonmetallic minerals, and about two-thirds of that value, in turn, are represented by the three biggest nonmetallic commodities: cement, stone, and sand and gravel. The demand for these commodities will continue to rise and the Bureau of Mines has been doing research on the problems involved.

OP 89-67. The Hydrogasification of Raw Bituminous Coal, Raymond W. Hiteshue. Proc. Synthetic Pipeline Gas Symp., Nov. 15, 1966, Pittsburgh, Pa., 1967, pp. 13-23. Highlights of laboratory results are presented together with a theoretical economic analysis of coal to high-Btu gas processes.

OP 90-67. Carbon Black Produced From Coal, by G. E. Johnson, W. A. Decker, A. J. Forney, and J. H. Field. Rubber World, v. 156, No. 3, June 1967, pp. 63-68. Carbon black has been produced from the pyrolysis of bituminous coal at 1,250° C in various inert and reactive gaseous atmospheres. Testing of the carbon black in rubber formulations showed it to be similar to commercial products.

OP 91-67. Control of Coal Seam Fires, by Leslie Johnson. Coal, v. 11, May-June 1966, pp. 6-10, 17. The Bureau of Mines is responsible for control of fires in coal deposits. The methods of controlling such fires are described, as well as the procedure for letting contracts for coal seam fire control.

OP 92-67. The Bureau's Ferrous Research as it Affects the U.S. Iron Ore Mining Industry, by Norwood B. Melcher. Proc. Ann. Meeting, Am. Iron Ore Assoc., June 29-30, 1966, Cleveland, Ohio, V-1 through V-10, pp. 53-62. The research of the Bureau of Mines as it relates to iron ore dates back more than 40 years. The research programs have included work on sponge iron, experimental blast furnace smelting tests, iron ore flotation, magnetic roasting techniques, iron ore pelletizing, and fuel injection.

OP 93-67. Progress Report on the Production of Pipeline Gas From Coal, by Sidney Katell. AGA Production Conf., May 23-24, 1966, Baltimore, Md., pp. 328-331. A review is made of progress in producing pipeline gas from coal, the expenditure involved, and the companies participating.

OP 94-67. Some Comments on the Distribution of Gold in a Part of the City Deep Mine, Central Witwatersrand, South Africa, by G. S. Koch, Jr., and R. F. Link. Proc. Symp. on Mathematical Statistics and Computer Applications in Ore Valuation, Johannesburg, March 1966. South African Institute of Mining and Metallurgy, Johannesburg, pp. 173-189. A statistical analysis of assay data from development and stope samples taken in a 1,000-foot-square block of ground in the City Deep mine, Central Witwatersrand, South Africa, is presented. The work was done by the use of statistical methods implemented by electronic computers that have proved effective in the analysis of assay data from North American ore deposits. The irregularity of the City Deep data is demonstrated, the sources of variation in the data are considered, and a mining strategy is suggested.

OP 95-67. Thermal Oxidation of n-Octane Vapor-Oxygen-Nitrogen Mixtures at Reduced Pressures, by J. M. Kuchta and G. H. Martindill. Combustion and Flame, v. 11, No. 3, June 1967, pp. 212-216. The slow oxidation of *n*-octane vapor-oxygen-nitrogen mixtures was investigated at reduced pressures and at temperatures up to where rapid reactions or "cool" flames may occur. At 250° C the rates of pressure rise were more dependent upon total pressure than upon the fuel and oxygen concentrations. The critical pressure for rapid reaction (abrupt pressure rise) decreased with increasing temperature, fuel concentration, and vessel radius. However, above approximately 290° C, abrupt pressure rises were not obtained and the reaction changed to a less temperature- and pressure-dependent process. The rate data were partly consistent with those predicted from thermal ignition considerations.

OP 96-67. Recovering Oil by Retorting a Nuclear Chimney in Oil Shale, by D. B. Lombard and H. C. Carpenter. J. Petrol. Technol., v. 19, No. 6, June 1967, pp. 727-734. A method is proposed for recovering oil by retorting oil shale shattered by deep underground nuclear explosions. Because most of the oil will be obtained from chunks of oil shale with maximum dimensions exceeding 1 foot, retorting times of up to several weeks are needed for complete recovery. A study of the heat economy of the retorting process in an undrground nuclear chimney suggests that the nuclear detonation itself and the subsequent controlled combustion of residual carbon in retorted oil shale will provide ample energy. The proposed method is shown to be thermally efficient. A 5-foot-diameter, 12-foot-high aboveground batch retort has been constructed for the experimental retorting of mixtures of oil shale particle sizes. Low rates of air and recycle gas, low retorting temperatures, and slow combustion front advance have characterized its operation. In spite of imperfect mist-separating equipment, recoveries of about 60 percent of Fischer assay have been obtained. The particle size distribution of 30 gallons per ton of oil shale has not been appreciably altered by the retorting. The operating conditions of a nuclear chimney retort will be defined by the recycle gas-to-air ratio and the overall rate of gas injection. Determination of optimum operating conditions will be complicated by the large number of factors involved. However, the proposed technique appears to be a promising one for recovering the oil from thick, deep oil-shale deposits.

OP 97-67. Trends in Froth Flotation—Reagent Use and Product Recovery, by Charles W. Merrill and James W. Pennington. Min. Cong. J., v. 52, No. 11, November 1966, pp. 24-26, 28, 30-31. The employment of froth flotation in the treatment of domestic minerals continued to expand rapidly in 1965. The number of plants reported to be operating in 1965, compared with plants operating in 1960, increased by over 30 percent; the tonnage of material treated increased more than 40 percent; the quantity of reagents consumed increased nearly 50 percent; and the quantity of concentrates recovered increased by 80 percent. Copper, copper-molybdenum, and molybdenum ores, phosphate rock, and potash were the leading materials treated. Spectacular percentage increases were recorded for iron ore and bituminous coal.

OP 98-67. Low-Temperature Thermal Data for *n*-Pentane, *n*-Heptadecane, and *n*-Octadecane. Revised Thermodynamic Functions for the *n*-Alkanes, C_5-C_{18}, by J. F. Messerly, G. B. Guthrie, S. S. Todd, and H. L. Finke. J. Chem. and Eng. Data, v. 12, No. 3, July 1967, pp. 338-346. From experimental heat capacity data, thermodynamic functions for the *n*-alkanes, C_5-C_{18}, in the liquid state were calculated for selected temperatures from 10° to 380° K.

OP 99-67. Cyclohexanethiol and 2,4-Dimethyl-3-Thiapentane: Low-Temperature Thermal Properties, by John F. Messerly, Samuel S. Todd, and George B. Guthrie, Jr. J. Chem. and Eng. Data, v. 12, No. 3, July 1967, pp. 426-430. From experimental heat capacity data, the thermodynamic functions of cyclohexanethiol and 2,4-dimethyl-3-thiapentane in the liquid state were calculated for selected temperatures from 10° to 370° K.

OP 100-67. Phase Equilibria in the System GeO_2-Al_2O_3, by John L. Miller, George R. McCormick, and Sarkis G. Ampian. J. Am. Ceram. Soc., v. 50, No. 5, May 1967, pp. 268-269. This note presents the results of a study of the system GeO_2-Al_2O_3 phase diagram.

OP 101-67. Evaluation of Materials for Ventilation Structures, by Edward W. Kawenski and Donald W. Mitchell. Min. Cong. J., v. 52, No. 3, March 1966, pp. 49-63. To assist in the design of effective ventilation systems, various materials and methods used in construction of stoppings were studied in the Bureau's Experimental Coal Mine. Air leakage tests were made on new and deformed stoppings, and the resistance of stoppings to pressure pulses, shock waves, and simulated ground movement was investigated.

OP 102-67. Sentinels of Safety Awards, by Forest T. Moyer. National Safety Council Newsletter, Min. Sec., October 1967. The annual National Safety Competition awards and honorable mentions in the underground metal, underground nonmetal, and open-pit mines are listed.

OP 103-67. Float Coal Hazard in Mines, by John Nagy and Donald W. Mitchell. Proc. 60th Regular Meeting, Rocky Mountain Coal Min. Inst., June 28-July 1, 1964, pp. 46-54. Results of initial research by the Bureau of Mines on the explosion hazard of float coal are presented, and methods for alleviating the hazard are discussed. Information is given from related studies on occurrence and rate of production of float coal, sampling techniques, and the transport and deposition of dust from the air current. Tentatively it is suggested that where float-coal deposits prevail, a minimum of 80 percent incombustible be maintained in the top one-eighth inch of dust on the ribs, floor, and roof.

OP 104-67. Design and Construction of a Thermal Radiation Probe, by A. A. Orning and C. H. Schwartz. Trans. ASME, J. Eng. for Power, v. 89, ser. A, No. 3, July 1967, pp. 395-397. A thermal radiation probe is described. A test in a pulverized-coal-fired furnace showed radiant flux decreasing from 130,000 to 60,000 Btu per square foot per hour, as the viewing direction was shifted from flame emission to wall reflection.

OP 105-67. Lithologies, Environments and Reservoirs of the Middle Mississippian Greenbrier in West Virginia, by William K. Overbey, Jr. Producers Monthly, v. 31, No. 2, February 1967, pp. 25-32. Comparison of lithologies observed in subsurface cores with outcrop samples of the basal members of the Greenbrier Group of the middle Mississippian in West Virginia indicate that oil and gas reservoirs found within this interval are the result of several slightly different but related depositional environments. These environments and the resulting lithologies are as follows: (1) Moderate to high energy environment above or near wavebase producing an oölitic limestone or a slightly sandy, oölitic limestone; (2) moderate to high energy beach and near-shore environment producing a sandy limestone-limy sand facies; and (3) moderate to high energy environment at or near wavebase producing a skeletal, biohermal limestone. In the subsurface all of the above lithologies were modified to some extent by dolomitization which produced reservoirs controlled primarily by the areal extent and degree of dolomitization. Methods of investigation to determine lithologies are discussed and possible methods of exploration for these primarily stratigraphic-type reservoirs are presented.

OP 106-67. Ground Control Rock Mechanics, by Louis A. Panek. Min. Cong. J., v. 23, No. 5. May 1967, pp. 60-62, 67-68. The ground control technology research program at the Denver Mining Research Center of the Bureau of Mines is reviewed.

OP 107-67. Calculation of the Average Ground-Stress Components From Measurements of the Diametral Deformation of a Drill Hole, by Louis A. Panek. In Testing Techniques for Rock Mechanics. ASTM Spec. Tech. Pub. 402, 1966, pp. 106-132. Determining the change of stress in rock based on measurements of the deformation of a drill hole is a procedure that is increasing in popularity. A closely related procedure involves the application of this principle to determine the existing stresses in a rock medium by cutting free (core drilling) an annulus containing the drill hole. In this report, expressions are derived from which one can calculate the stress ellipsoid—the three-dimensional change of stress or the existing three-dimensional stress field, as the case may be. Study of these equations shows that the stress components in three dimensions can be determined by measurements in only two drill holes and yields general principles that are useful in planning an efficient program of drilling and measurement. The need for some method of averaging the measurements arises even in the simplest situation, because one usually has available several sets of measurements and wishes to combine them into a single set of average stress components. Procedures, therefore, are given for calculating the least squares estimates of the stress components and their standard errors, and for evaluating or comparing calculated values by means of standard statistical inferences.

OP 108-67. The Search for Low-Sulfur Coal, by Harry Perry and Joseph A. DeCarlo. ASME 66-PWR-3, 1966, 27 pp. For special-purpose coals used in the production of coke, ceramics, and so forth, the sulfur content of the coal is a critical factor, and low-sulfur coals generally are used. Export markets, principally of special-purpose or metallurgical coal, also require coals of low sulfur content. In addition the increased attention to oxides of sulfur as a harmful air pollutant has resulted in great interest by coal-consuming industries in the availability of low-sulfur coals. The paper discusses the availability of low-sulfur coals and describes methods of reducing the emission of sulfur oxides from furnaces.

OP 109-67. Lessons From Some Recent Front-End Loader Accidents, by R. O. Pynnonen. Trans. Nat. Safety Council, v. 16, Mining, 1965, pp. 33-36. Information in this paper was obtained from written reports on 44 fatal accidents that occurred during the operation of rubber-tired front-end loaders powered by either diesel or gasoline engines at metal, nonmetal, and coal mines, stone quarries, gravel pits, and mills. The reports are analyzed and certain safety recommendations are proposed.

OP 110-67. Pyrrole: Chemical Thermodynamic Properties, by D. W. Scott, W. T. Berg, I. A. Hossenlopp, W. N. Hubbard, J. F. Messerly, S. S. Todd, D. R. Douslin, J. P. McCullough, and G. Waddington. J. Phys. Chem., v. 71, No. 7, June 1967, pp. 2263-2270. Experimental studies of pyrrole provided values of heat capacity for the solid, liquid, and vapor; temperature of a lambda-type transition of the solid; enthalpy of fusion; thermodynamic properties for the solid and liquid; enthalpy of vaporization; equation-of-state constants; vapor pressure; and standard enthalpies of combustion and formation. The chemical thermodynamic properties in the ideal gas state were calculated by methods of statistical mechanics.

OP 111-67. Economic Considerations of Exploration and Development, by E. Shekarchi. CENTO Symp. on Techniques for Mineral Investigation, Sept. 15, 1965, Isfahan, Iran, pp. 157-165. Close cooperation between the government and private sectors is necessary for the development of a strong mineral industry. Regional geological maps prepared by the government can outline target areas into which private companies can move for intensive mapping and investigation. Essential to both exploration and development is an atmosphere in which investors are assured a reasonable return on risk capital and ample time to develop a property to its full potential. To bring exploration and development to full scale, the private sector must have the marketing knowledge that will enable it to compete effectively in the world market and thereby increase the flow of foreign exchange into the country.

OP 112-67. Helium Storage in Cliffside Field, by Miles D. Tade. J. Petrol. Technol., v. 19, No. 7, July 1967, pp. 885-888. Since January 1963 the Bureau of Mines has been injecting crude helium into the Bush Dome structure of Cliffside field for storage in connection with the Government's helium conservation program. It is predicted that during the life of the injection program about 59 billion cubic feet of crude helium, containing 41.5 billion cubic feet of helium, will be injected. As of July 1, 1966, 15.3 billion cubic feet of helium, containing 10.7 billion cubic feet of conservation helium, was in storage.

OP 113-67. Western Coals: Some Trends in Utilization and Research, by Charles C. Boley and Wayne R. Kube. Western Resources Papers 1966, Natural Gas, Coal, Ground Water. Exploring New Methods and Techniques in Resources Research, University of Colorado Press, pp. 195-221. The purposes of this paper are to compare the present western coal industry to the coal industry of the nation and to other mineral wealth of the West, to present trends in utilization of coal for the nation and for the western area, to consder coal research trends and their coordination with utilization trends, and to present an outline of research being conducted on western coals by the Bureau of Mines.

OP 114-67. An Investigation of the Behavior and Control of Methane Gas, by Joseph Cervik. Min. Cong. J., v. 53, No. 7, July 1967, pp. 52-57. The flow of gas in U.S. coalbeds is governed predominantly by Darcy's law. Therefore, control measures and degasification techniques will be aimed primarily at reducing pressure, reducing permeability, or filling of the pore volume with a more viscous liquid.

OP 115-67. Methodology in Air Pollution Studies Using Irradiation Chambers, by Basil Dimitriades. J. Air Pollution Control Assoc., v. 17, No. 7, July 1967, pp. 460-466. This paper describes methods and techniques used at the Bartlesville Petroleum Research Center in conducting photochemical smog studies in its two irradiation chambers.

OP 116-67. Empirical Approach to Problems in Blasting Research, by W. I. Duvall, T. C. Atchison, and D. E. Fogelson. In Failure and Breakage of Rock. Proc. 8th Symp. on Rock Mechanics, 1966. American Institute of Mining, New York, 1967, pp. 500-523. This paper discusses how the Bureau of Mines has used the empirical approach to study problems related to vibrations from quarry blasting, comparison of explosives for rock breaking ability, and the generation and propagation of strain waves from cylindrical charges.

OP 117-67. Hexagonal Diamonds in Meteorites, by Sabri Ergun and Leroy E. Alexander. Science, v. 156, No. 3783, June 30, 1967, pp. 1770-1771. The existence of a possible hexagonal polymorph of diamond is experimentally confirmed by the recent synthesis of hexagonal diamond at high pressure and the discovery of hexagonal diamond in the Canyon Diablo and Goalpara meterorites.

OP 118-67. Use of Monopropellants To Alter Petroleum Rock Properties, by Ray V. Huff and Larman J. Heath. Producers Monthly, v. 31, No. 6, June 1967, pp. 12-15. A study was conducted to determine the technical feasibility of burning a monopropellant in a porous matrix to improve its permeability. Physical and chemical characteristics of possibly useful compounds were investigated. A proprietary monopropellant compound was used in the tests. Thermal decomposition of the monopropellant occurred in situ, resulting in the propagation of a flame front through the entire length of three Torpedo sandstone cores. Three Prue sandstone samples experienced only partial burning. Sandstone samples which were burned showed an average permeability increase of 214 percent.

OP 119-67. Here's What SO_2 Removal Costs, by Sidney Katell and K. D. Plants. Hydrocarbon Processing, v. 46, No. 7, July 1967, pp. 161-164. Two previous papers have outlined three processes which are being considered for the removal of SO_2 from powerplant flue gas. Pilot plant operations are underway for the two most promising of the processes discussed. Several new concepts are being considered and conceptual designs have been made. Economic consideration is preliminary but estimates are being made to determine the potential of the new concepts. An evaluation of dry processes indicates a favorable economic potential when compared to wet processes. For two systems undergoing intensive investigation in this country, the operating cost for both the alkalized alumina and the catalytic oxidation systems are about equal if the byproduct is sulfuric acid. However, since sulfur can be produced in an alkalized alumina system it would be an advantage if market conditions are unfavorable for sulfuric acid.

OP 120-67. *Catharanthus Lanceus* VII. Isolation of Tetrahydroalstonine, Lochnerinine, and Periformyline, by Edward M. Maloney, Norman R. Farnsworth, Ralph N. Blomster, Donald J. Abraham, and Andrew G. Sharkey, Jr. J. Pharmaceutical Sci., v. 54, No. 8, August 1965, pp. 1166-1168. A continuing study of *Catharanthus lanceus* leaf alkaloids for antineoplastic compounds has led to the solution of tetrahydroalstonine, lochnerinine, and a new alkaloid periformyline. Details concerning the isolation of these alkaloids and the structure elucidation of periformyline, the first example of an $N_{(a)}$-substituted formyl indole alkaloid to be found in nature, are presented.

OP 121-67. The Stress in Rock Around Surface Openings, by R. H. Merrill and D. W. Wisecarver. In Failure and Breakage of Rock. Proc. 8th Symp. on Rock Mechanics, 1966. American Institute of Mining, New York, 1967, pp. 337-350. This report describes the state of the art concerning the stresses around surface openings in rock. Also summarized are the results of in situ stress determinations near open pits.

OP 122-67. Explosive Fracturing Tested in Oil Shale, by J. S. Miller and W. D. Howell. Colorado Sch. Mines Quart., v. 62, No. 3, July 1967, pp. 63-73. An explosive-fracturing experiment was performed in Green River oil shale near Rock Springs, Wyo., as a prelude to research on in situ retorting oil from the shale. The objective of the test was to determine if a liquid explosive displaced in a sheet-like layer and detonated in the oil shale would explode with sufficient force to significantly crack the rock. Although the evaluation of results from this research is continuing, preshot surveys and comparable postshot tests indicate that a charge of 190 quarts of desensitized liquid nitroglycerin (NGl) was displaced a lateral distance of 22 feet at a depth of 147 to 149 feet and successfully detonated in the oil shale. Fracture-improvement ratios determined from before- and after-flow tests in six holes averaged 3.5.

OP 123-67. Extractive Processes, by C. H. Schack and B. H. Clemmons. Ch. 4 in Silver: Economics, Metallurgy, and Use, ed. by A. Butts. Handy and Harman, New York, 1967, pp. 57-77. Extractive metallurgy techniques currently employed to recover silver from primary ores and secondary scrap are reviewed and evaluated. Practically all primary silver is recovered by froth flotation concentration of various types of ore, followed by smelting and refining of the separate lead, cooper, and zinc concentrates. Any silver production gain from base-metal ores, which contribute about two-thirds of the total primary silver, is directly dependent on improvement in the market for base metals. Statistical data on old and new silver scrap are inadequate to make reliable conclusions about increasing the recovery of silver from secondary sources. Available information indicates that efficient reclamation practices are employed by large users of silver and that recovery of additional secondary silver involves solutions of problems of collection rather than processing.

OP 124-67. **See OP 183-67.**

OP 125-67. Mass Spectrometry, by A. G. Sharkey, Jr. Encyclopedia of Physics, ed. by Robert M. Besançon. Reinhold Pub. Corp., New York, 1966, pp. 404-406. The mass spectrometer is used primarily for the quantitative analysis of gases, liquids, and a limited number of solids. Mass spectrometry provides information concerning the mass-to-charge ratio and the abundance of positive ions produced from gaseous species. There are several techniques for the production and measurement of the ions, and the design of an instrument is determined by its proposed application.

OP 126-67. Book Review, by A. G. Sharkey, Jr. "Mass Spectrometry," ed. by C. A. McDowell. Materials Res. and Standards, v. 4, No. 8, August 1964, pp. 460-461.

OP 127-67. Secondary Oil Recovery by Steam Stimulation, by G. B. Shea. Independent Petrol. Monthly, v. 36, No. 10, February 1966, pp. 34-35.

The steam soak is an individual well stimulation process which includes a steam injection cycle, a short "soaking" period during which the well is shut in, and a production cycle. The generally satisfactory and sometimes spectacular results recently achieved in many steam soak projects have greatly intensified interest in this secondary recovery technique.

OP 128-67. Progress Report on Bureau of Mines—Atomic Energy Commission Corehole, Rio Blanco County, Colorado, by Kenneth E. Stanfield. Colorado Sch. Mines Quart., v. 61, No. 3, July 1966, pp. 33-44. In 1965 the Bureau of Mines, with the assistance and cooperation of the U.S. Atomic Energy Commission, drilled an exploratory corehole in the Piceance Creek basin, Colorado, to evaluate buried oil shales that might be amenable to fracturing by a nuclear explosive and subsequent recovery of oil by underground retorting. Preliminary results indicate continuous oil shales occurred at depths of 985 feet to the bottom of the hole at 2,600 feet and may extend another 600 feet below the sampled interval. Present plans are to deepen the hole and take boroscopic photographs of an interval exhibiting poor recovery. A second hole will be drilled at another site in the basin to locate thinner oil-shale beds under less overburden that may be more suitable for the proposed underground tests.

OP 129-67. Gauge for Determining Shock Pressures, by Richard W. Watson. Rev. Sci. Instr., v. 38, No. 7, July 1967, pp. 978-980. A simple inexpensive pressure gage is described that is capable of determining pressures associated with blasts, shocks, and detonation waves. As described, it is capable of operation over the range extending from about 1 to 100 kilobars. Application has been filed by the author for a patent on this device and "Notice of Allowance" was received July 10, 1967 (Serial No. 453,530).

OP 130-67. Mining, by Paul F. Yopes. Britannica Book of the Year, 1967, pp. 545-546. A brief review is given of mining production, industrial development, and technological advances in the mineral industries.

OP 131-67. A Method for Mica Determination by Heavy Liquid Separation, by R. B. Adair and J. S. Browning. Trans. SME, September 1967, pp. 248-252. The Bureau of Mines conducted laboratory research to determine the applicability of heavy-liquid separation to the evaluation of certain mica ores and plant products. After careful standardization of the particular mica ores and associated gangue, accurate analysis of muscovite content could be obtained from results of heavy-liquid separation. Where applicable, the method should be particularly suited to the analysis of ores and control of plant operations wherein savings in time would be of considerable advantage. Specifically, there are many instances where a quick plant control method should enable the production of a more uniform grade of mica concentrate.

OP 132-67. Cell for Determining Compressibility Factors. High Liquid-Gas Ratio Fluids, by Francis G. Archer and C. Kenneth Eilerts. Proc. 46th Ann. Conv. Nat. Gas Processors Assoc., Houston, Tex., March 1967, pp. 60-75. A piston-fitted cell has been developed by the Bureau of Mines to measure compressibility factors for fluids containing up to 16 gallons of liquid with 1,000 standard cubic feet of gas. The assembly of equipment can be used to mix a sample and measure its compressibility factors at pressures up to 6,000 psia and one temperature in an 8-hour period with an accuracy of 1 percent.

OP 133-67. Tests Yield Reliable Compressibility Factors, by Francis G. Archer and C. Kenneth Eilerts. Oil and Gas J., v. 65, No. 28, July 10, 1967, pp. 184-189. (For summary see OP 132-67.)

OP 134-67. Comparison of Detectors for Isotopic X-Ray Analyzers, by Philip G. Burkhalter and William J. Campbell. Proc. 2d Symp. Low Energy X- and Gamma Sources and Applications, University of Texas, Austin, Tex., March 27-29, 1967, ORNL-IIC-10, pp. 393-423. Isotopic X-ray analyzers for use as drill-hole probes and process monitors are being developed and evaluated as part of the Bureau of Mines heavy metals program. Optimization of the X-ray detector is required to analyze low-grade gold and silver ores, using energy dispersion techniques coupled with isotopic X-ray excitation. The following properties of gas, scintillation, and semiconductor X-ray detectors are compared: detection efficiency, pulse resolution, intensity linearity, energy linearity, stability, size, ruggedness, and cost. Scintillation detectors have satisfactory overall detection capabilities except for poor pulse resolution. Gas proportional detectors are excellent low-energy X-ray detectors except space charge results in pulse shifts with intensity. Semiconductor detectors are attractive because their sharp pulse resolution (less than 1 kev) allows multi-element determination by electronic pulse analysis.

OP 135-67. The American Society for Testing and Materials. I. Its Operation and Products. II. Initiating Research in ASTM Committees, by J. W. Caum and H. M. Smith. Current Eng. Practice (Bombay, India), v. 9, No. 9, March 1967, pp. 20-25. Describes the operation and products of ASTM, including the origin, organization, publications, technical committee organization, evolution of ASTM standards, and initiation of research.

OP 136-67. Integration of Partial Differential Equations for Multicomponent, Two-Phase Transient Radial Flow, by C. Kenneth Eilerts and Eudora F. Summer. Soc. Petrol. Eng. J., v. 7, No. 2, June 1967, pp. 125-135. A partial differential equation was developed and programed to compute the cumulation and flow of the liquid phase of a gas-condensate fluid. The radius at which this saturation obtains advances toward the external reservoir boundary with continued recovery, although it may move only 2 to 5 percent of that distance during the productive life of the well. This relatively high saturation can cause a serious diminution in delivery capacity. The pressure differential required for flow of gas through a formation with such saturation may be as much as three times greater than the corresponding differential in a formation where saturation is less than 2 percent.

OP 137-67. Immobility of Connate Water in Permeable Sandstone, by G. Edward Manger and William T. Wertman. Geol. Survey Prof. Paper, 575-C, 1967, pp. C192-C194. Some natural-state cores of moderately permeable Eocene sandstone, obtained by drilling with oil-base mud in Karnes County, Tex., appear to be saturated and other cores appear to be partially unsaturated. The variation of interstitial water chlorinity is related to the depositional environment of the different sandstone strata. These results suggest that a small fraction of connate water has remained immobile in the sandstone since the Eocene. Such immobility agrees with that found experimentally by Wyckoff and Botset and discussed theoretically by Irmay for a small fraction of fluid in a saturated permeable porous medium. Absence of significant diffusion over geologic ages seems to be necessary to explain the present results; reasons for this are not yet evident.

OP 138-67. Ternary Phases in the System $MgO-GeO_2-LiF$, by George Robert McCormick and Ernest G. Ehlers. J. Am. Ceram. Soc., v. 50, No. 8, August 1967, pp. 438-439. A study of the system $MgO-GeO_2-LiF$ was undertaken to investigate fluorogermanate compounds analogous to $Li_2Mg_4Li_2 \cdot Si_8O_{20}F_4$, $Li_2Mg \cdot Mg_5Si_8O_{22}F_4$, and $Li_{0.66} \cdot Li_{0.50}Mg_{1.50} \cdot Mg_{5.00}Si_{7.88}O_{21.90}F_{2.06}$ found in the system $MgO-SiO_2-LiF$; in addition compounds might be revealed for which no silicate counterpart is known. This study was intended to throw new light on both the germanates and the silicates, in particular on the relation and compatibility of the various compounds of magnesia and lithium fluoride.

OP 139-67. Summary of Stress Determination Made in the Proximity of Underground Openings, by Leonard Obert. In Failure and Breakage of Rock. Proc. 8th Symp. on Rock Mechanics. American Institute of Mining, New York, 1967, pp. 217-223. Summarizes the findings of 20 investigations of stress in rock in the proximity of underground openings using the borehole deformation procedure.

OP 140-67. Mineral Investigations Under the Wilderness Act, by M. H. Salsbury. Mines Mag., v. 56, No. 6, June 1966, pp. 4-8. Discusses the Wilderness Act (passed Sept. 3, 1964), its background and provisions, and the part that will be played by the Bureau of Mines and the Geological Survey in assessing the mineral resources of primitive areas that are proposed for inclusion in the Wilderness System.

OP 141-67. Proposed Mine Rescue and Safety Centers for CENTO Countries, by Donald P. Schlick. CENTO Symp. on Mine Health and Safety, Izmir, Turkey, Oct. 11-19, 1966, pp. 99-109. The author proposes that mine rescue and training stations be set up in close proximity to mining areas in each CENTO country—Iran, Pakistan, and Turkey. Suggestions are made for the housing, equipment, and staff requirements for mine rescue and training centers. An outline of a mine rescue training program is appended.

OP 142-67. High Resolution Gas Chromatographic Analysis of Auto Exhaust Gas, by D. E. Seizinger. Instrument News, v. 18, No. 1, October 1967, pp. 11-12. The design and operation of a high-resolution gas chromatograph for analyzing auto exhaust gas is described.

OP 143-67. Thermal Analysis of Natural Fuels, by John Ward Smith and Donald R. Johnson. Proc. 2d Toronto Symp. on Thermal Analysis, Toronto Sec., Chem. Inst. of Canada, Feb. 27, 1967, pp. 95-116. Problems and published experience with thermal analysis of natural fuels are reviewed, novel apparatus developed to solve these problems described, and applications to oil shale and a coal study presented.

OP 144-67. A Neutron Moisture Meter for Coal, by R. F. Stewart and A. W. Hall. Trans. SME, September 1967, pp. 269-272. A method has been developed for continuously measuring the moisture content of coal. The method is based on the thermalization of fast neutrons by hydrogen in the coal. Neutrons from a small radioisotope source penetrate the coal, are scattered by hydrogen, and measured by a thermal neutron detector. The number of thermal neutrons counted can be directly correlated with the moisture content of coal. In a pilot-scale system, moisture was measured continuously within 0.2 percent in coal moving at rates up to 20 tons per hour. The method is adaptable in industry for continuously measuring the moisture content of coal at high tonnage flow rates. Such an application would permit continuous recording of moisture in coal without sampling and would facilitate quality control.

OP 145-67. Multistage Cyclones for Heavy Liquid Concentration of Minerals, by R. B. Tippin and J. S. Browning. Trans. SME, September 1967, pp. 239-244. The feasibility of multistage heavy-liquid cyclone beneficiation of spodumene was successfully demonstrated in this investigation. The indicated recovery for the multistage circuits was mathematically estimated, as continuous test runs would be necessary to determine the true influence of a middlings recycle. In the three-stage circuit, both the concentrate analysis and spodumene recovery exceeded 90 percent. The two-stage circuits were unable to simultaneously yield an acceptable product with a satisfactory recovery.

OP 146-67. Minerals and Economic and Political Power: An Historical Survey, by William A. Vogely. Proc. Council of Economics, AIME, Feb. 28-Mar. 2, 1966, New York, 1966, pp. 268-275. The significance of mineral supplies and stocks during war or for a country's war potential is no longer great. The role of minerals in economic growth is a much more complex one. The process by which an economy changes its character from one based upon its mineral resource endowments to one which flourishes through accumulation of capital and technology is extremely complex and imperfectly understood. Much more research, both empirical and theoretical, of the relation between minerals and economic growth is clearly called for.

OP 147-67. Thermal Cracking of Low Temperature Lignite Pitch, by John S. Berber, Richard L. Rice, and Delmar R. Fortney. I&EC Product Research and Development, v. 6. No. 3, September 1967, pp. 196-200. Thermal cracking of low-temperature lignite pitch has proved to be an effective means of upgrading the pitch. Four products are obtained by the thermal cracking. About 15 to 20 percent of the pitch is converted to coke, about 20 to 40 percent is recovered as cracked pitch, about 20 to 30 percent is recovered as oil, and the balance is recovered as gas. The oil, upon distillation to 400° C, gives a distillate rich in aromatics which can be oxidized to phthalic and maleic anhydrides. The oil distillation residue has good binding qualities for carbon electrodes. The gas contains 10 to 15 percent ethylene as well as hydrogen and methane. The coke was calcined and used with the oil distillation residue pitch as a binder to produce a metallurgical electrode made totally from lignite tar products.

OP 148-67. A Look Ahead at Synthetic Hydrocarbon Technology, by Walter R. Hibbard, Jr. J. Petrol. Technol., v. 19, October 1967, pp. 1329-1333. Fuels to produce energy are vital to all residents of the United States. Although there are no present apparent shortages of fossil fuels, consideration of the long-term energy needs of the nation leads to the conclusion that fuels from supplementary sources may soon begin to enter into the domestic energy mix.

The present impetus of oil-shale research and development and recent announcements by Secretary of the Interior Stewart Udall pertaining to the management of oil-shale lands tend to support earlier predictions of the Bureau of Mines that there will be commercial production of shale oil within the next 10 years. It is probable that liquid and gaseous fuels from coal will begin to enter the market simultaneously with, or not much later than, shale oil. The limited knowledge of the total resources of domestic tar sands does not permit good predictions of when fuels from tar sands will become commercially significant.

OP 149-67. Combustion Characteristics of Condensed-Phase Hydrazine-Type Fuels With Nitrogen Tetroxide, by Theodore Christos, Yael Miron, Harry James, and Henry E. Perlee. J. Spacecraft and Rockets, v. 4, No. 9, September 1967, pp. 1224-1229. The Bureau of Mines Explosives Research Center investigated the combustion characteristics of hydrazine-type propellants and the resultant reactions occurring in low-thrust engines prior to ignition. Frozen hydrazine, monoethylhydrazine, unsymmetrical dimethylhydrazine and Aerozine-50 mixed with N_2O_4 at liquid nitrogen temperature exhibited a violent exothermic reaction upon warming between $-50°$ and $-70°$ C, depending on the fuel used. The Aerozine and N_2O_4 mixtures always yielded a detonationlike reaction; the other mixtures exhibited less violent reactions. Hydrazine exhibited an explosive reaction having a TNT equivalence of about 130 percent when explosively fired in atmospheres of air, O_2, or N_2O_4. Stoichiometric mixtures of the various liquid fuels and liquid N_2O_4 indicated TNT equivalences of about 160 percent in all cases. The structural and inertial response of simulated rocket engines to internal explosions was also studied.

OP 150-67. Rocket Fuels, by Glenn H. Damon. Fuels, by Staff, Bureau of Mines, under the direction of L. L. Newman, in sec 7, Fuels and Furnaces. Standard Handbook for Mechanical Engineers, ed. by T. Baumeister and L. S. Marks. McGraw-Hill Book Co., New York, 7th ed., 1967, pp. 7-45 through 7-51. This discussion is confined essentially to chemical rocket-propulsion systems. In general, propellant systems (fuel and oxidant) are discussed rather than the fuel alone because most rocket fuels require an exodizing agent and the overall performance of the rocket depends both upon the fuel and the oxidant. Rapid advances in propellant technology in the last few years make it difficult to give a meaningful comparison between the performance of solid- and liquid-fueled rocket engines. A comparison of the advantages and disadvantages of each system indicates that the choice of propellant largely depends on the mission to be accomplished.

OP 151-67. Dust Explosions in Buildings, by Henry G. Dorsett, Jr. Fuels, by Staff, Bureau of Mines, under the direction of L. L. Newman, in sec. 7, Fuels and Furnaces. Standard Handbook for Mechanical Engineers, ed. by T. Baumeister and L. S. Marks. McGraw-Hill Book Co., New York, 7th ed., 1967, pp. 7-38 through 7-45. Dust explosibility is affected by so many chemical and physical factors that a mathematical theory has yet to be developed. Empirical and experimental results are the chief guide in evaluating relative dust explosion hazards. The data evaluated are composition, fineness, and concentration of dust clouds; the effect and type of gases that may inhibit or prevent dust explosions; and the types of ignition sources. The explosive characteristics of selected dusts are tabulated.

OP 152-67. P-V-T Relations in the System Methane-Tetrafluoromethane: Part 1. Gas Densities and the Principle of Corresponding States, by D. R. Douslin, R. H. Harrison, and R. T. Moore. J. Phys. Chem., v. 71, No. 11, October 1967, pp. 3477-3488. The methane-tetrafluoromethane system was examined for conformity with the principle of corresponding states in terms of the Boyle reference point, the critical reference point, and mixing rules as applied to the reference temperatures and volumes.

OP 153-67. Transverse and Longitudinal Optical Properties of Graphite, by E. Ergun, J. B. Yasinsky, and J. R. Townsend. Carbon, v. 5, September 1967, pp. 403-408. Optical anisotropy of single crystals of graphite has been studied in the visible and ultraviolet spectrum from measurements of reflectance of polarized light normally incident on the (1012) face employing two immersion media. The spectrum of the real part of the transverse dielectric constant suggests the presence of electronic absorption and the imaginary part exhibits a peak at 4.8 ev explained by "π resonance." The real longitudinal dielectric constant remains more or less invariant and the imaginary part is zero or too small to be measured in the wave energy range 2 to 5.5 ev, indicating a transparency to polarized light when the electric vector lies along the optic axis.

OP 154-67. Predicted Waterflood Performance of a Pilot Pattern in the Fork Run Area, Ludlow Field, McKean County, Pa., by Karl-Heinz Frohne. Producers Monthly, v. 31, No. 8, August 1967, pp. 22-25. A series of waterflood performance predictions was made for the Cooper sand in the Fork Run area of the Ludlow fields, McKean County, Pa., to evaluate one of the possibilities of secondary recovery. The predictions were made using a digital computer and combined selected features of the Suder-Calhoun-Yuster waterflood calculations and the Craig, Geffen, and Morse waterflood prediction method. Predictions were made using four gas saturations (1.5, 10, 15, and 20 percent) and three different water-injection rates. Original oil in place in the pilot pattern was calculated to be 527,000 reservoir barrels, and primary recovery is expected to be approximately 11 percent. By flooding the pilot area with 1,370,000 barrels of water, secondary-recovery volumes are predicted to be 168,000, 127,000, 104,000, and 82,000 barrels of oil, respectively, for the four gas saturations. This production represents recovery of 35, 30, 26, and 22 percent of oil in place at the beginning of the respective floods. The predictions show that substantial amounts of oil may be recovered if sufficient water is injected.

OP 155-67. Gaseous Fuels, by R. M. Gooding. Fuels, by Staff, Bureau of Mines, under the direction of L. L. Newman, in sec. 7, Fuels and Furnaces, Standard Handbook for Mechanical Engineers, ed. by T. Baumeister and L. S. Marks. McGraw-Hill Book Co., New York, 7th ed., 1967, pp. 7-30 through 7-35. Gives data on the properties of gaseous fuels, including natural gas, manufactured gas, and liquefied petroleum gas.

OP 156-67. Petroleum and Other Liquid Fuels, by R. M. Gooding. Fuels, by Staff, Bureau of Mines, under the direction of L. L. Newman, in sec. 7, Fuels and Furnaces. Standard Handbook for Mechanical Engineers, ed. by T. Baumeister and L. S. Marks. McGraw-Hill Book Co., New York, 7th ed., 1967, pp. 7-20 through 7-30. Gives data on the properties of petroleum, petroleum products, and other liquid fuels such as coal carbonization products, ethyl and methyl alcohols, synthetic liquid fuels, and shale oil.

OP 157-67. Kinetics of Oxygen Exchange Between CO_2 and CO on Carbon, by M. Mentser and S. Ergun. Carbon, v. 5, September 1967, pp. 331-337. A study was made of the reversible exchange of oxygen between CO_2 and CO on a carbon surface,

$$CO_2 + C_f \underset{k'_1}{\overset{k_1}{\rightleftarrows}} CO + C_o$$

at 750° to 850° C and atmospheric pressure with carbon-14 used as a tracer. At these temperatures the rates of exchange were a few orders of magnitude greater than the rates of gasification; i.e., transfer of carbon from solid to gas phase. Activation energies for the forward and backward reactions were 53 and 36 kcal/mole, respectively. Direct determination of the equilibrium constant of the oxygen exchange reaction made in this study agreed well with indirect determinations made earlier. Thus oxygen exchange was established as an authentic and important step in the reaction sequence for the carbon dioxide-carbon reaction. The results showed further that oxygen exchange is not likely to become the rate-controlling step at higher temperatures and that the retarding effect of CO on gasification rates should diminish with increasing temperature.

OP 158-67. Peat, Wood, and Miscellaneous Solid Fuels, by L. L. Newman and W. H. Ode. Fuels, by Staff, Bureau of Mines, under the direction of L. L. Newman, in sec. 7, Fuels and Furnaces. Standard Handbook for Engineers, ed. by T. Baumeister and L. S. Marks. McGraw-Hill Book Co., New York, 7th ed., 1967, pp. 7-17 through 7-20. Discusses the preparation, composition, and heat values of peat, wood, charcoal, and miscellaneous byproduct fuels.

OP 159-67. Coal, by W. H. Ode. Fuels, by Staff, Bureau of Mines, under the direction of L. L. Newman, in sec. 7, Fuels and Furnaces. Standard Handbook for Mechanical Engineers, ed. by T. Baumeister and L. S. Marks. McGraw-Hill Book Co., New York, 7th ed., 1967, pp. 7-2 through 7-16. Discusses coal classification methods, coal composition and characteristics, coal mining and preparation, storage problems, sampling methods, and specifications for the purchase of coal.

OP 160-67. Tertiary Oil Recovery From a Consolidated Sandstone Core by the Alcohol and Alcohol-Kerosine Slug Injection Methods, by G. F. Rennick and J. Pasini III. Producers Monthly, v. 31, No. 8, August 1967, pp. 14-18. The objective of this work was to compare results of alcohol and combination alcohol-kerosine slug injection on tertiary oil recovery from a consolidated sandstone core. Experiments were conducted on a consolidated Berea Sandstone core, 168 cm long by 5 cm in diameter. The fluids used were isopropyl alcohol, kerosine, Soltrol C, and water containing 21,000 ppm calcium chloride. The solvent slug sizes were approximately 0.25, 0.375, and 0.50 pore volume. The rates of injection were about 27, 41, and 52 feet per day. The core was prepared for the test by saturating with Soltrol C and then flooding with brine to residual oil saturation. The pure alcohol slug was then injected and was followed by brine to complete the test. In the other tests, combination slugs of alcohol, kerosine, and alcohol were substituted for the pure alcohol slug. At the end of the slug injection, more residual oil was recovered by the combination slug (alcohol-kerosine-alcohol) than by the pure alcohol slug. However, the ultimate residual oil recoveries with the single alcohol slug were equal to or greater than those obtained with the combination slug. The effectiveness of the combination slug was further reduced as a result of the low kerosine recoveries. The water-oil ratios indicate that the displacement mechanism of the pure alcohol slug was drag-type, while that of the combination slug was the loose-piston type.

OP 161-67. Alterations in Structure and Physical Properties of Green River Oil Shale by Thermal Treatment, by P. R. Tisot. J. Chem. and Eng. Data, v. 12, No. 3, July 1967, pp. 405-411. Experimental data are presented showing changes in physical structure and physical properties that occur when oil shales of widely different organic content from the Green River Formation are heated under controlled conditions to 950° and to 1,500° F in a stress-free environment. Seven oil shales were investigated yielding from 1 to about 60 gallons of oil per ton of oil shale. Physical properties evaluated, before and after heating, were compressive strength, structural alterations, permeability, porosity, weight loss, and bulk density. These data serve as engineering guidelines for in situ combustion or other retorting processes.

OP 162-67. Explosives, by Robert W. Van Dolah. Fuels, by Staff, Bureau of Mines, under the direction of L. L. Newman, in sec. 7, Fuels and Furnaces. Standard Handbook for Mechanical Engineers, ed. by T. Baumeister and L. S. Marks. McGraw-Hill Book Co., New York, 7th ed., 1967, pp. 7-35 through 7-38. Gives data on the composition and properties of commercial explosives, chiefly ammonium nitrate blasting agents and dynamites, and includes data on military explosives that have been adapted for industrial explosive applications.

OP 163-67. High Temperature Viscosity of Gases Estimated Quickly, by Murray Weintraub and Paul E. Corey. Chem. Eng., v. 74, No. 22, Oct. 23, 1967, p. 204. A nomograph was prepared from the equation

$$\mu_1/\mu_2/ = f(T_{r1})/f(T_{r2})$$

where μ_1 and μ_2 are viscosities at corresponding reduced temperates T_{r1} *and* T_{r2} and $f(T_{r1})$ and $f(T_{r2})$ are complex logarithmic functions. Directions are given for its use in estimating the high-temperature viscosity of gases.

OP 164-67. Coke, by D. E. Wolfson. Fuels, by Staff, Bureau of Mines, under the direction of L. L. Newman, in sec. 7, Fuels and Furnaces. Standard Handbook for Mechanical Engineers, ed. by T. Baumeister and L. S. Marks. McGraw-Hill Book Co., New York, 7th ed., 1967, pp. 7-16 through 7-17. Discusses the types and uses of coke produced in the United States.

OP 165-67. Vibrational Spectra and Conformational Analysis of 2,3-Dichloropropene, by G. A. Crowder. J. Molecular Spectroscopy, v. 20, No. 4, August 1966, pp. 430-437. Infrared spectra in the region 65 to 3,500 cm^{-1} are presented for 2,3-dichloropropene. The torsional band was observed at 89 cm^{-1} for the vapor state, accompanied by hot bands at 77 and 84 cm^{-1}.

OP 166-67. Acetonitrile: Far-Infrared Spectra and Chemical Thermodynamic Properties. Discussion of an Entropy Discrepancy, by G. A. Crowder and Bobby Cook. J. Phys. Chem., v. 71, No. 4, March 1967, pp. 914-

916. Liquid- and vapor-state infrared spectra in the region 75 to 650 cm^{-1} were obtained for acetonitrile. A table of the chemical thermodynamic properties of acetonitrile at selected temperatures was prepared.

OP 167-67. Project Gasbuggy—Status Report, by C. H. Atkinson and Don C. Ward, J. Petrol. Technol., v. 19, No. 10, October 1967, pp. 1319-1324. Field work to test the nuclear fracturng concept commenced near Farmington, N. Mex., in early 1967. Data from two test wells have verified an earlier belief that the Pictured Cliffs gas sand at 4,000 feet would be suitable for the test. The 26-kiloton shot is planned for November 1967.

OP 168-67. Reaction of Coal and Graphite in a Microwave Discharge in H_2O and D_2O, by Yuan C. Fu and B. D. Blaustein. Chem. and Ind., No. 29, July 22, 1967, pp. 1257-1258. Coal, when reacted with water vapor in a microwave discharge, is readily gasified to produce H_2, CO, C_2H_2, and small amounts of other hydrocarbons. C_2H_2 accounts for as much as 95 percent of gaseous hydrocarbons produced.

OP 169-67. Mechanism of Bacterial Pyrite Oxidation, by Melvin P. Silverman. J. Bacteriology, v. 94, No. 4 October 1967, pp. 1046-1051. The oxidation by *Ferrobacillus ferroxidans* of untreated pyrite as well as HCl-pretreated pyrite was studied manometrically. It is probable that two mechanisms of bacterial pyrite oxidation operate concurrently: the direct contact mechanism which requires physical contact between bacteria and pyrite particles for biological pyrite oxidation and the indirect contact mechanism according to which the bacteria oxidize ferrous ions to the ferric state, thereby regenerating the ferric ions required for chemical oxidation of pyrite.

OP 170-67. Permeability and Capillarity in Petroleum Reservoir Engineering, by O. C. Baptist. In Permeability and Capillarity of Soils. American Society for Testing and Materials, Philadelphia, Pa., Spec. Tech. Pub. 417, 1967, pp. 84-87. The common methods for determining permeability and capillarity are outlined, and the uses of these results in petroleum engineering are summarized. Most of the changes noted when the single-phase permeability of a specimen is determined with gas and with water are attributable to such factors as gas slippage, interactions between the media and the fluid, bacterial growths, and incomplete saturations. Multiphase permeability, used in most reservoir calculations, is best determined by the unsteady-state displacement method. Analyses of data obtained from well tests are based either on the assumption of steady-state flow of incompressible fluids or the unsteady-state flow of slightly compressible fluids. Analyses of pressure buildup curves using the concept of unsteady-state flow are proving very useful in determining a variety of reservoir conditions such as permeability, well damage, reservoir volume, distance to faults, static reservoir pressure, and nterference between wells. Capillary pressure relations, used to predict connate water saturation in the reservoir, are best determined by displacement of fluids through a semipermeable barrier. The centrifuge method gives good results in homogeneous specimens, while the mercury injection method is useful for specimens not containing swelling clay minerals.

OP 171-67. Hydraulic Cells Measure Loads on Posts During Mining, by Anthony J. Barry, Richard H. Oitto, Jr., and Rudolph Sporcic. Coal Age, v. 72, No. 11, November 1967, pp. 66-68. Development of better roof-support patterns is seen as a major benefit of Bureau of Mines research. The cells make it possible to determine and record roof pressures and their variations in pillaring operations.

OP 172-67. Electroslag Melting of Titanium and Molybdenum, by R. A. Beall, E. D. Calvert, P. G. Clites, and J. T. Dunham. In Proc. 1st Internat. Symp. on Electroslag Consumable Electrode Remelting and Casting Technology, Mellon Institute, Pittsburgh, Pa., Aug. 9-10, 1967, Collection of Technical Papers, Part 1, 5th paper. The electroslag or Hopkins process is a potential technique for melting both titanium and molybdenum, and possibly other reactive and refractory metals. Advantages claimed for the process include (1) improved sidewall, (2) consistent grain orientation, and (3) removal of impurities. Titanium melting experience is reported for both laboratory- and production-scale ingots. Calcium fluoride was the only slag studied. Data on alloy homogeneity are given for small-scale ingots. Levels of impurity concentration are comparable to those in commercial double-vacuum-melted ingots. Based on physical and chemical properties, the slag selected for molybdenum melting was yttrium oxide. Ingots were prepared with unusually smooth sidewalls. The process appears to improve the ingot metal, particularly its workability. Melting parameters and upset forging tests are described.

OP 173-67. The DUA-Negative System, by Duane G. Blanks. Professional Photographer, September 1967, pp. 57-59. The Dua-Negative System is a method of making a second or duplicate negative from any original negative. This is accomplished directly, negative-to-negative, on ordinary photographic film.

OP 174-67. Geochemistry of Some Tertiary and Cretaceous Age Oil-Bearing Formation Waters, by A. Gene Collins. Environmental Sci. and Technol., v. 1, No. 9, September 1967, pp. 725-730. This research was done to interpret the relationships of ions dissolved in some oil-bearing Mississippi and Alabama formation waters, the relationships to their environment, and their origin. The waters were analyzed by published methods developed by the Bureau of Mines. Sodium, calcium, magnesium, chloride, bromide, iodide, bicarbonate, and sulfate ions were investigated. The age of water-bearing rock, the association of all samples with petroleum, and the depth of water-bearing rock were known environmental conditions. The data were analyzed using a digital computer factor analysis program. Correlations were found for several ions and for some ions and their environment. The bromide ion provided a means to distinguish the Tertiary age waters (low bromide concentration) from the Cretaceous age waters (relatively high bromide concentration).

OP 175-67. Normalization and Absorption Correction of Arbitrary X-Ray Scattering Intensities of Paracrystalline Substances, by Sabri Ergun, James Bayer, and Wayne Van Buren. J. Appl. Phys., v. 38, No. 9, August 1967, pp. 3540-3544. A method has been developed for normalization and absorption correction of X-ray scattering intensities of paracrystalline substances; i.e., matter in a state intermediate between crystalline and amorphous states. In the method the equation for the observed intensities is transformed into a linear form $\Phi(s, \mu T) = K[1 + g(s, \mu T)] + Ki(s)$, where $i(s)$ is the oscillatory part of the interference function. If a proper value is assigned to μT, a plot of Φ versus g yields a straight line (having a slope K) modified only by the oscillations of i. When MoK_α radiation is used, the period of such oscillations becomes small compared to the range of g. The mean value of i is zero in the medium- to high-angle range; therefore, a straight-line correlation of Φ with g to yield a slope having a value equal to that of the intercept allows the determination of μT and K with an accuracy within the precision of measurement of the scattered intensities. The method is readily programed for a computer.

OP 176-67. An Analytical Framework for Potential Ores, by Alvin Kaufman. Eng. and Min. J., v. 168, No. 6, June 1967, pp. 214-216. This paper explores and discusses the question of mineral reserves from the economic viewpoint. Mineral resources are the sum total of reserves, marginal resources, submarginal resources, and latent resources. Material exploitable under current conditions is considered a reserve. Potential ores, on the other hand, would be mineral materials demanding economic and technologic conditions more favorable than those currently existing. A variety of complex, intertwined factors affect the shift between potential ores and reserves.

OP 177-67. Design Data for Coal-Burning Open-Cycle MHD Systems. 1. Effect of Slag Formation on Duct Operation and Seed Recovery, by H. F. Feldmann, W. H. Simons, and D. Bienstock. Proc. Intersoc. Energy Conversion Eng. Conf., Aug. 13-17, 1967, Miami Beach, Fla., 1967, pp. 423-429. A mathematical model is presented which allows the computer computation of both the plasma and liquid slag phases from the combustion of "seeded" coal. Electrical and thermodynamic data for the plasma-liquid slag mixtures from the combustion of a potassium-seeded high-voltage bituminous coal are calculated using the model and the boundary between the plasma region and plasma-liquid slag regions determined. The mechanisms of seed loss in the slag are discussed, and the amount of seed loss as a function of controllable system parameters is presented. Computer data showing the effect of seed level and type on combustor temperatures, plasma electrical conductivity, and air pollution are also presented.

OP 178-67. Kinetics of Hydrogenation of Benzhydrol and Related Compounds Under Hydroformylation Conditions, by Yuan C. Fu, Harold Greenfield, Sol J. Metlin, and Irving Wender. J. Organic Chem., v. 2, No. 9, September 1967, pp. 2837-2841. The hydrogenation of benzhydrol, nuclear-substituted benzhydrols, triphenylcarbinol, and phenylmethylcarbinol under hydroformylation conditions with dicobalt octacarbonyl catalyst appears to proceed via an acid-base reaction between cobalt hydrocarbonyl and aromatic carbinol to give an oxonium salt (I), followed by loss of water to form a complex (II); e.g., $Ph_2CHCo(CO)_4$ for benzhydrol. The formation of complex II is the rate-determining step. Complex II hydrogenates to give an aromatic hydrocarbon as the product. The rate of the overall reaction is dependent on the aromatic carbinol concentration, hydrogen pressure, and dicobalt octacarbonyl concentration and is also affected by the structure of the carbinol. Unlike the hydrogenation of aldehydes or the hydroformylation of olefins, the hydrogenation of these aromatic carbinols is not inhibited by excess carbon monoxide.

OP 179-67. Effect of Hydrocarbon Type on Reactivity of Exhaust Gases, by R. W. Hurn, Basil Dimitriades, and R. D. Fleming. SAE Progress in Technology, v. 12, 1967, pp. 1-9. Unburned hydrocarbons and other products of combustion are recognized as contributors to photochemical air pollution. The work reported here was a first approach to finding an expression of exhaust gas quality—or compositional characteristic—that would associate directly with the photochemical activity of the composite sample. Olefins, aromatics, and partial oxidation products have been cited as the principal smog precursors in exhaust gas. However, results of this study indicate that, for the general case, collective determination of these classes provides an unreliable indication of reactivity. The findings are expected to be useful in further development of methods to measure—or predict—the air pollution potential of exhaust gas with increased reliability.

OP 180-67. Coal and Sulfur Dioxide Pollution, by Harry Perry and J. H. Field. ASME Preprint 67-WA/APC-2, November 1967, 9 pp. The scope of the air pollution problem is briefly reviewed. Sulfur oxides comprise less than 15 percent of total emissions but are of considerable present interest because most arise from combustion of relatively low-cost coal and residual oil. Emission limitations for sulfur oxides in several areas are cited. Ten general methods are enumerated to reduce urban levels of sulfur oxides, and their applicability is discussed. An up-to-date review is given of methods to remove sulfur from coal prior to combustion, of injection of limestone or dolomite into the boiler for in-process sulfur oxides removal, and of processes to remove sulfur oxides from stack gases.

OP 181-67. Methods for Producing Alumina From Clay—An Evaluation, by F. A. Peters, R. C. Kirby, and K. B. Higbie. J. Metals, v. 19, No. 10, October 1967, pp. 26-34. This paper summarizes and compares Bureau of Mines cost estimates for seven selected processes for producing metallurgical-grade alumina from clay. Processes discussed include acid-leaching, alum intermediate, and alkaline-sinter techniques. The effects of varying the principal operating-cost components—clay, reagents, electricity, fuel, and labor—are presented. Individual nomographs were prepared that permit easy assessment of several processes deemed most likely to be of commercial interest.

OP 182-67. Differential Pressure Measurement Problems and Techniques, by H. P. Richardson, John L. Gordon, David Cummins, and R. A. Guereca. Proc. 22d Annual ISA Conf. Part I. Measurement Standards Instrumentations, v. 22, pt. 1, September 1967, Preprint M3-3-PMA-67, 7 pp. Differential pressure transducer calibrations at 1 atmosphere are observed to shift as system pressures change. A technique and apparatus are described which are capable of providing 0.01 percent error calibrations above 2 psid for elevated system pressures. Transducer data below 2 psid, to 2,000 psia, are presented and related to sensitivity shifts and obtainable accuracy.

OP 183-67. Progress in High-Temperature Electrostatic Precipitation, by C. C. Shale. J. Air Pollution Control Assoc., v. 17, No. 3, March 1967, pp. 159-160. Current-voltage relationships for negative corona are given for a pilot-scale electrostatic precipitator with 3-inch electrode spacing at 80° to 1,500° F and 35 to 80 psig. Direct comparison is made with the electrical characteristics for a 1-inch spacing at 1,200° F over the same pressure range. Experimental results on both spacings agree well with electrostatic theory. Initial dust removal efficiencies for the pilot-scale precipitator ranged from 90 to 98 percent at 1,460° F and 80 psig, but continuous operation was not achieved owing to excessive thermal expansion of the internal parts of the unit.

OP 184-67. The Enthalpies of Combustion and Formation of Propylamine, Isopropylamine, and *tert*-Butylamine, by Norris K. Smith and William D. Good. J. Chem. and Eng. Data, v. 12, No. 4, October 1967, pp. 572-573. The enthalpies of combustion of propylamine, isopropylamine, and *tert*-butylamine were determined by oxygen-bomb calorimetry as part of a continuing systematic study of the thermodynamic properties of organic nitrogen compounds.

OP 185-67. The Enthalpy of Formation of Triethylamineborane, by Norris K. Smith and William D. Good. J. Chem. and Eng. Data, v. 12, No. 4, October 1967, pp. 570-571. The enthalpies of combustion and formation of trimethylamineborane were determined by rotating-bomb combustion calorimetry.

OP 186-67. Coal Injection in an Experimental Blast Furnace, by P. L. Woolf and H. H. Lowry. AIME Ironmaking Proc., v. 25, 1967, pp. 217-220. Injection of coal through the tuyeres of the Experimental Blast Furnace provided an effective means of reducing coke consumption. Replacement of coke at constant blast moisture was approximately pound for pound. Research was conducted cooperatively with Blast Furnace Research, Inc.

OP 187-67. Infrared Studies of Products of the Reaction Between Activated Zinc Sulfide and Potassium Ethyl Xanthate, by R. E. Coleman, H. E. Powell, and A. A. Cochran. Trans. AIME, v. 238, 1967, pp. 408-412. The article describes a detailed, fundamental study of one of the most important chemical reactions in industrial flotation processes, under various conditions found in industry.

OP 188-67. The Metal Carbonyl Catalyzed Decarboxylation of Aromatic Anhydrides and Acids, by Sidney Friedman, Marvin L. Kaufman, and Irving Wender. Ann. N.Y. Acad. Sci., v. 145, No. 1, Oct. 18, 1967, pp. 141-149. Dicobalt octacarbonyl catalyzes the selective decarboxylation of benzenepolycarboxylic acids to yield benzoic, isophthalic, and terephthalic acids. This method can be used to convert acids obtained by oxidation of coal to a simple mixture rich in phthalic acids.

OP 189-67. Appalachian Region Oilfield Reservoir Investigation, Keener, Big Injun, and Squaw Sands, Greenwood Oilfield, Central District, Doddridge County, W. Va., by Karl-Heinz Frohne. Producers Monthly, v. 31, No. 9, September 1967, pp. 14-16. The Keener, Big Injun, and Squaw sands were cored and logged in W. Leslie Rogers' E. H. Dotson well 1, Greenwood oilfield, Doddridge County, W. Va. The coring and logging operations are part of an extensive program by the Bureau of Mines to investigate the feasibility of secondary recovery in selected Appalachian oilfields. Geology of the field, lease development history, coring and logging operations, core and log analysis results, and lithology of the cored well are presented.

OP 190-67. Appalachian Region Oilfield Reservoir Investigations, Clinton Sand, S. S. Fry South Oilfield, Rose Township, Carroll County, Ohio, by C. David Locke. Producers Monthly, v. 31, No. 10, October 1967, pp. 11-13. Approximately 112 feet of core was taken from the Stray, Red, and White Clinton sands; and geophysical well logs were run in Belden & Blake Oil Production's Smith-Evans well 4, S. S. Fry South oilfield, Rose Township, Carroll County, Ohio. This well is producing from the White Clinton sand, while other wells in the area frequently produced from both the Red and White Clinton intervals. Both of these zones usually respond well to hydraulic fracturing. Core analysis showed that the average porosity for the productive zones in the cored well was about 5 percent and the average air permeability was less than 1 millidarcy. The work summarized in this report is part of an effort to evaluate secondary-recovery possibilities for the Clinton sand in this area of Ohio.

OP 191-67. Evaluation of Crude Oils, by C. M. McKinney. In Petroleum Processing Handbook, ed. by W. F. Bland and R. L. Davidson. McGraw-Hill Book Co., New York, 1967, pp. 2-1 through 2-56. The Bureau of Mines routine analysis procedure is described and data interpretation methods are explained. Tables are included showing data on 401 domestic and 96 foreign crude oils.

OP 192-67. Fracturing Oil Shale With Electricity, by N. M. Melton and Theodore S. Cross. Colorado Sch. Mines Quart., v. 62, No. 3, July 1967, pp. 45-61. The article discusses the preliminary laboratory and field experiments that were made to evaluate the use of electricity for fracturing oil shale.

OP 193-67. Improved Method for Chromatographic Determination of Helium in "Conservation" Gas Streams, by C. A. Seitz and S. E. Churchwell. J. Gas Chromatography, v. 5, November 1967, pp. 566-569. A procedure was developed for precise analysis of helium in the 45- to 65-percent and 90- to 100-percent ranges ($\sigma = 0.04$ percent) using standards prepared by the weight method.

OP 194-67. X-Ray Diffraction Data of Aluminocopiapite, by James H. Jolly and Helen L. Foster. Am. Mineral., v. 52, July-August 1967, pp. 1220-1223. Aluminocopiapite, essentially $(Mg,Fe^{2+})(Fe^{3+},Al)_4(SO_4)_6(OH)_2 \cdot 20H_2O$, has been identified on the basis of chemical and optical analysis from material collected in Alaska. The X-ray diffraction data on this aluminocopiapite should be useful in identifying this varietal type of copiapite.

OP 195-67. Autoxidation of Three 1-Alkylpyrroles, by E. B. Smith and H. B. Jensen. J. Org. Chem., v. 32, December 1967, pp. 3330-3334. Self-initiated autoxidation of 1-methylpyrrole, 1-isopropylpyrrole, and 1-butylpyrrole formed peroxidic polymers and carbonyl compounds thought to arise from peroxide decomposition. Four of these carbonyl compounds were isolated from 1-methylpyrrole oxidation products, and spectral examination detected their homologs in oxidation products of the other two pyrroles. It is suggested that 1-alkpyrroles react with oxygen by a free-radical peroxy addition process typical of conjugated dienes.

OP 196-67. Characterization of Non-Hydrocarbon Constituents of Petroleum by Microhydrogenation, by C. J. Thompson, H. J. Coleman, R. L. Hopkins, and H. T. Rall. Proc. 7th World Petrol. Cong., Apr. 2-9, 1967, Mexico City, D.F., 1967, pp. 93-108. A microhydrogenation technique, developed specifically for use in sulfur-compound identification studies, has been successfully applied to oxygen, nitrogen, halogen, and metal-containing compounds. By means af vapor-phase catalytic hydrogenation, the hetero-atom is quantitatively removed from the molecule, leaving a paraffin or cycloparaffin whose carbon structure has not been altered. Identification of the produced hydrocarbon identifies or contributes to the identification of the precursor. Such identifications would otherwise be difficult or impossible in many instances because of the limited number of reference compounds available. The method is rapid and quantitative and will handle samples as small as 5×10^{-6} ml. Data are presented showing the application of this technique to pure compounds and mixtures of pure compounds.

OP 197-67. Extracting Alumina From Silicates by Melting, Quenching, and Sulfuric Acid Leaching, by H. G. Iverson and H. Leitch. J. Metals, v. 19, No. 12, December 1967, pp. 28-31. More than 95 percent of the alumina was extracted from various silicates, such as anorthosite, clay, and kyanite, containing 30 to 45 percent alumina, in the melting-quenching-sulfuric acid leaching experiments conducted by the Bureau of Mines. Requirements for optimum extraction consisted of quenching the melted materials to a completely amorphous state and adjusting the weight ratio of SiO_2 to $CaO + Na_2O$ in the quenched product within the range of about 3.0 to 3.7. At higher ratios recovery of alumina decreased and at lower ratios gelation of the leach slurry ensued. The pregnant solution was readily separable from the leached residues, a basic sodium aluminum sulfate was precipitated from the solution at 200° C, by hydrolysis, and alumina was produced from the precipitate.

OP 198-67. A Survey of Other Selected Latin American Countries, by Sumner M. Anderson. Proc. Council of Economics, AIME, Annual Meeting, Feb. 28-Mar. 2, 1966, New York, 1966, pp. 376-388. This paper discusses the economic progress that is being made by Latin American countries, with emphasis on Argentina, Bolivia, Colombia, Chile, and Peru.

OP 199-67. The Interindustry Structure of the U.S. Mining Industries, by Kung-Lee Wang and Robert G. Kokat. Proc. Council of Economics, AIME, Annual Meeting, Feb. 28-Mar. 2, 1966, New York 1966, pp. 241-267. This paper is a condensed version of IC 8338, which is a report of the findings of a technical economic research study to determine the input-output relationships of the U.S. mining industries for the year 1958.

OP 200-67. Water Sensitivity Tests on Cores From Illinois, Indiana, and Kentucky, by Eliot J. White and Oren C. Baptist. API Drilling and Production Practice, 1966, pp. 92-99. The Bureau of Mines tested cores from 35 wells from 14 producing zones in the tristate area of Illinois, Indiana, and Kentucky to determine why rates of water injection were apparently low in some zones. Since only minor amounts of clay minerals are present in these sandstones, it is concluded that permeability reduction results from the movement of dislodged silica particles and other material, including the clays. Both single-phase and two-phase permeability measurements, however, showed that most samples have only low to moderate sensitivity to water and that permeability reduction from particle movement is usually not large. The average effective permeability to water was considerably lower than that to oil during two-phase flow, which is typical of most reservoir rock systems. It can be expected, therefore, that high injection pressures will be required to waterflood thin zones of low permeability.

OP 201-67. Thermodynamic Properties of Compressed Gases, by Roland H. Harrison, Richard T. Moore, and Donald R. Douslin. Proj. AF-9713 Task 9713-02, May 1966, 31 pp.; AD 487 591. Thermodynamic properties for pure methane, pure tetrafluoromethane, a 50-percent methane-50-percent tetrafluoromethane mixture, and a 25-percent methane-75-percent tetrafluoromethane mixture were computed. The values of the thermodynamic properties were determined over the same range of variables (pressure-volume-temperature) as measured, namely, 0° to 350° C at intervals of 25°, 0.75 and 1.0 to 12.5 mole per liter density at intervals of 0.5 mole per liter and at pressures from 3 to 400 atmospheres. Values of heat content, entropy, Gibbs energy, heat content function, activity coefficient, and Gibbs energy functions are tabulated.

OP 202-67. Food From Coal-Derived Materials by Microbial Synthesis, by Melvin P. Silverman, Joan N. Gordon, and Irving Wender. Nature, v. 211, No. 5050, Aug. 13, 1966, 735-736. Yeasts grown on certain coal-derived materials give protein in as high a yield as can be obtained from the best petroleum substrates. Fischer-Tropsch synthetic fuel fractions are excellent substrates for food production; a low-temperature coal tar fraction may also be used.

OP 203-67. World Demand for Mineral Products and the Shifting Supply of Mineral Raw Materials, by Alfred Petrick, Jr. Proc. Council of Economics, AIME, Los Angeles, Calif., Feb. 19-23, 1967, pp. 69-124. The objective of this paper is to examine trends in world demand, to analyze corresponding shifts in world supply of some major minerals, and then to interpret the implications of these changes for the future.

OP 1-68. A Simple Method for Determining the Volume of Closed Containers, by C. A. Seitz and David E. Emerson. Anal. Chem., v. 40, No. 1, January 1968, pp. 260-262. A procedure including equations for determining volume is given. An accuracy of 0.02 cm^3 for a 10-cm^3 volume is obtained.

OP 2-68. Inverse Gas-Liquid Chromatographic Studies of Asphalt. Comparison With Analyses by Fractionation, by T. C. Davis and J. C. Petersen. Anal. Chem., v. 39, No. 14, December 1967, pp. 1852-1857. Results of analyses of asphalts by inverse gas-liquid chromatography (GLC) have been compared with results of analyses by the Kleinschmidt chromatographic fractionation and the Rostler and Sternberg sulfuric acid precipitation procedures. Relationships between the two fractionation techniques are indicated.

OP 3-68. A Preliminary Study of Vapor Deposition of Rhenium and Rhenium-Tungsten, by J. G. Donaldson, F. W. Hoertel, and A. A. Cochran. J. Less-Common Metals, v. 14, No. 1, January 1968, pp. 93-101. The conditions for the most efficient vapor deposition of rhenium and rhenium-tungsten alloys were determined and the physical properties and microstructures of the products were studied.

OP 4-68. Techniques for Separating and Identifying Nitrogen Compounds in Petroleum and Shale Oil, by W. E. Haines, G. L. Cook, and G. U. Dinneen. Proc. 7th World Petrol. Cong., v. 9, December 1967, pp. 83-92. Nitrogen compounds are a major constituent of oil produced from the Green River oil shale and an important, though minor, constituent of petroleum. This paper summarizes the techniques used to separate and identify the nitrogen compounds in petroleum and shale oil.

OP 5-68. Promoters for Carbon Monoxide Reduction of Wustite, by S. E. Khalafalla and P. L. Weston, Jr. Trans. Met. Soc. AIME, v. 239, October 1967, pp. 1494-1499. Small amounts of alkali and alkaline earth metal oxides exert a strong accelerating effect on the carbon monoxide reduction of wustite to iron. The extent of the reaction rate enhancement is found to be proportional to the ionic radius and electronic charge of the promoter additive. Increasing the promoter concentrations accelerates reaction up to a maximal point, beyond which further increaes in promoter content exerts a less beneficial and, eventually, a deleterious effect. This phenomenon occurs more readily with increasing oxide basicity and establishes a limit to the reaction rate acceleration by the various promoters. The results can be explained by Vol'kenshtein's theory of lattice disturbance.

OP 6-68. Fire Hazards of Ammonium Nitrate-Sulfur Systems, by Charles M. Mason, David R. Forshey, and Frank J. P. Perzak. Agricultural and Food Chem., v. 15, No. 6, November-December 1967, pp. 954-966. The addition of sulfur to ammonium nitrate-based fertilizers has raised questions regarding the hazard of these mixtures when exposed to fire. Several techniques were used to evaluate this hazard. Sulfur has the same effect on detonability as other fuels when added to ammonium nitrate or ammonium nitrate systems. The thermal stability of ammonium nitrate-sulfur mixtures was about the same as ammonium nitrate mixed with fuel oil or polyethylene.

OP 7-68. Nonmetal Elements and Compounds, by J. C. Morris, D. R. Latham, and W. E. Haines. Anal. Chem. Ann. Rev., v. 39, No. 5, April 1967, pp. 171R-175R. This is the eighth in a series of reviews of analytical chemistry in the petroleum industry. It reviews the progress of analytical chemistry for sulfur, nitrogen, and oxygen compounds in petroleum for 1964-65.

OP 8-68. Separation of Sulfoxides From Petroleum Fractions by Cation Exchange Resin Chromatography, by I. Okuno, D. R. Latham, and W. E. Haines. Anal. Chem., v. 39, No. 14, December 1967, pp. 1830-1833. Petroleum chemists have generally considered that the bases in petroleum are nitrogen compounds. Evidence is presented to show that a portion of the weak bases are sulfoxides.

OP 9-68. Relationship Between Gravimetric Respirable Dust Concentration and Midget Impinger Number Concentration, by Murray Jacobson and T. F. Tomb. Am. Ind. Hyg. Assoc. J., v. 28, November-December 1967, pp. 554-556. Comparison of data obtained using size-selective gravimetric and midget impinger samplers shows that 1 milligram of respirable dust per cubic meter is equivalent to a number of concentration of 5.6 million particles per cubic foot.

OP 10-68. Structural Study of Asphalts by Nuclear Magnetic Resonance Spectroscopy, by Jerry W. Ramsey, Francis R. McDonald, and J. Claine Petersen. I&EC Product Research and Development, v. 6, December 1967, pp. 231-236. The usefulness of a nuclear magnetic resonance method for the determination of average structural formulas and formula weights of asphalts is evaluated.

OP 11-68. Organic Composition of Kentucky's New Albany Shale: Determination and Uses, by John Ward Smith and Neil B. Young. Chem. Geol., v. 2, No. 2, 1967, pp. 157-170. Elemental compositions were determined for total organic matter in three Devonian New Albany Shale sections of Kentucky. Application to characterizing black shales illustrates the uses of these compositions.

OP 12-68. Hydrogen Cyanide Produced From Coal and Ammonia, by G. E. Johnson, W. A. Decker, A. J. Forney, and J. H. Field. I&EC Process Design and Development, v. 7, No. 1, January 1968, pp. 137-144. Hydrogen cyanide has been produced by reaction of powdered coal with ammonia at 1,250° C. Yields as high as 0.7 cu ft/cu ft of NH_3 consumed were obtained. The resulting ammonia conversion of about 75 volume-percent approximates conversions obtained commercially in processes utilizing natural gas with platinum catalysts. Coals of higher volatile matter contents gave the best yields of hydrogen cyanide. Coal gases of higher methane contents when reacting with ammonia gave the higher yields of hydrogen cyanide. Cost studies indicate that hydrogen cyanide can be profitably coproduced with carbon black from coal and ammonia in a 40,000,000-pound-per-year-capacity plant at the corrent market price of hydrogen cyanide, if credit is taken for carbon black and char byproducts. These figures are based on heating the reactor electrically. If a cheaper method were devised, the economics of the process would be more favorable.

OP 13-68. Low-Frequency Infrared Region Aids Coal Minerals Research, by Clarence Karr, Jr., Patricia A. Estep, and John J. Kovach. Instr. News, v. 18, No. 2, 1967, pp. 1, 5-6. Infrared spectroscopy extended to 200 cm^{-1} is shown to be a valuable tool for mineral identification in samples of coal, mine refuse, and boiler deposits.

OP 14-68. High B.t.u. Gas by the Direct Conversion of Coal, by Paul S. Lewis, Sam Friedman, and Raymond W. Hiteshue. Fuel Gasification. ACS Advances in Chem. Ser. 69, 1967, pp. 50-63. The direct conversion of untreated coal into high-Btu gas offers means for augmenting natural gas supplies. The Bureau of Mines reports data for the dilute-phase hydrogenation of high-volatile A bituminous coal and for the hydrogenation of partially devolatilized coal (char) in a moving bed. Conditions are 1,500 and 3,000 psig and 725° C for coal and 700° and 900° C for char. The concept of integrating these two operations into a continuous process is discussed. Stream flows and compositions are given for a conceptional plant producing 90 million std cu ft per day of 916 Btu gas. Results indicate that development of a process is feasible, and the work is continuing.

OP 15-68. An Infra-red Study of Hydrogen Bonding in Asphalt, by J. C. Petersen. Fuel, v. 46, No. 4 and 5, July-September 1967, pp. 295-305. Hydrogen bonding in asphaltic residua was investigated by studying the OH and NH stretching bands of whole and diluted samples. Phenolic and/or alcoholic OH and pyrrole-type NH were found to exist largely as hydrogen-bonded complexes.

OP 16-68. The Hydrocarbon Constituents of Petroleum and Some Possible Lipid Precursors, by Harold M. Smith. J. Am. Oil Chem. Soc., v. 44, No. 12, December 1967, pp. 680-690. This report presents a complete qualitative picture of our knowledge of the hydrocarbon composition of petroleum as of April 1965. The material is presented in detail on an imaginative map called the Hydrocarbon Hemisphere which depicts the hydrocarbons identified in petroleum. All compounds are placed on the map according to boiling point. The accompanying text illustrates by structural formulas the several types of hydrocarbons identified, presents some quantitative data, and points out the possible geochemical significance of a number of the compounds with particular reference to lipids as posible source material.

OP 17-68. Temperature Controller for Thermoluminescence Studies, by Robert A. Wolf and Merle L. Bowser, Rev. Sci. Instr., v. 38, No. 12, December 1967, pp. 1806-1807. An electronic circuit is described which controls the rate of heating of mineral specimens used in studies of chemiluminescence and thermoluminescence. The temperature of the specimens can be heated from 25° C to 600° C at rates from 9° C per minute to 9° C per second.

OP 18-68. Zeta Potential Control: Its Application in Coal Preparation, by A. F. Baker and K. J. Miller. Min. Cong. J., v. 54, No. 1, January 1968, pp. 43-44. Recognition of the diverse applications of zeta potential control in mineral dressing led Bureau of Mines investigators to take a closer look at the tool for possible uses in coal preparation. Among processes under study are thickening, clarification of effluent water, filtration, dense-medium separation, and froth flotation.

OP 19-68. Magnetic Susceptibilities of Coals, by Doris Bivins and Sabri Ergun. Science, v. 169, No. 3810, Jan. 5, 1968, p. 83. Magnetic susceptibilities are reported for seven American coals of different rank. The susceptibilities were measured in magnetic fields parallel and perpendicular to the bedding planes. The coals have diamagnetic susceptibilities approximating -0.5×10^{-6} centimeter-gram-second unit. Only anthracite shows significant magnetic anistropy.

OP 20-68. Catalytic Gasification of Shale Oil, by P. L. Cottingham and H. C. Carpenter. In Fuel Gasification. Adv. in Chem. Ser. 69, 1967, pp. 180-189. Crude shale oil was hydrogasified at 1,000 pounds pressure over depleted uranium and cobalt molybdate catalysts at temperatures in the range of 880° to 1,102° F with depleted uranium and of 974° to 1,196° F with cobalt molybdate. With both catalysts the higher reaction temperatures produced greater hydrocarbon gas yields, greater percentages of methane in the gas, and greater methane yields expressed as percentage of conversion of the feed stock. The largest yields (4,340 cubic feet per barrel) and largest hydrocarbon gas yield (5,725 cubic feet per barrel) were obtained at the highest temperature (1,196° F) and lowest space velocity (0.25 V_o/V_r/hr) used. At these conditions methane yield was 75.8 volume-percent of the hydrocarbon gas and 49.7 percent of stoichiometric.

OP 21-68. Quantitative Infrared Multicomponent Determination of Minerals Occurring in Coal, by Patricia A. Estep, John J. Kovach, and Clarence Karr, Jr. Anal. Chem., v. 40, No. 2, February 1968, pp. 358-363. The quantitative multicomponent analysis of five commonly occurring mineral constituents of coal—quartz, calcite, gypsum, pyrite, and kaolinite—is described for the extended infrared region.

OP 22-68. An Improved Process for Making Prereduced Iron Ore Pellets, by M. M. Fine and R. B. Schluter. Ann. Meeting, AIME, New York, Feb. 25-29, 1968, Prepirnt 68-B-43, 22 pp. Commercial and experimental processes for manufacturing prereduced iron ore pellets ordinarily operate in the 2,100° F range. The authors have uncovered a group of simple chemical and mineral substances which accelerate liquid-phase sintering of metallic iron yet do not deter reduction of iron oxides to metal. Some of these compounds may be introduced as gases to the kiln atmosphere, others as solids are added to the reductants (e.g., lignite). The net result is that well metallized iron pellets with good crushing strength can now be produced at a little over 1,800° F. Both laboratory and continuous data are presented.

OP 24-68. High-Purity Vanadium, by K. P. V. Lei and T. A. Sullivan. J. Less-Common Metals, v. 14, No. 1, January 1968, pp. 145-147. The preparation of high-purity vanadium by a two-cycle molten-salt electrorefining process is described. Vanadium of 99.99-percent purity was prepared from 99.47 percent vanadium by refining in a KCl-LiCl-VCl_3 electrolyte at 620° C.

OP 25-68. Comment on the Granato-Hikata-Lucke Equations for the Recovery of Damping Following Plastic Deformation, by R. R. Nothdurft and A. E. Schwaneke. Scripta Met., v. 1, No. 3, December 1967, pp. 143-144. The purpose of the comment is to point out some errors that crept into the Granata-Hikata-Lucke equations about 10 years ago and that have been propagated through writings by other researchers. Incidentally, a reply to this comment by one of the writers referred to in the comment and acknowledging the pertinence of thearticle is contained in the same isue of Scripta Metallurgica.

OP 26-68. Surface-Joint Patterns Predict Wellbore Fracture Orientation, by William K. Overbey, Jr., and Robert L. Rough. Oil and Gas J., v. 66, No. 9, Feb. 26, 1968, pp. 84-86. Based on the premise that fractures induced hydraulically in subsurface rock tend to seek or follow the natural flaws (joints) in the rock, the Bureau of Mines began a comprehensive study of surface-joint patterns and orientations and their relationship to the orientation of induced subsurface fractures. Preliminary studies in Bradford oilfield are promising for this method of predicting fracture orientation.

OP 27-68. Air Pollution and the Coal Industry, by Harry Perry and J. H. Field. Trans. SME, December 1967, pp. 337-345. To alleviate pollution, more restrictive legislation is being enacted, either limiting emission of pollutants or the type of fuel that can be utilized. The nature and magnitude of air pollution problems affecting the mining, preparation, coking, and combustion of coal are described. Methods for combating particulate emissions by use of mechanical separators and electrostatic precipitators are discussed. Proposed methods of meeting the problem of gaseous emissions that are currently receiving considerable attention are described, with special emphasis on methods to decrease pollution by sulfur oxides.

OP 28-68. Conformational Analysis of Ethanethiol and 2-Propanethiol, by Don Smith, J. Paul Devlin, and Donald W. Scott. J. Molecular Spectroscopy, v. 25, No. 2, February 1968, pp. 174-184. Evidence for the existence of different molecular conformations of ethanethiol and 2-propanethiol was obtained by low-temperature infrared spectroscopy. Conformations of C_1 symmetry occur exclusively in crystalline ethanethiol and Crystals II of propanethiol and show up more prominently in the spectra of liquids and gases. However, both C_1 and Cs forms occur in Crystals I of 2-propanethiol. Energy differences between the forms were estimated from calorimetric data.

OP 29-68. Effect of Carbonization Conditions on the Composition of Low-Temperature Tar From Pittsburgh-Seam Bituminous Coal, by Clarence Karr, Jr., Joseph R. Comberiati, Patricia A. Estep, and Jesse O. Mapstone, Jr. J. Inst. Fuel, v. 40, December 1967, pp. 561-563. The influence of carbonization temperature, carrier gas, and carbonization method on the composition of five different low-temperature tars from a bituminous coal is shown.

OP 30-68. New Era Beckons for North Dakota Lignite, by Robert C. Ellman. Morning Pioneer, 2d Ann. North Dakota Industrial Ed., 1968, p. 14. Greater utilization of North Dakota lignite should result in increased capital investment and better employment opportunities for the presently predominantly farming and ranching economy.

OP 31-68. Energy Dispersion X-Ray Analysis Using Radioactive Sources, by William J. Campbell. In X-Ray and Electron Methods of Analysis. Plenum Press, New York, March 1968, pp. 36-54. There are three types of radioisotope sources—α-, β-, and γ-emitters. Typical α- and β-emitters are Po^{210} and H^3/Zr, respectively. Generally β-emitters are used to generate primary X-rays which, in turn, excite secondary X-rays in the sample. Gamma sources may be either monochromatic, such as Fe^{55} (Mn K) or high-energy γ-emitters used in conjunction with a secondary emitter Am^{241}-Cs.

In nondispersive analysis, energy discrimination is achieved by selective filtration, balanced filters, differential absorption in the detector, and electronic pulse amplitude discrimination. All of these methods may be used individually or in various combinations. Applications of these portable analyzers include prospecting and mining operations, monitoring of metallurgical processes, and automatic sorting of mail.

OP 32-68. Alcohols From a Neutral Fraction of Lignite Tar, by Sam Friedman, P. S. Lewis, and R. W. Hiteshue. High Pressure Technology, Chem. Eng. Prog. Symp. Ser., AIChE, v. 63, No. 76, pp. 1-6. Olefins in tar can be converted to high-molecular-weight alcohols in one step. Neutral oil, obtained from tar produced by carbonizing Texas lignite, containing 36 volume-percent olefins, was reacted with synthesis gas (2 H_2: 1 CO) at 185° C in a continuous system with dicobalt octacarbonyl as catalyst. Studies of variables were made using catalyst concentrations of 0.5 to 2.0 weight-percent cobalt, based on neutral oil, with residence time between 1 and 8 hours and pressure between 3,000 and 6,000 psi. Alcohols having carbon numbers in the range C_{10} to C_{24} were obtained with a maximum yield of 24 weight-percent, based on neutral oil, at 4,500 psi, 4-hour residence time, and 2.0 weight-percent cobalt. An increase in either residence time, pressure, or catalyst concentration resulted in higher yields but had little or no effect on the relative distribution of the alcohols. About 60 volume-percent of the alcohol product had carbon numbers in the range C_{11} to C_{17}.

OP 33-68. A Comparison of Five Spectrochemical Methods for the Analysis of High Purity Zinc, by Robert C. Gabler, Jr., and Maurice J. Peterson. Appl. Spectroscopy, v. 22, No. 1, January-February 1968, pp. 19-23. A comparison was made of five optical spectrographic methods for the analysis of high-purity zinc. Analytical capability was required for the determination of Ag, Al, Cd, Cu, Fe, Hg, Mg, Pb, and Sn in the range from 1 to 100 ppm. The factors considered were sensitivity of detection, handling ease, possible sources of contamination, analysis time, and precision and accuracy. The data show that a metal-direct arcing procedure is rapid, has high sensitivity of detection, and requires a minimum of sample handling. Solution-residue dc arc, point-to-plane ignited ac arc, and zinc oxide dc-arc procedures gave better reproducibility but lacked the required sensitivity of detection.

OP 34-68. The Production of Primary Titanium Metal, by Kenneth B. Higbie and John W. Stamper. Titanium for the Chemical Engineer. AIChE Materials Conf., Apr. 1, 1968, Philadelphia, Pa., DMIC Memo. 234, pp. 8-12. This report discusses titanium mineral resources, mining and mineral processing, and metal production technology. Production of titanium metal from its source compounds includes the following methods: magnesium reduction of titanium tetrachloride, sodium reduction of titanium tetrachloride, metallic reduction of titanium oxide, and electrolytic reduction of titanium tetrachloride. Titanium sponge can be consolidated to ingot form by powder-metallurgy techniques, but virtually all commercial ingots today are produced by the double consumable-electrode arc-melting process in an inert atmosphere or vacuum.

OP 35-68. Increasing Well Deliverability by Chemical Enlargement of Wellbores, by Ray V. Huff and Larman J. Heath. Spring Meeting, Division of Production, API, Amarillo, Tex., Apr. 3-5, 1968, API Preprint 851-42-B, 14 pp.; Producers Monthly, v. 32, No. 7, July 1968, pp. 2-6. Research was conducted by the Bureau of Mines in cooperation with the American Gas Association to investigate a phenomenon of chemical rock disaggregation. Laboratory and shallow field experiments were conducted using hydrazine hydrate ($N_2H_4 \cdot H_2O$) which was effective in disaggregating rock. Bandera, Bartlesville, Berea, Bigheart, Bradford 3d, Carrizo, Cottage Grove, Noxie, and Prue (Squirrel) sandstones were disaggregated. A theory has been developed which ascribes the phenomenon to the expansion of kaolinite by the absorption of aqueous solutions of hydrazine. X-ray diffraction analyses showed that the basal spacing of kaolinite was increased from 7.16 to 10.41 A. In a near-surface field experiment the diameter of a wellbore was enlarged from 4 to 12 inches. Clays were expanded by the hydrazine treatment, and this expansion resulted in a horizontal fracture and vertical tension fractures.

OP 36-68. High-Purity Titanium Electrowon From Titanium Tetrachloride, by O. Q. Leone, H. Knudson, and D. Couch. J. Metals, v. 19, No. 3, March 1967, pp. 18-23. Titanium with a Brinell hardness of 70 was electrowon from $TiCl_4$ in a LiCl-KCl-$TiCl_2$ electrolyte operated at 520° C using a ceramic diaphragm-type cell.

OP 37-68. Fracturing Oil Shale With Electricity, by Noel M. Melton and Theodore S. Cross. J. Petrol. Technol., v. 20, No. 1, January 1968, pp. 37-41. Laboratory studies to evaluate the use of electricity for fracturing various grades of Colorado oil shale were started in 1964. Breakdown voltages varied greatly from one grade of shale to another, ranging from a minimum of 300 volts to a maximum of 15,000 volts. With few exceptions, the shale samples were readily fractured at relatively low current levels. On the basis of encouraging results obtained in the laboratory, experiments were expanded to field tests to study electrical characteristics of oil shale when subjected to overburden pressure. These tests generally confirmed the laboratory experiments. Fracturing was accomplished at all electrode spacings used. The spacings varied from 3 to 129 feet. Based upon results obtained in these field experiments, additional fracturing tests were conducted in four shallow wells drilled in an oil formation. Some new permeable zones were created between wells. The induced permeability was improved by detonating two conventional nitroglycerin wellbore shots in one of the wells.

OP 38-68. Hydrogenation of Coal at Extreme Conditions, by Joseph A. Mima, Paul S. Lewis, Sam Friedman, and Raymond W. Hiteshue. Chem. Eng. Prog. Symp. Serv., v. 63, No. 76, 1967, pp. 55-61. An internally heated autoclave is described in which pressures up to 20,000 psi at temperatures up to 600° C were obtained. Product yields and distribution for the hydrogenation of high-volatile A bituminous coal were investigated. Coal conversions to liquids and gases of 90 percent at 480° C and 97 percent at 600° C were obtained at 20,000 psi without catalyst. Identical yields of organic liquids, 66 percent of the moisture- and ash-free coal, were produced at 480° C whether iron catalyst was present or not. With iron present in 1-percent concentration, based on moisture- and ash-free coal, the phenols content of the light oil was increased threefold by raising the pressure from 10,000 to 20,000 psi at 480° C, which also increased the yield of light oil by about 4 percent. The products at 600° were mainly methane and ethane, while the small yield of liquid was mainly benzene.

OP 39-68. Chromatographic Determinations of Column Dead Volume and Absolute Density of Adsorbents at Cryogenic Temperatures, by Al Purer, C. A. Hoffman, and D. A. Smith. J. Gas Chromatography, v. 6. March 1968, pp. 153-157. The determination of column dead volume and absolute density of column packing material for adsorption columns at cryogenic temperatures has been attained by a nondestructive method of column treatment.

OP 40-68. Constitutional Aspects of Oil-Shale Kerogen, by W. E. Robinson and G. U. Dinneen. Proc. 7th World Petroleum Congress, Mexico City, April 1967, Elsevier Publishing Co., Ltd., Essex, England, v. 3, 1967, pp. 669-680. The structure of the kerogen present in 12 domestic and foreign oil shales of different geologic age, environment, and source material was studied. Most of the observed differences appear to be related to the geologic age of the kerogen.

OP 41-68. Compression Waves Generated in Rock by Cylindrical Explosive Charges: A Comparison Between a Computer Model and Field Measurements, by A. M. Starfield and J. M. Pugliese. Internat. J. Rock Mechanics and Min. Sci., v. 5, No. 1, January 1968, pp. 65-77. A computer model is used to simulate the compressive strain waves generated in rock from the end detonation of long and short cylindrical explosive charges. The model synthesizes the strain wave by superposing the waves from detonation of a number of concentrated explosive charges. In situ strain data were recorded by strain gages mounted in a granite gneiss at various distances and positions with respect to 2½-foot and 27-foot charges of a high-pressure gelatin (HP) and a more slowly detonating mixture of prills and fuel oil (PFO). The good agreement between the strain data obtained in the field and the computer-generated data shows that the model can be used to predict the strain waves generated in rock by cylindrical explosives charges. For relatively short end-initiated HPG charges, the resulting strain is not spherically symmetric even at large distances in the rock. Furthermore the peak strains due to both long and short charges are shown to be greatly influenced by the detonation velocity of the explosive.

OP 42-68. Laser-Spark Excitation of Homogeneous Powdered Materials, by A. B. Whitehead and H. H. Heady. Appl. Spectroscopy, v. 22, No. 1, January-February 1968, pp. 7-12. The laser microprobe has been applied to the excitation of trace elements homogenously distributed in powdered materials. Precision of intensity ratios is about ±1 percent (coefficient of variation), and detection levels are comparable to those of the dc arc. Matrix effects were studied for four different materials and found to be significantly less than in the dc arc. Use of the probe as the source in a "universal" method is suggested.

OP 43-68. Development in Continuous Carbonization in the U.S., by D. E. Wolfson. Iron and Steel Eng., v. 45, No. 3, March 1968, pp. 69-75. Formcoke is being produced in two pilot plants and subsequently tested in experimental blast furnaces. One plant produces briquets from noncoking coal while the other operates on coking coal. The future of this process (along with other continuous methods) will depend on the economics of the processes as well as future furnace requirements and coking coal availability and cost.

OP 44-68. Improving Permeability in Underground Formations—A Progress Report, by W. E. Eckard, J. L. Eakin, and Larman J. Heath. IOCC Bull., v. 9, No. 2, December 1967, pp. 54-70. Two new research projects have been initiated to achieve increased fluid flow capacity in oil and gas reservoirs, underground gas-storage reservoirs, and in oil-shale formations using technology from the explosives and space industries. Bureau of Mines petroleum research engineers have injected and detonated a chemical explosive in an underground fracture system to alter formation permeability. To obtain some idea of the effectiveness of thermal methods in altering permeability, they have injected and burned a high-energy fuel-oxidant mixture in porous rock samples. Explosive fracture experiments have been conducted at depths to about 148 feet in an oil-shale formation using from 40 to 190 quarts of explosive. After detonation average air injection rate between wells, at essentially the preshot injection pressure, was improved from threefold to eightfold. Laboratory experiments have proved that combustion of a monopropellant within the rock interstices in two different types of sandstone specimens is technically feasible. Permeability increases have been achieved from 1.5- to 10.3-fold, although matrix temperature was raised only to approximately 450° C. Sandstone samples have been chemically altered and essentially complete disaggregation has been accomplished.

OP 45-68. Bureau of Mines Conducts Diamond Drilling Experiments, by W. E. Bruce. Mines Magazine, v. 58, No. 4, April 1968, pp. 17-21. Drillability experiments being conducted by the Bureau of Mines are described. These experiments, consisting principally of diamond drilling in the laboratory and field, are aimed at establishing indices for predicting rock drillability.

OP 46-68. Chemistry of Waters From Some Louisiana Petroleum-Bearing Formations, by A. G. Collins, D. R. Thompson, and C. A. Pearson. Symp. on Developments in Petroleum Environmental Chemistry, Div. of Petroleum Chemistry and Div. of Water, Air, and Waste Chemistry, ACS Meeting, San Francisco, Calif., Apr. 2-5, 1968, Preprints, v. 13, No. 2, pp. E35-E41. To determine the relationship between subsurface brines and their environment and origin, 124 samples were taken from Louisiana petroleum-bearing formations and interpretations were made based on analysis of their dissolved constituents. Analyses were made for lithium, sodium, potassium, calcium, magnesium, strontium, barium, boron, chloride, bromide, iodine, bicarbonate, carbonate, and sulfate. The analytical methods used were developed by the Bureau of Mines. Samples obtained from the gulf coast area are Tertiary in age, whereas those obtained from northern Louisiana are Tertiary and Cretaceous in age. Analytical data were subjected to factor analysis using a digital computer. Good correlations were found for the following: Total dissolved solids (TDS) and sodium, TDS and potassium, TDS and chlorine, lithium and calcium, lithium and strontium, sodium and chlorine, potassium and chlorine, calcium and bromide, and strontium and bromide. Log-log plots of a normal evaporite brine were made and compared with plots of the Louisiana waters. Bromide, calcium, and strontium can be used to distinguish the Tertiary waters from the older waters.

OP 47-68. Air Pollution Research in Relation to Coal's Future in the Electric Energy Market, by Richard C. Corey. Combustion, v. 39, No. 10, April 1968, pp. 21-29. This article describes the problem of the emission of sulfur oxides to the atmosphere by coal-burning electric power stations, the sulfur content of American coals, and research by the Bureau of Mines and others on removal of sulfur from coal and sulfur oxides from coal combustion products.

OP 48-68. Byproduct Uranium Recovered With New Ion Exchange Techniques, by D. R. George, J. R. Ross, and J. D. Prater. Min. Eng., v. 20, No. 1, January 1968, pp. 1-5. A survey of the copper mining industry in Western United States revealed that uranium is almost universally present in the solutions resulting from leaching the waste ore dumps to recover copper. The U_3O_8 content ranges from about 2 to 15 ppm and a potential production of up to 1,000 tons of U_3O_8 per year is indicated. A 6-week pilot plant test at the Bingham Canyon mine of the Kennecott Copper Corp. showed that the uranium is readily recoverable by ion-exchange techniques. The design of the new type of countercurrent ion-exchange columns and operation of the pilot plant are described.

OP 49-68. Large Powerplants Fired With Dakota Lignite, by Wayne R. Kube, Gordon H. Gronhovd, and James L. Elder. North Dakota Quart., v. 35, No. 3, Summer, 1967, pp. 87-93. This article gives a brief résumé of the development of lignite utilization and discusses the current and expected increase in lignite production resulting from the installation of large thermal-electric powerplants in North Dakota.

OP 50-68. Rock Mechanics and the Design of Structures in Rock, by Leonard Obert and Wilbur I. Duvall. John Wiley & Sons, Inc., New York, 1967, 650 pp. This book attempts to bring together and present in one place the general fundamentals and pertinent information required for an understanding of rock mechanics and the design of structures in rock. More specifically this book contains (1) a brief mathematical treatment of stress, strain, elasticity, and inelastic effects to provide the reader with the necessary theoretical background for analyzing the stresses, strains, and deformations in structures; (2) a discussion of the methods and procedures for measuring the mechanical properties of rock and a consideration of mechanisms of failure; (3) a description of the instruments and procedures for measuring stress, strain, deformation, and other related quantities, together with results from both laboratory and field investigations; and (4) a discussion of procedures based on both theoretical and empirical results for designing, analyzing, and evaluating the stability of underground structures.

OP 51-68. Preignition Phenomena in Small A-50/NTO Pulsed Rocket Engines, by H. E. Perlee, T. Christos, Y. Miron, and H. K. James. J. Spacecraft and Rockets, v. 5, No. 2, February 1968, pp. 233-235; discussion, No. 8, August 1968, p. 1008. The Bureau of Mines study of the hardstart phenomenon encountered in the Aerozine-50/N_2O_4 pulsed rocket engine under simulated altitude conditions has concentrated primarily on the preignition period, the time interval between the first appearance of propellant in the combustion chamber and subsequent ignition. Results are given for propellant systems consisting of nitrogen tetroxide as the oxidant in combination with hydrazine, monomethylhydrazine, unsymmetrical dimethylhydrazine, or Aerozine-50.

OP 52-68. The Shock Sensitivity of Explosive Films, by Richard W. Watson, John Ribovich, and Frank C. Gibson. Pyrodynamics, v. 6, 1968, pp. 39-51. Using a highly instrumented two-dimensional analog of the card-gap test, studies have been carried out to determine characteristics of the initiation and propagation of detonations in thin films of liquid explosives. Both the high-velocity and low-velocity detonation regimes are observed to occur, depending upon film thickness, explosive material, and the strength of the initiating stimulus. The high-velocity detonations are observed to travel at velocities nearly equal to the ideal hydrodynamic detonation velocity for the particular system under investigation. At lower stimulus levels, low-velocity reactions are observed to take place; these have velocities both above and below the velocity of sound in the unreacted material. The qualitative characteristics of the low-velocity detonations in films are found to closely resemble those established for low-velocity detonations in liquid columns. A simple physical model, based on fluid cavitation, has been developed to describe this latter case. In addition, the effects of desensitizing additives on the threshold values of the initiation stimulus required to produce high-velocity detonations or low-velocity detonations are discussed. Comparisons are then made between the behavior of the thin film systems and previously established behavior of detonating columns for the same explosives.

OP 53-68. Electrowinning of Niobium, by M. M. Wong and D. E. Kirby. Electrochem. Technol., v. 6, No. 3-4, March-April 1968, pp. 119-123. Operating parameters for electrowinning of columbium from the KCl-KF-K_2NbF_7-Nb_2O_5 electrolyte system were studied. Successive electrodepositions from the optimum electrolyte composition with a replenishment of Nb_2O_5 and K_2NbF_7 after each deposition maintain a steady level of performance and produce metal with an average oxygen content of approximately 400 ppm.

OP 54-68. Respirator Responsibility, by Robert H. Schutz. AASE J., v. 13, No. 5, May 1968, pp. 6-8. There are three parts to the responsibility involved in respiratory protection. 1. The Bureau of Mines must be certain that its respirator approval schedules include all necessary requirements to insure that devices are safe and reasonably comfortable to use. 2. Manufacturers should make devices that perform in accordance with schedule requirements, must use nontoxic materials, and maintain high quality in the product. 3. The user must select the correct respirator for his work, use it in the proper manner, and maintain it in an approved condition.

OP 55-68. A Laboratory Investigation of High-Temperature Corrosion on Fireside Surfaces of Coal-Fired Steam Generators, by S. A. Goldberg, J. J. Gallagher, and A. A. Orning. Trans. ASME, Series A, J. Eng. Power, v. 90, No. 2, April 1968, pp. 193-198. Three experimental approaches gave significant information on high-temperature fireside corrosion: 1. Sodium and potassium chlorides, injected through a gas flame, were deposited as such and then converted to sulfates on an iron surface. 2. Samples of mixed alkali and iron sulfates first showed decomposition and then formed melts at temperatures as low as 1,070° F. This temperature is within the range that might be expected for fireside surface temperatures on superheater and reheater tubes of large steam generators. 3. Alkali metal chlorides and sulfates, in partial coverage of metal discs and in a flue gas atmosphere, formed fused deposits at temperatures as low as 900° F. Complex alkali iron sulfates may cause corrosion either by direct electrolytic corrosion or by altering the normally protective iron oxide scale so that the metal is exposed to direct oxidative corrosion.

OP 56-68. X-Ray Absorption and Emission, by William J. Campbell and James D. Brown. Anal. Chem., Ann. Rev., v. 40, No. 5, April 1968, pp. 346R-375R. This 1968 review consists of a critical evaluation of new developments and tabular summaries of X-ray spectrography and electron probe microanalysis. A 695-item bibliography is included.

OP 57-68. Phase Relations in the Niobium-Gallium System, by L. L. Oden and R. E. Siemens. J. Less-Common Metals, v. 14, 1968, pp. 33-40. Niobium-gallium alloys and diffusion couples were studied in the composition range 0 to 70 weight-percent Ga by metallography, thermal analysis, electron microprobe, and X-ray diffraction. Five intermetallic compounds were identified; their tentative formulae, modes of formation, and melting or decomposition temperatures are as folows: (1) Nb_3Ga, peritectic, 1,900° ± 20° C; (2) Nb_5Ga_3, congruent, about 1,800° C; (3) NbGa, peritectic, 1.490° ± 20° C; (4) Nb_5Ga_4, peritectic, 1,280° ± 10° C; (5) $NbGa_3$, peritectic, 1,240° ± 10° C. A eutectic reaction occurs between the first two compounds at 1,750° ± 25° C and 25 weight-percent Ga. The solubility of Ga in Nb decreases from 12 weight-percent at 1,900° C to about 7 weight-percent at 1,600° C.

OP 58-68. Crystal Data for Sodium Tetragermanate, by J. H. Jolly and R. L. Myklebust. Acta Cryst., v. B24, pt. 3, March 1968, p. 460. Single-crystal X-ray studies on sodium tetragermanate, $Na_2Ge_4O_9$, gave $a_0 = 11.335$ $c_0 = 9.697$, space group $P6_3/m, Z = 6$. This colorless transparent compounds with $\omega = 1.731$ and $\epsilon = 1.773$ has a measured density of 4.41 g/cm³ (27° C). Indexed powder data are listed.

OP 59-68. In-Place Recovery of Shale Oil "Promising," B of M Scientist Says, by Harold W. Sohns. Oil Daily, Mar. 29-31, 1968, p. 10. The article describes briefly the advantages and problems of in-place retorting of oil shale, summarizes past and present research by the Bureau of Mines, and discusses the nature of future research.

OP 60-68. Reclaiming and Recycling Metals and Minerals Found in Municipal Incinerator Residues, by Carl Rampacek. Proc. Symp. Mineral Waste Utilization, March 27-28, 1968, pp. 124-131. This article describes the Bureau of Mines program to reclaim and recycle the metal and mineral values currently lost in incinerator residues. Studies to develop reliable methods for sampling and analyzing residues from grate-type and rotary-kiln furnaces and to define the residues as raw material for the metallurgist are summarized. Composition and bulk data are tabulated. The most promising procedure developed to date for separating the metal and mineral values in the residues into products suitable for recycling is described. A method for homogenizing various metal fractions was used in sampling the individual products for chemical analyses. Chemical data for a few remelted and smelted metals are tabulated. Problems still to be overcome and the nature of future research are outlined.

OP 61-68. Offshore Mining Present and Future, by Michael J. Cruickshank, Charles M. Romanowitz, and Milton P. Overall. Eng. and Min. J., v. 169, No. 1, January 1968, pp. 84-91. The paper describes where we stand in the art of ocean mining and how we will attack the problems of tomorrow as the mining industry probes the deeper and more hostile environment of the sea.

OP 62-68. Some Significant Facts Concerning the Composition of Petroleum (translated into Russian), by H. M. Smith. In Organicheskaya Geokhimiya. Izdatel, stvo Nedra, Moscow, v. 1, 1967, pp. 63-81; Proc. Oil Scientific Sessions, Budapest, Hungary, v. 2, Oct. 8-12, 1962, pp. 474-512. This article discusses crude oil variety in composition, gasoline variety in composition, variety in gasoline yield, paraffin-isoparaffin relationships, aromatic content of gasolines, hydrocarbon interrelationships, isoprenoids, naphthenes, high-boiling aromatics, nonhydrocarbons, porphyrins, and metal contents. The composition of crude oil, when fully known, should provide many keys to its origin and accumulation and many facts that would be significant test for the acceptability of theories of petroleum origin; this article is a part of a modern, in-depth discussion of the subject.

OP 63-68. Turbidity Measurements as an Indicator of Solids Content of Neutralized Mine Waters, by Maurice Deul. Proc. 2d Symp. on Coal Mine Drainage Research, Mellon Institute, May 14-15, 1968, Pittsburgh, Pa., 1968, pp. 35-38. Turbidity measurements are accurate indicators of suspended solids content only for a narrow range of sizes and solids composition. For acid mine waters neutralized with lime or limestone, the suspended solids content, as estimated by a Jackson candle turbidity apparatus, diverges greatly from the actual solids content determined gravimetrically. The experimental results show that turbidity measurements do not given an accurate estimate of the concentration of suspended solids in neutralized mine water effluent.

OP 64-68. Computer Program (FORTRAN II) for Use in Surface Area Determination by Gas Chromatographic Means, by Robert W. Friedman. Laboratory Practices, June 1968, v. 17, No. 6, pp. 710-711. A computer program in FORTRAN II language is presented for use in the determination of surface areas using the continuous flow gas chromatographic method.

OP 65-68. An Experimental Study of Ferrous Iron Oxidation in Acid Mine Waters, by Ann G. Kim. Proc. 2d Symp. on Coal Mine Drainage Research, Mellon Institute, May 14-15, 1968, Pittsburgh, Pa., 1968, pp. 40-45. The rate of oxidation of ferrous iron in an acid environment depends upon the concentrations of ferrous iron and dissolved oxygen and upon the temperature. Samples of natural mine water were studied to determine the effect of aeration upon the rate of oxidation. Eight 1-liter samples were used for each test. Four were aerated (at rates of 200 cubic centimeters per liter per minute and 2,000 cubic centimeters per liter per minute); two were in open containers to allow normal oxygen diffusion from the air into the water; and two were in closed containers with only the dissolved oxygen originally present in the water. Aeration was found to have no beneficial effect upon a low ferrous iron water (34 ppm), because the water had an adequate amount of dissolved oxygen. It did decrease the time necessary for complete oxidation in waters with 175 to 260 ppm ferrous iron, evidently by keeping the water saturated with dissolved oxygen.

OP 66-68. Mine Air Sealing: A Progress Report, by Noel N. Moebs. Proc. 2d Symp. on Coal Mine Drainage Research, Mellon Institute, May 14-15, 1968, Pittsburgh, Pa., 1968, pp. 255-264. A small, abandoned above-drainage coal mine in the Upper Freeport coalbed in western Pennsylvania, which discharges acid water, was air sealed in 1966 to determine if the acidity and iron of the discharge could be reduced. The geologic and hydrologic environment of the mine were investigated to aid in evaluating the effectiveness of air sealing and indicate the controlling factors. The mine effluent flow rate and quality have been monitored continuously since 1963. Ground water levels, quality, and composition of the overburden were obtained from drill holes. The atmosphere in the sealed mine was sampled periodically, and the differential air pressure across the seal was recorded. Since May 1966, when the mine was sealed, the average total acidity of the effluent has continued to decrease despite an oxygen level of 16 to 18 percent and lack of any differential air pressure across the seal, which indicate so-called "breathing" of the mine.

OP 67-68. Factors in Neutralizing Acid Mine Waters With Limestone, by E. A. Mihok and C. E. Chamberlain. Proc. 2d Symp. on Coal Mine Drainage Research, Mellon Institute, May 14-15, 1968, Pittsburgh, Pa., 1968, pp. 265-273. A continuous limestone neutralization pilot plant capable of handling 100 gpm of acid-iron water was designed, constructed, and operated to study some of the factors controlling neutralization and oxidation processes. Rapid neutralization of acid water was achieved with the use of coarse crushed limestone in a rotary-kiln-type reactor. Subsequent aeration of neutralized water from the reactor removes soluble ferrous iron at the rate of 1 to 4 ppm per minute.

Ferrous iron removal during neutralization and aeration is pH and temperature dependent. In the limestone reactor, at normal mine water temperatures, soluble iron is removed at a rate of 30 to 35 ppm per minute. Although the pH of the neutralized waters ranged from 6.5 to 7.5, sufficient alkaline activity was not achieved to bring about mass precipitation of insoluble ferrous hydroxide, despite an excess of finely divided limestone remaining in suspension. The presence of an abnormally high concentration of CO_2 in the atmosphere (about 0.16 percent) at the reactor site may cause pH suppression.

OP 68-68. Direct Method for Unfolding Convolution Products—Its Application to X-Ray Scattering Intensities, by Sabri Ergun. J. Appl. Cryst., v. 1, Pt. 1, April 1968, pp. 19-23. A method is described for unfolding the convolution products based on substitution of successive foldings. It is illustrated by correcting the observed X-ray patterns of a carbon black for instrumental broadening. The applicability of the method is briefly discussed. It has been found that accurate solutions are quickly obtained if the function desired is integrable and everywhere differentiable. The method requires no analytical expressions and is ideally suited for computers.

OP 69-68. Charge-Transfer Complexes and Electrochemical Cells—Coal Batteries, by R. A. Friedel, J. Electrochem. Soc., v. 115, No. 6, June 1968, pp. 614-615. Spectrometric work on various systems involving coal was begun 2 years ago for the purpose of determining whether or not coal would form charge-transfer complexes with donor and/or acceptor substances. Measurements by magnetic resonance, infrared, and ultraviolet-visible spectrometry have indicated that coal forms both donor and acceptor charge-transfer complexes. Recent reports of the discovery of a charge-transfer battery (perylene + I_2) promoted an attempt to try coal + I_2. With a magnesium anode a 1-inch-diameter disk cathode, prepared from ground Pittsburgh coal + I_2, produced an open-circuit voltage of 1.6 volts and a current density of 114 microamperes/cm^2. Jedo anthracite + I_2 produced 1.4 volts and 440 microamperes/cm^2. The time required to construct one of these batteries is about 15 minutes. The charge-transfer complex formed by pyridine and coal, with coal the acceptor in this case, is also a successful battery. Various coals have been found to be successful battery components; no unsucessful coals have been found. Also charge-transfer complexes with coal as the acceptor substances, e.g., pyridine + coal, are successful battery components.

OP 70-68. The Infrared Spectra of Oxygen-18 Labelled Chars, by R. A. Friedel, R. A. Durie, and Y. Schewchyk. Carbon, v. 5, 1967, pp. 559-564. As a contribution to the study of the origin of the 1600-cm^{-1} band in the infrared spectra of coals and chars the infrared spectra of the chars from oxygen-18 labeled linoleic acid, benzoic acid, sodium benzoate, and phenol have been investigated. The oxygen content of most of the chars is low (ranging from 0.5 to 3.9 percent), but all exhibit a strong absorption band near 1600 cm^{-1} in the infrared spectrum. No frequency shift due to the isotope effect was apparent. These observations appear to suggest that oxygen-containing groups may not be contributing, either directly or indirectly, to the intensity of the 1600-cm^{-1} band. However, final assessment of the implications of these observations must await data on the oxygen isotopic frequency shift in a relevant conjugatively chelated carbonyl system.

OP 71-68. Techniques for Diesel Emissions Measurement, by R. W. Hurn and W. F. Marshall. Soc. Automotive Eng., Midyear Meeting, Detroit, Mich., May 20-24, 1968, SAE Paper 680418, 10 pp. Methods used in diesel emissions measurement at the Bureau's Bartlesville Petroleum Research Center are described; limitations, adequacy, and needs for further development of each are discussed. Smoke measurements are reported from work with the Hartridge meter, as well as newly developed instruments that are used to view smoke plumes directly and which seem to offer advantage over smokemeters previously used. Experience in odor assessment by a human panel using reference odor materials is reported to be encouraging. Odor intensity is judged with much greater reliability than odor quality; capability to assess the latter remains wholly inadequate.

Results in application of the methods for measuring diesel emissions are intended to illustrate the use of experimental techniques to reveal engine and fuel factors as they influence the character, amount, and air-polluting effect of diesel emissions. Although the data do not permit reliable assessment of any of the factors, they are useful in showing orders of magnitude and possible relative significance of the respective emissions in the several categories.

OP 72-68. Distribution of Gaseous Products From Laser Pyrolsis of Coals of Various Ranks, by F. S. Karn, R. A. Friedel, and A. G. Sharkey, Jr. Carbon, v. 5, 1967, pp. 25-32. The irradiation of coal by laser energy is one of the more promising new methods of pyrolyzing coal rapidly at high temperatures. Gaseous products from the laser irradiation of coals of various ranks were analyzed by mass spectrometry. The total gas yield varied inversely with coal rank, showing a fourfold increase between anthracite and lignite. The atomic C-H ratio for the gases was lower than for the corresponding coal. Yields of acetylene, hydrogen, carbon monoxide, and carbon dioxide generally increased between anthracite and lignite. Changes were most pronounced between anthracite and low-volatile bituminous coal. Liquid products were not detected. The infrared spectrum of the solid residue showed few of the characteristic coal bands.

OP 73-68. Use of High-Resolution Mass Spectometry To Identify Products From Microwave Discharged in Coal-D_2O Mixtures, by T. Kessler and A. G. Sharkey, Jr. Spectroscopy Letters, v. 1, No. 4, 1968, pp. 177-180. Reactions of carbonaceous materials and H_2O in microwave discharges are known to produce H_2, HCN, CO, CO_2, and light hydrocarbon gases (primarily C_1 and C_2) in varying amounts. To determine if the solid or the H_2O is the source of hydrogen in formation of the above products, coal and graphite have been reacted with D_2O. Low-resolution mass spectra of the gaseous products from the D_2O experiments indicated the possibility of nondeuterated and corresponding deuterated compounds in the reaction mixture. Conventional separation and analytical techniques are not applicable to mixtures of this type. This communication describes the use of a high-resolution mass spectrometer, operated at a resolution 35 percent less than theoretically required for separation of the H_2-D doublet, to electrically measure precise masses for mixtures containing micromole amounts of deuterated and nondeuterated light gases.

OP 74-68. Spark-Source Mass Spectra of Several Aromatic Hydrocarbons Using a Spinning Electrode, by T. Kessler, A. G. Sharkey, Jr., W. M. Hickam, and G. G. Sweeney. Appl. Spectroscopy, v. 21, No. 2, March/April, 1967, pp. 81-85. The purpose of this investigation was to evaluate the application of a spark-source mass spectrograph equipped with a spinning-electrode system for the study of various high-molecular-weight materials derived from coal. Eight structural types having molecular weights from 178 to 252 corresponding to those substances previously seen in an electron-impact mass spectrum of the coal-tar pitch were affirmed by this technique. Easily interpreted mass spectra of phenanthrene, anthracene, and chrysene were obtained by the spinning–electrode system. Mass spectra obtained from synthetic mixtures of anthracene and chrysene demonstrated that the technique is applicable for semiquantitative analysis.

OP 75-68. Mossbauer Spectroscopy of Iron in Coal, by John F. Lefelhoczk, Robert A. Friedel, and Truman P. Kohman. Geochim. et Cosmochim. Acta, v. 31, 1967, pp. 2261-2273. Fe^{57} Mössbauer spectra of coal samples were measured in order to obtain information about the so-called "organically-bound" iron in coal. Nine vitrain or whole-coal samples of rank from lignite (72 percent C) to anthracite (93 percent C) have been investigated. Five coals which were known from chemical analysis to contain sulfide iron yielded the symmetric two-line spectrum of pyrite, with a room-temperature isomer shift relative to sodium nitroprusside of $\delta = +0.54$ mm/sec and a quadrupole splitting of $\Delta = 0.58$ mm/sec. Five coals which were believed from chemical analysis to contain "organic" iron yielded a symmetric two-line spectrum with $\delta = +1.38$ mm/sec and $\Delta = 2.62$ mm/sec. These parameters, including the equality of line intensities, differ from those of any known Mössbauer spectrum; they indicate high-spin iron (II) in sixfold coordination.

OP 76-68. Carbon-13 Nuclear Magnetic Resonance Studies of 3-Substituted Pyridines, by H. L. Retcofsky and R. A. Friedel. J. Phys. Chem., v. 72, No. 1, January 1968, pp. 290-293. Carbon-13 magnetic shieldings for eight 3-substituted pyridines are reported and compared with those of the corresponding monosubstituted benzenes. Thirty of the 40 carbon shieldings measured in the spectra of the pyridines yield substituent effects that are within ± 1.3 ppm of those found for the benzenes. Shieldings of the carbons in the 6-position in the pyridines are shown to reflect electron release or withdrawal by substituent groups.

OP 77-68. Experimental Test of the Theory of Carbon Chemical Shifts in Conjugated Molecules, by H. L. Retcofsky, J. M. Hoffman, Jr., and R. A. Friedel. J. Chem. Phys., v. 46, No. 11, June 1967, pp. 4545-4546. Carbon-13 NMR chemical shifts in naphthalene, biphenyl, phenanthrene, pyrene, and triphenylene are presented. Spectral assignments for the first two compounds were unambiguously determined by measurements on suitably deuterated derivatives; those for the second two compounds were based on chemical shift-structure correlations found for similar compounds. Theoretical shieldings were calculated using the Karplus-Pople equation.

OP 78-68. E.P.R. g-Values of Coals, by H. L. Retcofsky, J. M. Stark, and R. A. Friedel. Chem. and Ind., No. 31, Aug. 5, 1967, pp. 1327-1328. Although several papers dealing with EPR studies of coals have appeared in the literature, no systematic study of the *g* values for an extensive number of coals has been reported. *g* values of 19 coals, including a peat and meta-anthracite in addition to several bituminous, lignitic, and anthracitic coals have been determined and found to vary from values typical of semiquinones to values quite close to those of aromatic hydrocarbon radicals.

OP 79-68. C^{13} and H^1 Nuclear Magnetic Shieldings and Electrical Effects of *Ortho* Substituents in Monosubstituted Pyridines, by H. L. Retcofsky and F. R. McDonald. Tetrahedron Letters, No. 21, 1968, pp. 2575-2578. Carbon-13 and H^1 nuclear magnetic shieldings for atoms in the 5-position of ten 2-substituted pyridines are reported. A linear relationship was found between both the carbon and proton shieldings and Hammett's chemical reactivity parameters. Comparison with results for monosubstituted benzenes suggest that σ_p constants, as usually determined from kinetic or equilibrium studies of *para*-substituted benzene derivatives, are applicable to 2-substituted pyridines.

OP 80-68. Vehicle Emissions vs. Fuel Composition, by R. K. Stone and B. H. Eccleston. Proc. API, v. 48, sec. 3, 1968, pp. 705-742. Test results showed that at high ambient temperatures a large reduction in evaporation losses was realized when fuel volatility was lowered from 10 to 8 pounds RVP. However, the reduction in evaporative losses was paralleled by a small increase in exhaust emissions with lower volatility fuel. The amount of photochemically reactive hydrocarbon in evaporative losses was reduced substantially either by lowering fuel volatility or by substituting saturated for unsaturated C_4 and C_5 hydrocarbons. The reactivity of the exhaust hydrocarbon was also reduced by the substitution. Carbon monoxide emissions showed a small increase as fuel volatility was reduced; nitrogen oxides and aldehydes were not significantly affected by fuel changes made in this study.

OP 81-68. Are Resources Enough for Growth?, by David B. Brooks. Appalachia, v. 1, No. 10, June-July 1968, pp. 41-42. Natural resources may provide a basis for regional growth if the region can add to the value of the resource before shipping or if it can produce required inputs locally or if it can utilize the income locally. There are grounds for hope that the coal industry can provide such a basis in Appalachia.

OP 82-68. Explosives Research To Improve Flow Through Low-Permeability Rock, by J. L. Eakin and J. S. Miller. J. Petrol. Technol., v. 19, No. 11, November 1967, pp. 1431-1436. Small-scale surface tests were conducted to determine the feasibility of using a nitroglycerine-base explosive for creating rock fractures. Prior to underground testing, surface and near-surface tests with liquid explosives showed that explosions in sheetlike layers simulating underground fractures would propagate through the layers. Successful surface tests were conducted using layers of explosive placed between glass plates and explosive-saturated sand confined in small-diameter metal tubes. Tests also showed that explosions propagate through the pores of Berea sandstone saturated with a liquid explosive. Encouraging results were produced by a shallow test in which extensive fracturing was effected with 5¾ quarts of nitroglycerin (NGI) detonated in limestone, and with a 50-quart charge of NGI displaced into a permeable zone at a depth of 42 feet in Green River oil shale. Cores, caliper logs, down-hole camera surveys, elevation measurements, and airflow tests showed the effects of the latter explosion. Fracture improvement ratios determined on eight test holes ranged from 2.3 to 19.1 and averaged 8.0. (SPE preprint 1715, presented at SPE 3d Conf. Drilling and Rock Mechanics, Austin, Tex., Jan. 25-26, 1967, 10 pp.)

OP 83-68. Structure of Carbon, by Sabri Ergun. Carbon, v. 6, 1968, pp. 141-159. Recent developments concerning the hexagonal polymorph of diamond and the orthorhombic, quinoid structure of carbon proposed by Pauling are reviewed. Advancements in the analysis of paracrystalline carbon are analyzed critically. Atomic radial distribution functions indicate that graphitelike layers in some carbons are much larger than the profiles of the (hk) reflections indicate. Profile analyses of the ($00l$) reflections of a carbon black P33, indicate that a layer domain in the black has at least one adjacent domain parallel to it and that the fraction of carbon in stacks having n layers decreases exponentially with n. From comparative studies of graphitizable and nongraphitizable carbons it is concluded that graphitizable carbons contain large layers and their stacking is extensive. Layer growth and increase in stacking height with heat treatment are, to a great extent, the result of annealing of distortion and interstitials. Evidently linkages connecting small layer groups prevent their graphitization.

OP 84-68. The Infrared Spectrum of Dawsonite, by Patricia A. Estep and Clarence Karr, Jr. Am. Miner., v. 53, No. 1-2, January-February 1968, pp. 305-309. The infrared spectrum to 200 cm^{-1} is presented for pure natural dawsonite, compared with synthetic dawsonite (alkalized alumina), and is shown to be reliable for identification.

OP 85-68. Effect of Pressure and Oxidant Concentration on Autoignition Temperatures of Selected Combustibles in Various Oxygen and Nitrogen Tetroxide Atmospheres, by Aldo L. Furno, Agnus C. Imhof, and Joseph M. Kuchta. J. Chem. & Eng. Data, v. 13, No. 2, April 1968, pp. 243-249. Minimum autoignition temperatures were determined at various pressures from 25 to 740 mm of Hg for a number of combustibles in air, oxygen, and nitrogen tetroxide with either nitrogen or helium diluents. The combustibles included hydrogen, n-butane, n-hexane, n-heptane, 1-chlorobutane, 1,2-dichloroethane, 1,1,1-trichlorethane, trichloroethylene, methylene chloride, hydrazine, monomethylhydrazine, and unsymmetrical dimethylhydrazine.

OP 86-68. Potassium Recovery by Chemical Precipitation and Ion Exchange, by D. R. George, J. M. Riley, and J. R. Ross. Chem. Eng. Prog., v. 64, No. 5, May 1968, pp. 96-99. A process is described for recovering potassium from complex brines. Potassium is precipitated from a cold brine as the relatively insoluble perchlorate by addition of sodium perchlorate. The potassium perchlorate is recovered and converted to potassium chloride, sulfate, or carbonate by ion exchange metathesis whereby sodium perchlorate is simultaneously recovered for recycle.

OP 87-68. Refuse Mulch Boosts Tomato Yield, by C. O. Hawk, Sam Friedman, E. B. McCullough, and R. W. Hiteshue. Coal Age, v. 73, No. 6, June 1968, pp. 90-94. In a small field experiment involving 100 tomato plants, half of which were mulched with coal-washery refuse, the mulched plants grew faster and bore more and larger fruit than unmulched plants. The increase in yield was greatest up to about midseason. The yield ratio (yield of mulched plants divided by yield from unmulched plants) for ripe fruit during this period was 1.2 to 1.3. The ratio for the entire season was 1.13. The increased yield is believed to result in large measure from the dark-colored mulch capturing more solar radiation, consequently producing a warming effect in the soil. There was no evidence either of poisoning of the plants by the mulch or of a beneficial effect attributable to a nutrient property of the mulch.

OP 88-68. Wide-Line Nuclear Magnetic Resonance Spectroscopy of Sulfur-33 in Minerals, by Clarence Karr, Jr., and Harry D. Schultz. Spectroscopy Letters, v. 1, No. 5, May 1968, pp. 205-210. Nuclear magnetic resonance spectra of S^{33} in solid samples were obtained for the first time. Although the natural abundance of S^{33} is quite low (0.74 percent), good signals were obtained for sphalerite (ZnS) and pyrrhotite ($Fe_{1-x}S$). In addition, separate signals were obtained for the first time for a binary mixture of sulfur compounds (sulfur dissolved in liquid CS_2).

OP 89-68. Dense Medium Separation, by E. R. Palowitch and A. W. Deurbrouck. Pt. 1 of ch. 9, Wet Concentration of Coarse Coal, in sec. 4, Coal Cleaning Methods. Coal Preparation. American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, 3d ed., 1968, pp. 9-3 through 9-37. This section covers the following aspects of wet concentration of coarse coal: The history, the four types of separating media which are being or have been used commercially (organic liquids, dissolved salts in water, aerated solids, and suspensions of fine solids in water), separatory vessels, dense medium processes, and separator designs.

OP 90-68. Hydraulic Concentration, by A. W. Deurbrouck and E. R. Palowitch. Pt. 2 of ch. 10, Wet Concentration of Fine Coal, in sec. 4, Coal Cleaning Methods. Coal Preparation. American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, 3d ed., 1968, pp. 10-32 through 10-65. This section discusses the principal fine-coal washers used in the United States today: wet concentrating tables, cyclones, launders, feldspar jigs, and hydrotators.

OP 91-68. Absolute Viscosity Determinations by Means of a Coiled-Capillary Viscosimeter. Data for Helium-Carbon Dioxide Mixtures, by H. P. Richardson, D. Cummins, and R. A. Guereca. Proc. ASME 4th Symp. on Thermophysical Properties, University of Maryland, Apr. 1-4, 1968, pp. 372-379. A unique high-pressure gas viscosimeter incorporating a helical 200-foot stainless steel capillary and a constant-volumetric-rate pump is described. A Dean number of less than 10 is used as the experimental criterion for steady-state laminar flow. Techniques for evaluating parameters for absolute viscosity determinations are discussed. Absolute viscosity data for gaseous helium-carbon dioxide mixtures at 20° C and pressures to 1,000 psia are presented. The data are believed accurate to within 0.5 percent.

OP 92-68. Calibration of Differential Pressure Indicators at High System Pressures, by H. P. Richardson, John L. Gordon, David Cummins, and R. A. Guereca. Rev. Sci. Instr., v. 39, No. 6, June 1966, pp. 841-842. A technique and apparatus are described for accurately (±0.01 percent) calibrating differential pressure indicators beyond the normal operating range of available high pressure manometers.

OP 93-68. Influence of Amount of Ash on Ignitibility of Coal Dust-Methane-Air Mixtures, by J. M. Singer. Fuel, v. 47, No. 3, May 1968, pp. 223-234. This investigation represents one phase of the long-range program conducted by the Bureau of Mines to obtain a better understanding of the ignition hazard of coal dusts in mines and to improve the firing of low-grade pulverized fuels and the technology of coal-fired MHD generators. In the present study, the hot gas ignition method for determining lower ignition limits was applied to hybrid mixtures containing coals with approximately the same VM (34 to 36 percent) but with varying percentages of ash (2.6 to 12.7 percent). The ignitibility of a deashed coal with less than 0.2 percent ash content and a relatively high VM (59.7 percent) was compared with that of the ash-containing coals.

As the ash content of the coals was increased, the ignitibility of the experimental hybrid mixture decreased for mixtures containing more than 30 to 35 mg/l coal dust; for hybrid mixtures containing less than 30 mg/l coal dust this effect was negligible. Chemical inhibition by the metal salts present in the coal is favored as an explanation for the decreased ignitibility of hybrid mixtures containing coals of relatively low ash. The elutriation process by which float coal dust suspensions form in mines may act to remove some of the ash matter from the suspended coal, thus increasing its ignitibility. Deashed coal mixtures appear to be more ignitible than mixtures of coals with a lower VM and some ash matter.

OP 94-68. Geologic Factors Affecting Density Logs in Oil Shale, by John Ward Smith, Harold E. Thomas, and Laurence G. Trudell. Trans. Soc. Prof. Well Log Anal. 9th Ann. Logging Symp., June 23, 1968, pp. 1-17. Oil-yield estimation from density logs in Colorado's Green River Formation oil shale is adversely affected by the major occurrence of crystalline nahcolite in cavities left after nahcolite solution. Their effects on accuracy of oil-yield estimation are examined.

OP 95-68. Similarity Between the Electrochemical Elimination of Sulphur From Coal and From Dibenzothiophene, by H. W. Sternberg, C. L. Delle Donne, and I. Wender. Fuel, v. 47, No. 3, May 1968, pp. 219-222. When dibenzothiophene was reduced electrochemically under the same conditions as coal, sulfur was eliminated only after four hydrogen atoms had been added to the dibenzothiophene ring. A similar pattern of sulfur removal had been observed previously during the electrochemical reduction of coal where sulfur was eliminated only after 25 hydrogen atoms per 100 carbon atoms had been added to the coal.

OP 96-68. Hydrogen Detectors, by Alexander Strasser, I. Liebman, and S. R. Harris. Cryogenic Eng. News, v. 2, No. 12, December 1967, pp. 16-20. As a part of a broad investigation on the safe use of hydrogen in space flight operations, the Bureau surveyed the performance of 13 hydrogen detectors. Characteristics investigated included: accuracy and reproducibility, effect of high hydrogen concentrations, effect of temperature and humidity, response and recovery times, response to gases other than hydrogen, ignition hazards, effect of wind, zero drift. The instruments were distinguished mainly by the sampling mechanism and the way in which hydrogen is sensed and displayed.

OP 97-68. Compositional Studies of an Asphalt and Its Molecular Distillation Fractions, by R. V. Helm and J. C. Petersen. Anal. Chem., v. 40, No. 7, June 1968, pp. 1100-1103. Molecular distillation of a Wilmington, Calif., asphalt that was prepared in the laboratory gave fractions whose sulfur, oxygen, nitrogen, and aromatic contents increased with molecular weight. Paraffinic content was nearly constant with molecular weight. The increase in aromatic content with molecular weight was offset by a decrease in the naphthenic content. Although the total oxygen content increased with molecular weight, the acid oxygen decreased. A correlation between the naphthenic content and the acid oxygen was shown. Methylene chloride, as a solvent, permitted the resolution of the 1700 cm^{-1} carbonyl band of the asphalt and its fractions into three discrete bands at 1740, 1700, and 1655 cm^{-1}. Carboxylic acids appear responsible for the 1740 cm^{-1} band in the asphalt and its distillation fractions. These acids were found to be associated in the asphalt. A model naphthenic acid, cyclohexanecarboxylic acid, associated with functional groups in the asphalt.

OP 98-68. Characterization of Carbonaceous Material From the Puerto Rico Trench of the Atlantic Ocean, by R. A. Friedel and A. J. Nalwalk. Nature, v. 217, No. 5126, Jan. 27, 1968, pp. 345-347. Oceanographic sampling in the 4-mile-deep Puerto Rico Trench in the Caribbean Sea unexpectedly recovered carbonaceous rocks. Hard chert and soft clay samples have been examined spectroscopically in order to characterize the organic materials. The spectral results were compared with similar spectral data from coals, petroleum, and shale oil kerogen. The organic material from both the hard and soft rocks are most similar to kerogen.

OP 99-68. Iron Ore Waste—Occurrence, Beneficiation and Utilization, by M. M. Fine and L. F. Heising. Proc. Bureau of Mines-IIT Research Institute Symp. on Mineral Waste Utilization, Mar. 28, 1968, Chicago, Ill., May 1968, pp. 73-77. Wastes generated in iron mining include overburden and coarse tailings which are metallurgically unattractive. Fine tailings nad lean ores could be a new source of iron units. Taconite rejects constitute a huge waste containing much iron, but technology for its recovery is yet to be developed.

OP 100-68. Utilization of Ferrous Scrap, by Norwood B. Melcher. Proc. Bureau of Mines-IIT Research Institute Symp. on Mineral Waste Utilization, Mar. 28, 1968, Chicago, Ill., May 1968, pp. 132-137. This report reviews all of the metallurgical research of the Bureau of Mines relating to the refining and utilization of ferrous scrap. The separation of impurities from scrap by thermal and leaching processes is reviewed, and a process for using ferrous scrap as a reductant in magnetic roasting is described.

OP 101-68. Comments on Recent Bureau of Mines Prereduced Pellet Research, by Norwood B. Melcher. Congres International sur la Production et l'Utilization des Minerais Re ..cs (International Meeting on the Production and Utilization of Prereduced Minerals), May 29-31, 1967, Evian, France. June 1968, pp. 49-52. This paper reviews recent Bureau research on the use of promoters and inhibitors to the reduction of wustite at 1,000° C. Additives including the alkali metals and boron used as inhibitors are discussed. The economics of prereduction in a simulated commercial plant of 2 million long tons per year, and the effect of prereduction on blast furnace production costs are evaluated.

OP 102-68. A Minnesota Clay Resource and Its Utilization for Iron, Ore Pelletizing, by Jams H. Aase and George E. Leonhard. Proc. 29th Ann. Min. Symp. and 41st Ann. Meeting Minnesota Sec., AIME, Duluth, Minn., Jan. 15, 1968, pp. 1-7. Field and laboratory investigations of clays from the Cook, Minn., area established the presence of large reserves of this commodity. The clays, when chemically activated with sodium compounds, could serve as a binder for magnetic taconite pellets. Use of the activated clays instead of bentonite could result in an appreciable savings to the industry.

OP 103-68. Rupture Mechanism of a Liquid Film, by Israel Liebman, John Corry, and Henry E. Perlee. Science, v. 161, July 26, 1968, pp. 373-375. The rupture mechanism of edge-supported liquid films appears to involve the viscous and drag energies as well as previously postulated kinetic and surface energies. Although details are obscure, the mechanism appears to involve a liquid-gathering process at the free edge, followed by fragmentation of this thickened edge into drops whose radii are approximately 50 times the film's original thickness.

OP 104-68. A Progress Report on Increasing Permeability by Explosives and Heat, by W. F. Eckard. Proc. Tech. Sessions Kentucky Oil and Gas Assoc. 30th and 31st Ann. Meetings, 1966 and 1967, Kentucky Geological Survey, Ser. 10, Special Pub. 15, pp. 70-80. Early field and laboratory experiments on rock fracturing using a chemical explosive and thermal alteration of rock using a monopropellant are described.

OP 105-68. The Separation of Neon From the High-Helium-Content Natural Gases and the Atmosphere for Isotopic Analyses, by David E. Emerson, Elmer T. Suttle, and C. A. Hoffman. Internat. J. Mass Spectrometry and Ion Phys., v. 1, No. 2, June 1968, pp. 105-110. The purpose of this work was to improve the determination of the isotopic composition of neon from natural gases and the atmosphere. The apparatus and method described concentrates neon directly from high-helium-content natural gases or from the atmosphere by utilizing two adsorption traps of activated coconut charcoal at 30° and 77° K.

OP 106-68. Factors Influencing Diesel Emissions, by W. F. Marshall and R. W. Hurn. SAE West Coast Meeting, San Francisco, Calif., Aug. 12-15, 1968, SAE Paper 680528, 9 pp. The Bureau of Mines has done experimental work on a variety of truck and bus engines to determine the influence of engine and fuel factors on both quantitative and qualitative aspects of objectionable combustion products. Results of this work are reported.

OP 107-68. Effects of Rolling Temperature on Creep and Other Properties of Certain Zn-Cu Alloys, by L. A. Neumeier and J. S. Risbeck. Pres. at Am. Soc. Metals 1968 Materials Eng. Exposition and Cong., Detroit, Mich., Oct. 14-17, 1968, Tech. Rept. D 8-24. 5, 17 pp. As part of a study of the effects of varied composition and processing conditions on the properties of wrought zinc alloys, Zn-Cu alloys containing up to 2 percent Cu were rolled to 92 percent reduction at from room temperature to as high as 720° F. Microstructure, hardness, tensile strength, thermal expansivity, and creep resistance were evaluated. The properties are very sensitive to composition, rolling temperature, and percentage reduction and also vary with sheet orientation. Conditions producing highest hardness or tensile strength do not result in best creep resistance. Cold-rolled alloys undergo significant softening as rolling progresses, resulting from recrystallization to small grain sizes and rejection of ϵ-phase from solid solution. Low tensile strength and poor creep resistance also result. The higher tensile strengths occur for rolling at 320° to 400° F, but the lower creep rates result for the structures produced by rolling at higher temperatures. Increased copper contents require progressively higher rolling temperatures to realize best creep resistance. Substantially better creep resistance can be developed than had been reported previously. Limited evidence indicates that grain-boundary sliding occurs during steady-state creep of the hot-rolled alloys.

OP 108-68. Induction Heating in Zone Melting of Organic Compounds, by Henry Plancher, J. C. Morris, and W. E. Haines. Anal. Chem., v. 40, No. 10, August 1968, pp. 1592-1594. A technique and an apparatus for using induction heating with an imbedded susceptor to produce and maintain low-volume molten zones in the zone melting of organic materials have been devised and are described.

OP 109-68. Instrumented Card-Gap Test, by John Ribovich, Richard W. Watson, and Frank C. Gibson. Am. Inst. Aeronautics and Astronautics J., v. 6, No. 7, July 1968, pp. 1260-1263. A modification of the card-gap test for determining the sensitivity of explosives has been made that eliminates some of the anomalies encountered in the interpretation of results. The Bureau of Mines conceived and developed the continuous detonation velocity apparatus and peak pressure sensing gages which were employed to provide quantitative analyses.

OP 110-68. High-Resolution Mass Spectrometry Investigation of Coal-Tar Pitch, by A. F. Sharkey, Jr., J. L. Shultz, T. Kessler, and R. A. Friedel. Proc. ASTM Comm. E-14 Meeting on Mass Spectrometry, Denver, Colo., May 14, 1967, pp. 443-446. High-resolution mass spectrometry was used to investigate an 80° to 85° C softening point coal-tar pitch. The purpose of this study was to obtain information for a subsequent investigation of altered fractions of coal tar, such as weathered road tar. Precise masses were obtained for 29 molecular ions (not including alkyl derivatives) containing the heteroatoms, N, O, and S. Thirteen of these masses, representing structural types not previously reported for coal tar, can be accounted for on the basis of recombination of radicals derived from lower molecular weight components.

OP 111-68. Effects of Bleeder Entries During Atmospheric Pressure Changes, by John W. Stevenson. Min. Eng., v. 20, No. 6, June 1968, pp. 61-64. During the study, three atmospheric pressure changes in excess of 0.60 in of mercury occurred. Data collected during these drops led to the following conclusions:

1. During the study, the bleeder system worked effectively. About 160 cfm of methane (230,000 cu ft per day) was continuously draining from the interior of the gob into the bleeder entries.
2. In the area investigated, the major factor causing an increase in methane was the rate of coal extraction.
3. The rate of atmospheric pressure drop and the total amount of drop are important because they influence the rate of methane outflow from the gob.

It was also observed that underground response in the ventilating current to surface atmospheric change was virtually instantaneous. During atmospheric pressure drops, methane drainage from the gob area into the bleeder returns increased, although the ventilating pressure differential between any two underground locations was not influenced by atmospheric pressure changes.

OP 112-68. Analysis of Sulphur in Coals by X-Ray Fluorescence, by M. Berman and E. Ergun. Fuel, v. 47, No. 4, July 1968, pp. 285-301. A study has been made of the analysis cf sulfur in coals by X-ray fluorescence and the factors influencing the precision of the analysis. It has been found that, for accurate analysis of sulfur, coals must be pulverized to less than 2 microns and pressed into a slab with a smooth face. If a correction is made (using X-ray fluorescence) for the other inorganic elements that exist in coals in appreciable quantities, namely magnesium, aluminum, silicon, calcium, iron, the sulfur content can be determined more accurately than by the standard chemical methods. Variations in the relative amounts of hydrogen, carbon, nitrogen, and oxygen in coals have only a minor influence on the calculated results. The study has been applied to 38 American coals.

OP 113-68. Helium, by L. W. Brandt. Encyclopedia of the Chemical Elements, ed. by C. A. Hempel, Reinhold Pub. Corp. New York, 1968, pp. 256-268. This discussion of helium includes the following categories: Discovery, occurrence, origin on earth, production, production process, production data, isotopes, physical properties, chemical properties, liquid helium, helium-3, helium conservation program, shipments, uses, and current research.

OP 114-68. Behavior of Coal-Gas Reservoirs, by Joseph Cervik. Presented at Soc. Petrol. Eng., AIME, 4th Ann. Eastern Regional Meet., Pittsburgh, Pa., Nov. 2-3, 1967, SPE Preprint 1973. 4 pp. Gas occurs in coalbeds in an adsorbed and a free gas state. Adsorbed gas is stored in the micropore structure and its transport is governed by Fick's law. The free gas occurs in the fracture system and flows according to Darcy's law. These two modes of mass transport are interdependent. Production decline curves are of the constant percentage decline type and, thus, show no indications of flow characteristics peculiar to coal-gas reservoirs. The effectiveness of surface boreholes as a degasification scheme, depends upon both good fracture permeability and a high fracture density. Conventional methods of reservoir engineering analysis are not applicable to coalbeds.

OP 115-68. A Comparison Between Log and Core Analyses From Appalachian Area Oil Wells, by J. R. Duda and C. I. Pierce. Producers Monthly, v. 32, No. 5, May 1968, pp. 2-3. Comparison between log and core analyses is made for six formations penetrated by three wells in the Appalachian area. Two wells in northwestern Pennsylvania and one in north central West Virginia were diamond rotary cored using water-base mud and then surveyed with a suite of geophysical logs. The cores were analyzed in the laboratory to determine their physical properties. Gamma-ray, neutron, density, and resistivity logs were used to determine the porosity and fluid saturations of the cored formations. This article shows some discrepancies that occurred between core and log analyses. Results of this comparison indicate that sampling frequency of one sample per foot of core does not provide good representation of heterogeneous rock and that adequate compensation of the logs for borehole effects can not always be made.

OP 116-68. The Effect of Mild Heating on the 1600 cm^{-1} Region in the Infra-red Spectrum of Coals, by R. A. Durie, Y. Schewchyk, and R. A. Friedel. Fuel, v. 46, No. 1, pp. 53-58. It has been found that a part of the water associated with the vitrains of bituminous coals and most of that associated with a brown coal absorbs at the anomalously low frequency of about 1600 cm^{-1}. It could therefore contribute to the observed integrated absorption intensity of this band with coal samples unless stringent precautions are taken to keep the coal, in the halide disks used, dry. In some conditions the water can account for 15 to 20 percent of the observed intensity.

OP 117-68. Gas Chromatographic Analysis of Low Molecular Weight Alkyl Thiols and Sulfides Separated on Open Tubular Columns, by Robert W. Freedman. J. Gas Chromatography, v. 6, No. 9, September 1968, pp. 495-496. A good separation of C_1-C_4 saturated alkyl thiols and sulfides has been achieved by the use of an open tubular column. Saturated C_1-C_5 alkanes are all eluted prior to methanethiol. Plots of relative hydrogen flame detector response per mole give two distinct families of curves for thiols and sulfides. Each is nearly linear with carbon number.

OP 118-68. Recovery and Production of Alumina From Waste Solutions by Solvent Extraction, by D. R. George, K. E. Tame, S. R. Crane, and K. B. Higbie. J. of Metals, September 1968, pp. 1-5. Significant tonnages of aluminum are discarded in waste solutions from mineral processing. Preliminary samples and information on flow rates at 14 copper mines suggest that more than 2,000 tons of alumina per day may be available and that several individual mines might have a production potential of 300 to 1,000 tpd from solutions containing 25 to 100 lb of alumina per 1,000 gal. These estimates should be regarded as provocative conjectures. The true potential cannot be determined until information is available on the rate of leaching of aluminum from the waste rock and the extent to which the concentration of aluminum in the solutions is controlled by equilibrium conditions. On the basis of preliminary surveys, research was initiated in July 1966 that resulted in development of a solvent extraction procedure for recovering aluminum and producing alumina from copper waste dump leaching solutions. A preliminary appraisal, based on published cost estimates, for producing alumina from clays by acid leaching, suggested that on a scale of 300 to 1,000 tons of alumina per day, production costs might be competitive with alumina produced from bauxite by the Bayer process. Production of alumina from clays by acid leaching is not competitive with the Bayer process today, but production from waste solutions enables the elimination of capital equipment and operating costs for the head-end operations including mining, crushing, calcining, grinding, leaching, filtration, and evaporation. In addition, there are opportunities for further improvements in the economics through recovery of valuable byproducts, including uranium, yttrium, and a number of the rare-earth elements.

OP 119-68. Rapid Excavation, by Thomas E. Howard. Scientific American, v. 217, No. 5, November 1967, pp. 74-76, 81-85. The development of rapid excavation techniques, the evolution of excavating machines, the present state of the art, and the problems to be overcome in the development of the excavation and supplementary technology needed in the future are discussed.

OP 120-68. A Unique Approach to Oil-Production Decline Curve Analysis With Applications, by C. D. Locke, L. A. L. Schrider, and M. K. Romeo. Pres. at Soc. Petrol. Eng., AIME, 43d Ann. Fall Meeting, Houston, Tex., Sept. 29-Oct. 2, 1968, SPE Preprint 2224, 4 pp. A unique method of decline-curve analysis has been developed which greatly facilitates the estimation of future performance of an individual well or field while maintaining a high degree of mathematical accuracy. A computer program has been written which allows the user to obtain the best approximation to hyperbolic or exponential decline curves with a minimum amount of effort. A unique part of the hyperbolic curve fit is that initial approximations to unknown constants are not necessary—the constants are generated internally. Thus, the program allows the user greater freedom of operation, a high degree of mathematical accuracy, and the ability to update information with a minimum of effort. Field data studies are included to show the accuracy and versatility of the method. The technique is shown to be superior to two other methods investigated.

OP 121-68. Kinetics of the Thermal Decomposition of Tungsten Hexacarbonyl, by R. V. Mrazek, S. B. Knapp, and F. E. Block. Trans. Met. Soc., AIME, v. 242, June 1968, pp. 995-1000. The mixed homogeneous and heterogeneous kinetics of the thermal decomposition of tungsten hexacarbonyl were studied by employing a batch reactor. The system was such that a sample of tungsten hexacarbonyl could be injected into the preheated reactor, and the progress of the reaction followed by a simple pressure measurement. Both the homogeneous and heterogeneous reactions were found to be first order, and approximate activation energies were determined for each reaction. It is shown that the disproportionation of carbon monoxide to give carbon and carbon dioxide cannot be the source of carbon in tungsten deposits prepared by this reaction.

OP 122-68. Surface Studies Predict Orientation of Induced Formation Fractures, by William K. Overbey, Jr., and Robert L. Rough. Producers Monthly, v. 32, No. 6, June 1968, pp. 16-19. Natural and induced vertical fractures in oil-bearing reservoirs affect oil production from both primary- and secondary-recovery operations. Preliminary investigations have demonstrated the feasibility of correlating observed surface fracture trends with oil-reservoir fractures induced by hydraulic fracturing.

Magnetic bearings of major vertical joints in outcropping formations were compared with compass bearings from bottom-hole packer-impression surveys of hydraulically induced wellbore fractures. The orientation of vertical fracture trends was established by plotting nearly 2,000 joint strike measurements from Salamanca Sandstone outcrops at 16 locations throughout the Bradford oilfield in McKean County, Pa., and the Allegany oilfield, Allegany County, N.Y. One dominant set of joints trending N 50° E to N 76° E correlated very well with wellbore fracture orientations in 19 to 21 packer-surveyed wells in the two oilfields. The formation outcrop survey bearings were augmented by similar data obtained from aerial photographs and topographic relief maps.

OP 123-68. Vapor Pressure Detector for Liquid Elution Chromatography. Its Potential Use in Shale-Oil Characterization, by R. E. Poulson and H. B. Jensen. Anal. Chem., v. 40, No. 8, July 1968, pp. 1206-1212. A continuous, wet-wick, thermistor-type, differential vapor pressure detector was studied for use in liquid elution chromatography. When thermistors matched to 14-ppm resistance per degree were used, the observed detection limit was 0.8×10^{-6} mole kg^{-1} with cyclohexane solvent. The effective sensing volume of the detector was 90 μl at a flow rate of 2.0 ml/hour, decreasing at lower flow rates. An alkane-alkene type analysis on a shale-oil middle distillate is demonstrated on a small silica gel column. A post-column stream splitter to increase system throughput is described. Available resolution is presented for typical, 0.254-cm-id, adsorbent-packed columns of various lengths. The resolution was evaluated for columns operated with 0.2-cm HETP in the presence of a 90-μl detector-volume effect relative to the zero extra-column volume case. The observable resolution with detector broadening for a 4-m column is 90 percent of the available for bands eluting in 3 column-void volumes. The capability of this type of small-column system is compared with the capability of TLC. The small-column system can generate as much resolution as a TLC system in appreciably less time.

OP 124-68. Inexpensive Oil Vapor Trap for Use With Rotary Vacuum Pumps, by Wallace W. Roepke and Kenneth G. Pung. Vacuum, v. 18, No. 8, August 1968, pp. 457-458. This note describes an inexpensive molecular sieve trap that can be fabricated easily in any laboratory.

OP 125-68. Torsional Bands in Far-Infrared Spectra of Thiols and Amines, by D. W. Scott and G. A. Crowder. J. Molecular Spectroscopy, v. 26, No. 4, August 1968, pp. 477-484. In continuation of earlier work by the authors in which torsional bands were observed in the far-infrared spectra of 2-propanethiol and cyclohexanethiol, torsional bands also have been observed for ethanethiol, 2-methyl-2-propanethiol, n-propylamine, isopropropylamine, and t-butylamine. In the alkanethiols, force-constant calculations show that interactions between SH and CH_3 torsions are relatively unimportant; however, in contrast, interactions between NH_2 and CH_3 torsions are important in the alkylamines. Methanethiol vapor has a complex set of infrared bands between 60 and 500 cm^{-1} that arises from coupling between internal and overall rotation.

OP 126-68. USBM Examines Exotic Ways of Breaking Rock, by Staff, U.S. Bureau of Mines, Twin Cities Mining Research Center. Eng. and Min. J., v. 169, No. 4, April 1968, pp. 85-92. Mining, a dynamic process, may also be defined as an economic system for separating a desired rock, a metallic or nonmetallic mineral from its natural environment. The system has four basic technological categories: Rock disintegration, materials handling, ground control, and environmental control. All mining operations today, whether large or small, face economic and technological problems in one or more of these classifications. The U.S. Bureau of Mines, using a total systems approach, has developed a framework of technological research in each category at four regional centers in the United States. The Twin Cities Mining Research Center near Minneapolis, Minn., is responsible for rock disintegration research.

The Center is attacking the problem of rock disintegration by theoretical and experimental studies covering a wide range of mechanisms which accomplish disintegration by imparting energy to rock. The Center's long-range objective is to develop new and improved rock disintegration techniques as part of new and improved mining systems.

OP 127-68. Analysis of Termination Effects on Atomic Radial Density Curves, by John R. Townsend and Sabri Ergun. Carbon, v. 6, 1968, pp. 19-26. There is evidence to indicate that carbon blacks are made up of distorted large graphite-like layers rather than small turbostratic crystallites. Atomic radial density curves offer a direct means of determining the true structure by revealing the extent of coherently scattering domains. Aside from experimental problems, the major difficulties with the radial density distribution method for determining atomic arrangements in matter have been the limited resolution and false structure usually found in the density curve. These defects are largely due to the fact that scattering data can only be obtained over a finite angular range instead of the infinite range required by theoretical considerations. False structure produced by this cut-off can be suppressed by use of an artificial convergence factor, but this further reduces the resolution of the density curve. A critical analysis is made of the termination effects and a method is described that provides a procedure for directly correcting the radial density curve for the cut-off effects with no sacrifice in resolution.

OP 128-68. Threat of Sonic Booms to Explosives Facilities, by Robert W. Van Dolah. Am. Soc. Safety Eng. J., v. 13, No. 9, pp. 12-14. The potential consequences of sonic booms are direct initiation of explosives, unfavorable instrument reaction, window breakage, startle reaction in personnel, bric-a-brac movement. Of these the latter two fall within the range of the ordinary reaction to sonic booms; window breakage would occur with heavy to intense sonic booms.

OP 129-68. History and Measurement of Helium, by A. H. Tacquard. Gas Measurement (Nat. Gas Measurement Assoc.), v. 2, No. 5, pp. 2-7. The measurement of helium gas volumes, in the Bureau's helium conservation program, is done by conventional methods but, in some ways, is different from the measurement of natural gas.

OP 130-68. The Concept and Testing of Formation Fracturing With Nuclear Explosives and Thoughts on Future Applications, by Charles H. Atkinson. Proc. 4th Petroleum Economics and Evaluation Symp., Dallas Section SPE, AIME, 1968, SPE 2061, pp. 49-54. Development of the nuclear explosive fracturing concept and Project Gasbuggy and other proposed gas reservoir stimulation tests are reviewed. Economics of future application are considered. Areas suitable for the technique and estimates of potential gas recovery are shown. The paper points out the desirability of utilizing the results of Project Gasbuggy in planning additional gas-stimulation projects.

OP 131-68. Discontinuities in Some Thermodynamic Quantities at the Critical Point of an Analytical Fluid, by Robert E. Barieau. J. Chem. Phys., v. 49, No. 5, Sept. 1, 1968, pp. 2279-2282. For an analytical fluid it is shown that at the critical point the following discontinuities exist:

$$C_V\begin{pmatrix}2 \ \text{phases} \\ n/V_T=\rho_c\end{pmatrix} - C_V \Big/ RZ_c = \frac{3p_{at}^2}{p_{aaa}},$$

$$d^2p/dt^2 - (\partial^2 p/\partial t^2{}_a) = (p_{at}/5p_{aaa})[16p_{at} - 20p_{aat} + (3p_{at}\,p_{aaaa})/p_{aaa}],$$

$$T_c[(d^2G/dT^2) - (\partial^2 G/\partial T^2)_\rho](RZ_c)^{-1} = \tfrac{1}{5}p_{at}/p_{aaa}[p_{at} - 10p_{aat} + (3p_{at}\,p_{aaaa})/p_{aaa}],$$

where $a=(\rho/\rho_c)-1$; $p=(P/P_c)-1$; $t=(T/T_c)-1$; G is the Gibbs free energy or chemical potential; C_V is the heat capacity at constant volume; n is the total number of moles in the calorimeter; V_T is the total inside volume of the calorimeter; ρ_c, P_c, T_c are the critical molal density, critical pressure, and critical temperature, respectively; $Z_c = P_c/\rho_c RT_c$; and p with subscripts indicates partial derivatives of p evaluated at the critical point.

OP 132-68. Developments in Oil-Shale Technology, by G. U. Dinneen, K. E. Stanfield, G. L. Cook, and H. W. Sohns. Chem. and Eng. Prog. Symp. Ser., v. 64, No. 85, 1968, pp. 15-21. Green River oil shale represents a huge potential source of energy. This paper discusses the technological aspects of the efforts to utilize this resource. Much information has been gained about the origin of the Green River Formation, the mineral present in it, the reactions of the kerogen, and the composition of the shale oil. Production of shale oil is discussed: (1) Mining, crushing, and aboveground retorting and (2) experimental in situ retorting.

OP 133-68. Transient Flow Characteristics of Low Permeability Gas Reservoirs and Improvement of Deliverability by Nuclear Explosion, by C. Kenneth Eilerts and and Eudora F. Sumner. SPE J., v. 8, No. 3, September 1968, pp. 209-223. The transient flow characteristics of gas reservoirs with permeabilities less than 0.1 millidarcy were computed using programs that give effect to variation in permeability and fluid density and viscosity. Improvement of permeability in the area of the well by nuclear explosion markedly increases the percentage of gas in place that can be recovered at a given flow rate and pipeline pressure. The factor by which delivery capacity is improved depends on the magnitude of effects due to non-Darcy flow prior to the shot.

OP 134-68. Liquid Level Monitoring by Capacitance Measurement, by G. E. Fasching and Joseph Pasini III. Instruments and Control Systems, v. 41, No. 7, July 1968, pp. 111-112. An automatic control system was developed in connection with the recovery of crude oil from shallow, pressure-depleted, low-permeability reservoirs. An integral part of the controller is a liquid level measuring system which monitors 1,000-cc supply vessels, giving and recording precise measurements of the volumes of liquids injected into long sandstone cores. High permittivity-low resistivity and low permittivity-high resistivity fluids can be measured with essentially equal accuracy, sensitivity, linearity, and stability.

OP 135-68. Operating Coal-Fired, Open-Cycle MHD Systems at Low Air/Fuel Ratios, by H. F. Feldman, W. H. Simons, J. Sax, and D. Bienstock. ASME Winter Annual Meeting and Energy Systems Exposition, New York, Dec. 1-5, 1968, 68-WA/ENER-15, 9 pp. Operation of magnetohydrodynamic generators at below stoichiometric air-coal ratios results in a substantial increase in the electrical conductivity of the combustion products and with it the potential of lowering magnet and capital costs.

OP 136-68. Atomic Absorption Graph Paper, by Thomas E. Green. Atomic Absorption Newsletter, v. 7, No. 5, September-October 1968, p. 98. Describes a graph paper with spacing that permits direct plotting of percent absorption readings from an atomic absorption spectrophotometer.

OP 137-68. Graphs Quickly Predict Waterflood Performance, by R. V. Higgins, D. W. Boley, and A. J. Leighton. Part 1, World Oil, v. 167, No. 3, September 1968, pp. 89-96; Part 2, No. 4, October 1968, pp. 152, 158-163. A quick, graphical method is presented which uses continuously changing relative permeabilities to determine oil recovery for a 5-spot waterflood. Forecasts can be completed in about 30 minutes with accuracy of 2 percent.

OP 138-68. Computer Usage for Evaluation of Design Parameters and Cost of Heat Exchangers, by P. R. Jones and S. Katell. Trans. Am. Assoc. Cost Eng., 12th Nat. Meeting, Houston, Tex., June 17-19, 1968, pp. 35-1 through 35-11. A computer program was written for the design of shell-and-tube heat exchangers on a price optimum basis to meet the following requirements: (1) Triangular pitch; (2) single or multiple pass; (3) heating or cooling; and (4) no change in phase. This program was the third in a series and was for a case in which outside pumping costs were immaterial. The program was made adaptable to various fluids and to various tube dimensions by reading in many of the required data in tabular form. Price optimum design was obtained for four tube diameters and standard pitch. Standard shells whose area equaled or exceeded the required area were listed also.

OP 139-68. Pyrolysis of Coal Macerals by Laser Irradiation, by F. S. Karn and A. G. Sharkey, Jr. Fuel, v. 47, No. 3, May 1968, pp. 193-195. The purpose of this investigation was to determine the gaseous products from concentrates of macerals of a high-volatile bituminous coal irradiated with 6-joule pulses from a ruby laser. Total gas yield varied directly with volatile matter of the macerals. Major gases evolved were hydrogen, carbon monoxide, and acetylene. Relative concentrations of these gases and also several minor components in the pyrolysis product varied little among macerals.

OP 140-68. Photographic Study of Laser Irradiation of Coal and Graphite, by F. S. Karn and J. M. Singer. Fuel, v. 47, No. 3, May 1968, pp. 235-240. Irradiation of coal or graphite by a normal-laser pulse produces a luminous plume which has been recorded by high-speed photography. Photographs taken at the rate of 21,000 frames per second were used to measure the rate of plume growth. The effective measured laser pulse was 1.2 msec, of much longer duration than giant laser pulses. Plume growth rate was 1.1×10^4 cm/sec for bituminous coal and 0.9×10^4 cm/sec for graphite which is much slower than growth rates of graphite plumes formed by giant pulse laser irradiation. Vaporization rate for graphite was 14 g/cm^2 sec^1, approximately the rate expected at atmospheric pressure based on carbon boiling-point data.

OP 141-68. Composition of Pyridine Extracts From Reduced and Untreated Coals as Determined by High-Resolution Mass Spectrometry, by T. Kessler, R. Raymond, and A. G. Sharkey, Jr. Proc. ASTM Committee E-14 Meeting, Pittsburgh, Pa., May 1968, pp. 356-358. High-resolution mass spectrometric analyses of pyridine extracts obtained from reduced and untreated vitrain have shown (1) a greater concentration of oxygen-containing compounds in the reduced vitrain compared to the untreated vitrain; (2) an approximately eightfold decrease in organic sulfur compounds in the vitrain following reduction, which is consistent with the decrease in sulfur as shown by ultimate analyses; (3) a lower concentration of higher molecular weight hydrocarbons such as 3-ring aromatics in the reduced vitrain; and (4) a significant increase in the amount of hydroaromatic compounds in the reduced vitrain.

OP 142-68. Calculation of Imbibition Relative Permeability for Two- and Three-Phase Flow From Rock Properties, by Carlon S. Land. SPE J., v. 8, No. 2, June 1968, pp. 149-156. Relative permeability functions are developed for both two- and three-phase systems with the saturation changes in the imbibition direction. An empirical relation between residual nonwetting-phase saturation after wave imbibition and initial nonwetting-phase saturations is found from published data. From this empirical relation, expressions are obtained for trapped and mobile nonwetting-phase saturations which are used in connection with established theory relating permeability to pore-size distribution. The resulting equations yield relative permeability as a function of saturation having characteristics believed to be representative of real systems. The relative permeability of water-wet rocks for both two- and three-phase systems, with the saturation change in the imbibition direction, may be obtained by this method after properly selecting two rock properties: the residual nonwetting-phase saturation after the complete imbibition cycle and the capillary pressure curve.

OP 143-68. The Optimum Gas Saturation for Maximum Oil Recovery From Displacement by Water, by Carlon S. Land. 43rd Ann. Fall Meeting of SPE, AIME, Houston, Tex., Sept. 29-Oct. 2, 1968, SPE Preprint 2216, 12 pp. The influence of a free gas saturation on recovery by water drive is investigated. A digital computer is used to calculate the combined oil recovery from solution-gas drive to various states of depletion and then oil recovery by water displacement at these states of depletion. Results of these calculations are compared, and optimum conditions for the maximum oil recovery are found for various fluid-rock systems. For most of the fluid-rock systems, the calculations show an optimum gas saturation other than zero. Using fluid and rock properties as parameters, graphs are plotted showing the optimum gas saturation and the increase in oil recovery brought about by the gas saturation. The effects of fluid properties and relative permeability on the optimum gas saturation are seen in these graphs. The graphs can be used as guides in connection with other considerations in determining the optimum time to start a waterflood. They should also be helpful in determining the MER of a water-drive reservoir.

OP 144-68. Comparison of Log and Core Analysis Results for an Extremely Heterogeneous Carbonate Reservoir, by L. C. Marchant and E. J. White. Trans. Soc. Professional Well Log Analysts, 9th Ann. Logging Symp., June 23-26, 1968, pp. L1-L16. Log and core analysis results for the Ratcliffe interval of the Madison Formation in Montana's Flat Lake oilfield were compared. Data for 79 wells were included in the study. In contrast to most published log-core analyses comparisons, which force porosity log response to match the corresponding core porosities, the log analyses in this study were relatively independent of the core analyses. The only core analysis data used in the log analyses were the matrix densities and modified residual oil saturations. Sonic and resistivity log porosities averaged 10 percent greater and 11 percent less, respectively, than the corresponding core porosities. Water saturations derived from both sonic and resistivity logs were consistently lower than the corresponding core residual water saturations.

OP 145-68. Mass Flowmeter Compensation, by J. R. McVey and R. D. Doebbling. Instruments and Control Systems, v. 41, No. 9, September 1968, p. 136. An automatic correction device that corrects for inaccuracies in mass flowmeters by determining percents of flow and that accumulates a predetermined error for these points is described.

OP 146-68. Optical Data Processing of Multispectral Photographs of Sedimentary Structures, by Howard J. Pincus and Syed A. Ali. J. Sedimentary Petrology, v. 38, No. 2, June 1968, pp. 457-461. Two-dimensional Fourier transforms (diffraction patterns) of photographs of the same specimen illuminated in five different ways provide a means for comparing the information so obtained. Faint cross-lamination in a specimen of Fairview limestone is best revealed by transmitted infrared radiation.

OP 147-68. Electric Paramagnetic Resonance of Coals During Electron Irradiation, by H. L. Retcofsky, A. G. Sharkey, Jr., and R. A. Friedel. Fuel, v. 46, No. 2, March 1967, pp. 109-114. Four vitrains from coals of different ranks were irradiated with 6 Mev electrons produced by a linear accelerator. Electron paramagnetic resonance (EPR) spectra were obtained at several intervals during and after the irradiation. Changes in EPR absorption as a result of sample irradiation indicated the presence of newly formed radical species in a lignite and a low-volatile bituminous coal. These new radicals persisted after the irradiation had ceased but proved to be short-lived species. Irradiation of a high-volatile A and a high-volatile C bituminous coal produced no detectable amounts of new radicals.

OP 148-68. Electron Spin Resonance in American Coals, by H. L. Retcofsky, J. M. Stark, and R. A. Friedel. Anal. Chem., v. 40, No. 11, September 1968, pp. 1699-1704. An electron spin resonance study of a coalification series consisting of samples of peat and lignitic, subbituminous, bituminous, and anthracitic coals was carried out as part of a continuing investigation of the chemistry and structure of coal. Concentrations of unpaired electrons, spectral linewidths, and g values were all found to vary smoothly with the rank of the coals with the exception of those for meta-anthracite which is known to be more highly electrically conducting than the other members of the series. The results are interpreted in terms of existing theories of coal metamorphosis and suggest that the unpaired electrons in coals are free radical electrons occurring in organic structures containing carbon, hydrogen, and oxygen.

OP 149-68. Carbon-13 Nuclear Magnetic Resonance Studies of 2-Substituted Pyridines, by H. L. Retcofsky and R. A. Friedel. J. Phys. Chem., v. 72, No. 7, July 1968, pp. 2619-2622. Carbon-13 magnetic resonance spectra of ten 2-substituted pyridines have been obtained and analyzed. Substituents included both electron-releasing and electron-withdrawing groups. Only half of the 50 carbon shieldings measured yielded substituent effects that agree, within experimental error, with those found for the corresponding monosubstituted benzenes. Differences between substituent effects on the ring carbons for the two series of compounds ranged from −4.5 to 21.1 ppm, where a positive sign means that replacement of the hydrogen atom in the 2-position of pyridine by a substituent leads to smaller paramagnetic shifts (or larger diamagnetic ones) than replacing a hydrogen atom in benzene with the same substituent. These differences were found to be most pronounced for the carbons in the 2-position and, for these carbons, to correlate well with the electronegativity of the first atom of the substituent group. Paramagnetic shifts for the C-2 carbons were found to be much smaller than expected in those cases where considerable quantities of electronic charge had been removed by strongly electronegative groups. Shieldings of the carbon atoms in the 5-position, *para* to the substituent, were found to reflect electron release or withdrawal by substituent groups. Substituent carbon atoms directly bonded to C-2 were all found to be less shielded than the corresponding ones in 3- and 4-substituted pyridines.

OP 150-68. A Chromatographic Procedure for Traces of Hydrogen in Pure Helium, by H. L. Rhodes. J. Gas Chromatography, v. 6, September 1968, pp. 488-490. An automatic process chromatograph procedure is presented for fast qualitative and quantitative analyses for trace qualities ($1 \leq 100$ ppm) of hydrogen in 99.995 percent (Grade A) helium. This unique method utilizes a single column twice, which alows effective addition of column length without loss of efficiency, and vents the major component. A conventional thermal conductivity detector and 1-millivolt potentiometric recorder are used to produce analyses with laboratory precision and sensitivity, about 100 ppm full scale.

OP 151-68. Clinton Sand Reservoir Study—A Progress Report, by Leo A. Schrider. Producers Monthly, v. 32, No. 7, July 1968, pp. 10, 12-14. In the evaluation of the waterflood potential of the Clinton sand, Hocking County, Ohio, it has become vividly clear that a better understanding of reservoir factors is vital. The effects of two of these factors, fluid saturation and fracture direction, are presented. A data retrieval and trend surface mapping technique was used to compile the large quantity of reservoir information. The usefulness and application of this data bank are discussed along with results of a trial test. Results of this research should be valuable to operators planning secondary-recovery operations in the Clinton sand reservoir in Ohio.

OP 152-68. High-Resolution Mass Spectrometric Investigation of Heteroatom Species in Coal Carbonization Products, by J. L. Shultz, T. Kessler, R. A. Friedel, and A. G. Sharkey, Jr. Proc. ASTM Committee E-14 Meeting, Pittsburgh, Pa., May 1968, pp. 359-361. Studies of the high-resolution mass spectra of complex mixtures indicate the power of this technique to detect species containing heteroatoms in highly aromatic matrices and to provide data relating compositional changes to chemical or physical properties. Coal-tar pitch, original and weathered road tars, and coke-oven pitches were investigated by the high-resolution mass spectromatic technique.

OP 153-68. Rock Matrix Properties of the Ratcliffe Interval (Madison Limestone), Flat Lake Field, Montana, by E. J. White, L. C. Marchant, and D. K. Roberts. Rocky Mountain Regional Meeting, SPE, AIME, Billings, Mont., June 5-7, 1968, SPE Preprint 2127, 13 pp. Correlations between porosity, permeability, saturation characteristics, mineral constituency, and pore geometry inferred from mercury injection measurements for a heterogeneous carbonate reservoir are discussed. The fluid flow properties of the reservoir are considered.

OP 154-68. Are Natural Resources Enough? by David Brooks. Mountain Life & Work, v. 45, No. 11, November 1968, pp. 3-6, 8. Natural resources alone cannot be relied on for economic growth in Appalachia unless they are combined with forces leading to a higher value for the product or to the provision of more inputs or greater circulation of generated income within the region.

OP 155-68. Mining and Mineral Recovery, by Michael J. Cruikshank. Ch. 11 in Undersea Technology Handbook Directory. Compass Publications, Inc., Arlington, Va., pp. A81-A90. This chapter presents, in summary and tabular form, the current activities in mining and mineral recovery from the oceans.

OP 156-68. The Magnesium-Titanium Phase Diagram to 1.0 Pct Titanium, by L. C. Fincher and D. H. Desy. Trans. Met. Soc., AIME, v. 242, No. 10, October 1968, pp. 2069-2073. The magnesium-rich end of the magnesium-titanium phase diagram was investigated. The solubility of titanium in magnesium ranged from 0.018 weight-percent Ti at 700° C (0.012 weight-percent at 650° C by extrapolation) to 1.035 weight-percent Ti at 1,500° C. The solidus for compositions ranging from 0.03 to 1.00 weight-percent Ti was determined to be 650° $\pm 1°$ C by thermal analysis. The titanium solid solubility values ranged from 0.08 weight-percent at 350° C to 0.19 weight-percent by extrapolation to 650° C. The freezing reaction is peritectic. No intermetallic compounds were found in the system; the phase in equilibrium with molten magnesium saturated with titanium was found to be titanium with magnesium in solid solution. Solid titanium will dissolve at least 1.32 weight-percent Mg.

OP 157-68. The Alkalized Alumina System for SO_2 Removal: Design and Operation of a Continuous Pilot Plant, by D. H. McCrea, J. H. Field, and E. R. Bauer, Jr. ASME Winter Ann. Meeting and Energy Systems Exposition, New York, December 1-5, 1968, Preprint 68-WA/FU-3, 9 pp. A process for removing sulfur oxides from hot flue gas by chemical sorption on a solid and recovery of the sulfur by reduction is described. Design and operation of a continuous pilot plant are discussed, and economic potential of the process is reviewed. Better than 90 percent of the sulfur oxides in the flue gas from the combustion of pulverized coal can be removed with less than 2-in H_2O pressure loss by sorbent entrained in the reactor. Prior removal of fly ash is not required. The solid is readily regenerated by reduction in a slowly moving packed bed.

OP 158-68. Shift Conversion of Synthesis Gas Containing Sulfur, Dust, and Carbon Dioxide, by M. W. Wilson and F. D. Plants. I&EC Process Design and Development, v. 7, No. 4, October 1968, pp. 526-529. Carbon monoxide in synthesis gas containing various sulfur compounds, dust, and carbon dioxide was converted over standard chromium-promoted iron catalyst at temperatures to 1,000° F, pressures to 300 psig, and space velocities (wet) to 5,000 v/v/hour. In 30-day continuous tests, CO conversions were lower than with purified gas over nonsulfided catalyst but were comparable when the residence time was increased by raising the pressure. Dust in the gas did not appear to decrease catalyst activity, but dust concentrations of 400 grains per 100 scf increased the pressure drop and reduced the gas flow through the converter. Conversions of CO were generally independent of type of sulfur in the gas. Space velocities are given for specified conversions of sulfur-laden gas at 900° F and 0, 100, 200, and 300 psig.

OP 159-68. Electroslag Melting of Titanium Slabs, by S. L. Ausmus and R. A. Beall. Internat. Trans. Vacuum Metall. Conf., 1967, 1968, pp. 675-694. Calcium fluoride has been proved to be an effective nonreactive flux for the electroslag process as applied to titanium. This investigation established that the production of slab-shaped titanium ingots by cold-mold electroslag melting requires more power and lower melting rates than conventional arc-melting techniques. Preliminary evaluation by chemical analysis indicated the electroslag melted titanium was equal to or slightly superior to conventional vacuum arc-melted materials. It may be possible to convert the electroslag melted titanium directly to sheet or plate and eliminate the necessity of the double melting now required for the conventional process.

OP 160-68. Analytical Uses of Energy Balances, by William A. Vogely. Proc. 7th World Power Conf., Moscow, Oct. 20-24, 1968, Sec. B, Paper 84, 15 pp. Energy balances call for energy requirements and sources expressed in commensurate units, usually heat. If these balances are complete, the flow of energy through the economy can be traced in such units, and the transformation functions of one form or source of energy to another can be specified. Thus, energy balances permit the analysis of the energy sector as a whole, rather than on a commodity by commodity basis, and, therefore, can be used analytically to answer a number of problems that would otherwise be beyond comprehensive analysis. In this paper, four such analytical uses are described, and examples are given.

OP 161-68. Retorting Ungraded Oil Shale as Related to In Situ Processing, by H. C. Carpenter, S. S. Tihen, and H. W. Sohns. Division of Petroleum, American Chemical Society, Preprints, v. 13, No. 2, April 1968, pp. F50-F57. In the study of retorting characteristics of large pieces of oil shale, charges ranging in grade from 26 to 48 gallons per ton have been processed with yields as high as 80 percent of Fischer assay.

OP 162-68. Fluorescent Dye Penetrants Applied to Rock Fractures, by R. D. Gardner and H. J. Pincus. Internat. J. Rock Mech. Min. Sci., v. 5, 1968, pp. 155-158. Under ultraviolet illumination, non-particulate fluorescent dye penetrants clearly mark the surface traces of fractures in minerals and rocks. The use of fluorescent penetrants has been effective in studying the development of fractures in rock specimens deformed in the laboratory.

This paper outlines the fluorescent penetrant method as used in a series of experiments concerned with studying the generation and propagation of extension fractures in flexed specimens of a porphyritic granite. Photographs taken before and after deformation are presented and from these the pattern of fracture development can be studied. Fracture traces down to 0.05 mm wide have been observed and photographed.

This technique is applicable to other rock types in a variety of laboratory situations, and its possible use in in situ studies is now being investigated.

OP 163-68. Effect of Pressure and Temperature on Flammability Limits of Chlorinated Hydrocarbons in Oxygen-Nitrogen and Nitrogen Tetroxide-Nitrogen Atmospheres, by J. M. Kuchta, A. L. Furno, A. Bartkowiak, and G. H. Martindill. J. Chem. and Eng. Data, v. 13, No. 3, July 1968, v. 421-428. Limit-of-flammability data were obtained in oxygen and nitrogen tetroxide atmospheres for several chlorinated hydrocarbons that are currently of interest as solvents in rocket and space flight applications. Flammability diagrams that define the complete range of flammable mixtures that can occur with the combustibles are presented for various mixture temperatures (25° to 200° C) and pressures (760 to 50 mm of Hg). Generally, the range of flammable compositions does not vary greatly with temperature or pressure if the vapor pressure of the combustible is not a limiting factor. The range of flammable mixtures for the combustibles is usually greater in oxygen-nitrogen than in nitrogen tetroxide-nitrogen atmospheres. The minimum oxidant concentrations required for flame propagation are much less in atmospheres containing oxygen and tend to increase with the number of substituted chlorine atoms in the combustible.

OP 164-68. Qualitative Applications of the NMR Spectra of Alkylpyridines: Part 1. Chemical Shifts of the Ring Protons. Part II. Chemical Shifts of the Protons of the Alkyl Substituents, by F. R. McDonald, A. W. Decora, and G. L. Cook. Appl. Spectroscopy, v. 22, No. 4, July-August 1968, pp. 325-336. Part I. Spectroscopic identification of pyridine compounds isolated from complex substances such as shale oil is greatly aided by NMR chemical-shift data on the pyridine-ring protons. Chemical shifts of the ring protons in CCl_4 and C_6H_6 solution and the differential shift of the protons in these two solvents are reported. A paramagnetic shift is observed in the directional character of the proton alpha to the nitrogen in the pyridine ring. These data are used to determine structural information from the spectrum of a mixture of pyridine homologs.

Part II. The NMR chemical shifts of protons on alkyl groups attached to pyridine rings are discussed. Data on 31 alkylpyridines are included. The spectra and tabulated differential shifts of 15 monosubstituted pyridines in CCl_4 and hexadeuterobenzene (B_6-d_6) are given; and the data on the chemical shifts and the differential shifts in the solvents CCl_4 and C_6H_6 or B_z-d_6 for the di-, tri-, and tetra-substituted pyridines are tabulated. A paramagnetic shift is noted for some protons on alkyl groups attached alpha to the pyridine nitrogen. The use of the data in a qualitative identification of two pyridine homologs is demonstrated on a fraction from shale oil.

OP 165-68. Vapor Pressure Relations of 13 Nitrogen Compounds Related to Petroleum, by Ann G. Osborn and Donald R. Douslin. J. Chem. and Eng. Data, v. 13, No. 4, October 1968, pp. 534-537. Compilations of vapor pressures measured by static and ebulliometric methods, covering four orders of magnitude in pressure, are given for key members of classes of pyrroles, pyridines, amines, piperidines, and pyrrolidine which were selected in a related project for a comprehensive study of their thermodynamic properties. Constants of the Antoine and Cox vapor pressure equations are provided to aid in interpolating or extrapolating the experimental results.

OP 166-68. Catalytic Dehydrogenation of Coal. III. Hydrogen Evolution as a Function of Rank, by L. Reggel, I. Wender, and R. Raymond. Fuel, v. 47, No. 5, September 1968, pp. 373-389. Catalytic dehydrogenation of vitrains from coals of various ranks is discussed in detail. Pure hydrogen gas is a valuable product.

OP 167-68. Predicting Gasoline-Storage Stability, by F. G. Schwartz, C. S. Allbright, and C. C. Ward. Oil and Gas J., v. 66, No. 46, Nov. 18, 1968, pp. 150-153. A test method is described for predicting the deterioration of gasoline during storage for either 32 weeks at 110° F or 5 years at ambient temperatures.

OP 168-68. Thermal Conductivity and Thermal Diffusivity of Green River Oil Shale, by S. S. Tihen, H. C. Carpenter, and H. W. Sohns. Proc. 7th Conf. on Thermal Conductivity. NBS Spec. Pub. 302, September 1968, pp. 529-535. This paper contains data on the thermal conductivities and thermal diffusivities of raw, retorted, and burned Green River oil shales of various grades at normal and elevated temperatures. An equation correlating these factors is presented.

OP 169-68. Combination Method for Predicting Waterflood Performance for Five-Spot Patterns in Stratified Reservoirs, by James A. Wasson and Leo A. Schreider. J. Petrol. Technol., v. 20, No. 10, October 1968, pp. 1195-1203. A method of predicting waterflood performance has been developed that combines certain facets of several previously published prediction techniques. The manner of combination has required the development and use of some new and little known relationships and has eliminated several of the weaker assumptions inherent in the original individual prediction methods. This approach, which was designed for computer solution, has removed the necessity of referring to plotted curves and permits the analytical prediction of waterflood performance for a five-spot well pattern in either homogeneous or stratified reservoirs. The predicted values are expressed in common oilfield units rather than in abstract or dimensionless terms. The calculation procedure has been programed in FORTRAN IV and the entire program listing is available to potential users.

OP 170-68. Flammability Characteristics of Combustible Gases and Vapors, by Michael G. Zabetakis. In Handbook of Laboratory Safety, ed. by N. V. Steere. Chemical Rubber Co., Cleveland, Ohio, 1967, pp. 140-163. This report gives a number of rules and graphs that can be used to predict the behavior of flammable mixtures at various temperatures and pressures.

OP 171-68. Differential Extraction of Rare-Earth Elements in Quaternary Ammonium Salt-Chelating Agent Systems, by D. J. Bauer and R. E. Lindstrom. Proc. 7th Rare-Earth Research Conf., v. 1, October 1968, pp. 413-423. Solvent extraction studies utilizing quaternary ammonium compound-chelating agent systems resulted in superior adjacent rare-earth element separation factors. Samarium oxide of 99-percent purity was produced in a 20-stage sequence.

OP 172-68. Alkalized Alumina Process, by Sidney Katell. Air Pollution Control Conf., University of Missouri, Columbia, Mo., Nov. 19, 1968, Preprints, pp. F1-F2. The alkalized alumina system for the removal of sulfur dioxide from powerplant flue gases is currently in the pilot plant stage at the Bureau of Mines Coal Research Center at Bruceton, Pa. A description is made of this installation together with some of the data attained to date. The economics for applying this system to an intercommercial installation is briefly described.

OP 173-68. Infrared Spectral Observations for a Series of Mono- and Dialkylacetylenes, by R. F. Kendall. Spectrochim. Acta, v. 24A, No. 11, November 1968, pp. 1839-1845. Infrared spectra determined on a series of straight-chain alkylacetylenes revealed absorption bands previously unreported. The wave number positions observed for these bands answer some of the questions posed by earlier workers regarding the molecular spectra of actylenic hydrocarbons. Structural correlations of potential analytical application are discussed.

OP 174-68. Preparation of Rare-Earth and Yttrium Metals by Electrodeposition and Vacuum Distillation of Alloys, by E. Morrice, J. E. Murphy, and M. M. Wong. Proc. 7th Rare-Earth Research Conf., October 1968, v. 2, pp. 485-498. Gadolinium, dysprosium, and yttrium are difficult to electrowin as high-purity liquid metals because of their high melting points ($>$1,300° C). Samarium metal is difficult to prepare directly by electrolysis because the metal reacts with the electrolyte. In this study, the rare-earth metal was electrodeposited on a solid manganese, chromium, or iron cathode to form a low-melting alloy. The alloy was then vacuum distilled to yield the rare-earth metal. A typical samarium metal product, obtained as the distillate from vacuum distillation of a samarium-iron alloy, contained 150 ppm oxygen, 80 ppm carbon, and 50 ppm iron as impurities. Gadolinium metal, obtained as a residue from the distillation of a gadolinium-chromium alloy, contained in ppm, 300 oxygen, 200 carbon, and less than 100 chromium.

OP 175-68. A Rotatable Microscope Slide Ring Holder for Petrographic Analysis, by R. J. Willard. Mineralogical Magazine, v. 36, No. 282, June 1968, pp. 888-890. A ring holder device is described for use as an accessory with a petrographic microscope. The device permits traversing of a thin section of uncommon dimensions in any chosen direction.

OP 176-68. Fifty Years of Petroleum Chemistry at the Bartlesville Petroleum Research Center, by John S. Ball. Division of Petroleum Chemistry, American Chemical Society, Preprints, v. 13, No. 3, August 1968, pp. 210-215. The Bartlesville Petroleum Research Center, established 50 years ago, has made important contributions to petroleum chemistry in the fields of analysis, composition, thermodynamics, and geochemistry.

OP 177-68. Comparison (1958-63) Producing Technologies and Expenses in U.S. Petroleum Industry, by Richard F. Zaffarano. Producers Monthly, v. 32, No. 5, May 1968, pp. 8-9. Analysis of estimates of direct operating expenses for materials, supplies, and repair parts consumed in the leased production of crude oil and natural gas in the United States (1958-63) indicated slight shifts have occurred within selected categories of input requirements. This article identifies and briefly discusses the technology used to improve production efficiency. In addition a method is described which, although not new, was used to develop estimates of operating expenses needed for a national study.

OP 178-68. Electroslag Melting of Titanium Slabs, by S. L. Ausmus and R. A. Beall. Trans. Internat. Vacuum Metallurgy Conf., June 1967, New York, 1968, pp. 675-694. (For summary see OP 159-68.)

OP 179-68. High-Speed Solenoid Valve Control Circuit, by Merle L. Bowser. Instruments and Control Systems, v. 41, July 1968, pp. 93-94. An electronic circuit is described that is used to control rapid activation of solenoid valves by a deliberate overvoltage. A timing circuit is also described that controls the time sequence of operation of two valves.

OP 180-68. Application of Aboveground Retorting Variables to In Situ Oil Shale Processing, by Harry C. Carpenter and Harold W. Sohns. Colorado Sch. Mines Quart., v. 63, No. 4, October 1968, pp. 71-82. In the study of retorting characteristics of large pieces of oil shale, charges ranging in grade from 26 to 48 gallons per ton have been processed with yields as high as 80.8 percent of Fischer assay. Linear models relating to retorting variables were developed.

OP 181-68. An Inverse GLC Study of Asphalts Used in the Zaca-Wigmore Experimental Road Test, by T. C. Davis and J. C. Petersen. Proc. Ann. Meeting Assoc. Asphalt Paving Technologists, Feb. 13-15, 1967, Denver, Colo., v. 36, 1968, pp. 1-14. Inverse gas-liquid chromatography (GLC) was used to study asphalts evaluated in the Zaca-Wigmore Experimental Road Test. The retention behavior of a number of test compounds was determined on the asphalts both before and after oxidation within the GLC column. The retention behavior of the test compound phenol on the oxidized asphalts correlated with the performance of the asphalts in road service, and this was further supported by a similar correlation with accelerated weathering durabilities of coating-grade asphalts. The phenol test compound retention data on the oxidized road asphalts were also found to relate to changes in viscosity as measured by the microfilm durability test. Because test compound retention behavior is related to chemical composition and molecular association forces of the asphalt, the correlation with performance affirms the importance of chemical composition to asphalt performance on the road.

OP 182-68. Mobile Combustion Sources, by R. W. Hurn. Ch. 33, pt. 7, in Sources of Air Pollution and Their Control. Air Pollution, ed. by A. C. Stern. Academic Press, Inc., New York, rev. 2d ed., v. 3, 1968, pp. 55-95. The automobile is identified as the principal source of pollutants in the mobile category. Emissions from this source are discussed with regard to origin within the vehicle, the nature of pollutants discharged, and technical measures being taken to decrease and control the discharge of these pollutants at acceptable levels.

OP 183-68. An Improved Method for Separating Copper and Steel From Copper-Containing Ferrous Scrap, by Vance G. Leak and M. M. Fine. Secondary Raw Materials, v. 6, No. 7, July 1968, pp. 27-29. A method of separating copper from copper-containing ferrous scrap consists of immersing the scrap in a heated (1,200° C) bath of molten salt or slag. The copper melts and collects at the bottom of the vessel from which it may be periodically withdrawn. The function of the molten bath is to prevent oxidation of the metals and to improve heat transfer.

OP 184-68. Timing Mark Counter, by I. Liebman, J. Corry, and H. E. Perlee. Rev. Sci. Instr., v. 39, No. 10, October 1968, pp. 1591-1593. A simple optical device has been developed for automatically counting time marks on motion picture film at a maximum rate of 300 counts per minute. This device enables one to scan extensive film records quickly without having to manually count and record the timing marks.

OP 185-68. Limestone Neutralization—A Low Cost and Effective Treatment for Acid Mine Waters, by E. A. Mihok and Maurice Deul. Coal Age, v. 73, No. 12, December 1968, pp. 65-70. A method was devised to use wet autogenous grinding of coarse limestone to generate a slurry of limestone fines to treat any desired quantity of acid mine water. The process as finally developed consists of (1) producing a very fine (minus 400-mesh) limestone slurry; (2) mixing the slurry with mine water; (3) aerating the resulting mixture to remove carbon dioxide and precipitate iron; and (4) separating the solids from the liquid by sedimentation. The limestone process has inherent advantages over the conventional lime process; namely, lower cost, widely available raw material, simplicity in design and operation, and much smaller volume of precipitated solids.

OP 186-68. The Effect of Time and Depth of Burial on the Naphtha and Gas Oil Content of Crude Oil, by Harold M. Smith. Proc. Oklahoma Acad. Sci., v. 47, 1968, pp. 195-205. The amounts of naphtha and gas oil fractions in more than 6,000 crude oils were correlated with depth and geologic age of the producing formation.

OP 187-68. Direct Steelmaking With Prereduced Iron Ore in an Electric Arc Furnace, by H. A. Tucker, F. X. Tartaron, H. L. Goldstein, and J. J. Kociscin. Blast Furnace and Steel Plant, v. 56, December 1968, pp. 1070-1084. Experimental steelmaking heats were conducted to simulate commercial, single-slag, basic electric furnace practice for carbon steel production. The furnace burdens were 75 percent prereduced materials and 25 percent scrap, or 25 percent pig iron. Several comparative all-scrap tests were made. The procedure and data are given in two sections, one dealing with the batch melting of prereduced iron ore briquets and the other with the continuous feeding and melting of prereduced iron ore powder, both using a 1-ton electric arc furnace. Prereduced iron ore, in either briquet or powder form, can be melted and refined to a high-quality steel in an electric arc furnace.

OP 188-68. Finite Element Model Study of Slope Modification at the Kimbley Pit, by Wilson Blake. Trans. Soc. Min. Eng., AIME, v. 241, December 1968, pp. 525-534. A mathematical model based on the finite element method of stress analysis has been used to describe the behavior of the western wall of the Kimbley pit as its slope was steepened from 45° to 57°. Theoretical stress changes because of slope modification are slight except at the toe of the modified slope. Magnitudes of stress created are small when compared with the strength of a competent rock. Resulting displacement patterns point out the need for determining the in situ state of stress at a site prior to excavation or modification. A comparison of model results with field measurements shows that, in general, the model has described the measured behavior of the west wall of the Kimbley pit remarkably well.

OP 189-68. Fly Ash Utilization—Problems and Prospects, by John H. Faber. Proc. Symp. Mineral Waste Utilization, Mar. 27-28, 1968, Chicago, Ill., 1968, pp. 99-107. Fly ash has a future as a valuable raw material instead of a solid waste from power generating stations. The properties, availability, and present and future uses for this commodity are discussed, uses that include fly ash use in concrete, bituminous concrete filler, lightweight aggregate, soil stabilization, agricultural applications, and new building materials.

OP 190-68. Bureau Contribution to Slope Angle Research at the Kimbley Pit, Ely, Nevada, by Robert H. Merrill. Trans. Soc. Min. Eng., AIME, v. 241, December 1968, pp. 513-525. In 1960 the Kennecott Copper Corp. and the Bureau of Mines began a joint research program to determine the changes in stress, strain, and displacement created by changes in slope angles. The field site was the Kimbley pit near Ely, Nev. A new slope angle and pit configuration was selected and instruments were installed to measure changes in stress, strain, displacement, microseismic noise rate, and sonic velocities in the west wall of the pit. Between February and November 1966 the west slope was changed from an average angle of 45° to a slope angle that started at 45° on the south wall and gradually increased to 57½° at the center of the west wall and to 61° on the north wall. The pit was deepened from 500 feet to about 550 feet. Measurements made between November 1965 and September 1967 showed that the pit wall was stable before the excavation began, that changes in the measured quantities occurred in the pit wall during excavation, and that the wall returned to a condition of equilibrium after the mining was completed.

OP 191-68. The Interpretation of Heat Capacity Measurements Through Two-Component Liquid-Liquid Critical Regions, by Robert E. Barieau. J. Phys. Chem., v. 72, No. 12, November 1968, pp. 4079-4081. The heat capacity, per mole, at constant volume and constant number of moles of a two-component, three-phase (two liquid phases and a vapor phase) system is given by $C_v(3 \text{ phases}) = -u_1 T(d^2\bar{G}_1/dT^2) - (1 - u_1)T(d^2\bar{G}_2/dT^2) + (V_T/n)T(d^2P/dT^2)$, where u_1 is the filling mole fraction of component 1, V_T is the total volume, and n is the total number of moles. $\bar{G}_1$ and $\bar{G}_2$ are partial molal Gibbs free energies or chemical potentials of components 1 and 2, respectively. The above equation is derived and it is shown how heat capacity measurements can be determined so that the three quantities $d^2\bar{G}_1/dT^2$, $d^2\bar{G}_2/dT^2$, and d^2P/dT^2 can be calculated from the measurements.

OP 192-68. Delayed Coking of Low-Temperature Lignite Pitch, by John S. Berber, Richard L. Rice, and Robert L. Lynch. I&EC Product Research and Development, v. 7, No. 4, December 1968, pp. 270-274. Delayed coking of a Texas lignite pitch was investigated over a temperature range of 800° to 1,200° F. An evaluation of the three products, coke, gas, and oil, is described. The effect of coking temperature was of major interest. As expected, an increase in coking temperature increased the yield of coke and gas and decreased the oil yield.

OP 193-68. Spectroscopic Identification of Basic Nitrogen Compounds in Wilmington Petroleum, by C. F. Brandenburg and D. R. Latham. J. Chem. and Eng. Data, v. 13, No. 3, July 1968, pp. 391-394. A study of the basic nitrogen compounds in Wilmington (Calif.) petroleum fractions has produced considerable information on their composition. Characterization of the classes of basic nitrogen compounds in the 130° to 350° C distillate fractions was made by low-voltage mass spectral analyses. Two individual compounds—an alkyl-substituted cyclopentapyrindan and an alkylcycloalkyl-substituted pyridine—were separated and identified. Procedures used to separate the compounds from the oil included distillation, mineral acid extraction, and gas-liquid chromatography. The identifications were made by a combination of mass, infrared, ultraviolet, and nuclear magnetic resonance spectrometry.

OP 194-68. Mineral Economics and the Ocean, by David B. Brooks and Barbara S. Loyd. Proc. Symp. on Mineral Resources of the World Ocean, sponsored by Geological Survey, University of Rhode Island, and U.S. Navy, July 11-12, 1968, Newport, R.I., Occasional Pub. 4, 1968, pp. 23-30. Reviews the economic setting for possible development of ocean non-fuel mineral resources.

OP 195-68. X-Ray Fluorescent Analysis of Beryllium for Vanadium Through Copper in the Periodic Table, by L. Carpenter, J. M. Nishi, and R. H. Fehler. Appl. Spectroscopy, v. 20, No. 6, November-December 1966, pp. 359-362. Elements in the periodic table from atomic number 23 through 29, vanadium through copper, were determined from 0.0025 to 10.00 percent in beryllium metal and compounds convertible to beryllium oxide. Metal samples were dissolved in hydrochloric acid, evaporated to dryness, and oxidized at 900° C. The beryllium oxide was combined in equal portions with boric acid and pelletized. A fixed time-variable count method was used to obtain values for establishing analytical curves from which concentrations of samples were read.

OP 196-68. Petroleum Hydrocarbons Formed by Irradiation of a Simulated Sediment, by James W. Davis and Robert T. Johansen. Preprints, Div. of Petrol. Chem., Am. Chem. Soc., Symp. on Hydrocarbons From Living Organisms and Recent Sediments, v. 13, No. 4, September 1968, pp. B26-B31. A geochemical investigation by the Bureau of Mines provided information and data that tend to support the hypothesis that petroleum is formed by irradiation of ancient organic detritus intermixed with radioactive mineral. Simulated sediments containing either siliceous, calcareous, or clay minerals and a probable petroleum precursor were exposed to external gamma radiation. The resulting gaseous products of the mixtures were analyzed and compared as to chemical entity and quantity of each with those from identical irradiation of the precursor alone. Irradiating a mixture of calcareous mineral, precursor (behenic acid), and water produced three times the quantity of gaseous hydrocarbon obtained when only the precursor was irradiated. An irradiated mixture containing bentonite, precursor, and water produced similar results but 70- to 100-mesh silica plus precursor and water similarly treated formed less hydrocarbon. However, an irradiated mixture of 3.9 m^2g^{-1} surface area silica, prepared with the fatty acid covering each silica particle to a theoretical thickness of 1 molecular layer, produced a tenfold increase in methane over the precursor treatment.

OP 197-68. Use of Carbonic Acid To Concentrate Kerogen in Oil Shale, by Rex D. Thomas. Preprints, 155th Nat. Meeting, Div. of Fuel Chem., Am. Chem. Soc., Symp. on Oil Shale, Tar Sands, and Related Material, Mar. 31-Apr. 5, 1968, v. 12, No. 1, March 1968, pp. F111-F116. A new method of concentration of the organic material using carbonic acid was investigated. Carbonic acid was selected because it dissolves the major mineral constituents (carbonates), yet should not attack the organic material. Centrifuging the treated oil shale gives a high yield of organic material.

OP 198-68. Abandoned and Scrap Automobiles, by William A. Vogely. Proc. Surgeon General's Conf. on Solid Waste Management for Metropolitan Washington. Public Health Service, U.S. Department of Health, Education, and Welfare, Washington, D.C., July 19-20, 1967, pp. 51-60. The Bureau of Mines made a survey of the auto wrecking industry and published the results in 1965. This report summarizes the findings of this survey and its application to the problems of solid waste disposal in the United States.

OP 199-68. Cost Evaluation Techniques Applied to Mineral Resource Planning, by William A. Vogely. Proc. Am. Assoc. Cost Eng., Houston, Tex., June

17-19, 1968, pp. 8-1 through 8-14. Cost evaluation techniques have become an integral tool for mineral resource planning within the Bureau of Mines. This development has occurred within the past 18 months as a result of several factors. First, a strategic planning system has been designed and placed into operation by the Bureau. Implicit in such a system are forecasts of demand, resource supply, and technology, all of which involve cost evaluation. Second, the programing, planning, and budgeting system initiated within the Department of the Interior require quantification of the costs and benefits of programs. Such quantification in the case of mineral resource projects requires cost evaluation techniques. Third, with respect to application of U.S. mining and mineral leasing laws, costs are becoming important from the point of view of legality of mining claims and with respect to determining the proper user charges under the mineral leasing acts. A commodity profile of aluminum, attached as an appendix to the paper, gives an example of the information that must be acquired about a mineral commodity in order to apply cost evaluation techniques.

OP 200-68. The Economic Factors of Mineral Waste Utilization, by William A. Vogely. Proc. Symp. Mineral Waste Utilization, Chicago, Ill., Mar. 27-28, 1968, pp. 7-19. The economic forces which lead to the generation of waste and the organization of markets and their impact upon waste are examined. Some areas where, without damage to our technologic and economic efficiency, greater utilization of minerals can be achieved in the interest of conservation are identified, and the problem of social cost of waste generation is explored. The first part of the report concerns the solid wastes which are generated as part of the process of mining the mineral and transforming it into finished goods of some character. The second part has to do with the minerals that can be recovered from scrap metal.

OP 201-68. Measuring the Benefits of Minerals Research, by William A. Vogely. Proc. Council of Economics, AIME, Los Angeles, Calif., Feb. 19-23, 1967, pp. 29-38. The planning, programing, and budgeting system being initiated within the Department of the Interior requires explicit analysis of alternatives in arriving at proposed programs. The planning system being established in the Bureau of Mines approaches this problem by the application of what might be called "framework criteria" to arrive at a schedule of acceptable research projects. A cost-benefit analysis to the degree possible must be conducted to aid in establishing proposed programs. The outline of a usable system of measuring the benefits of research is presented, with some discussion as to how the measurements are derived. An appendix outlines a successful research project on recovery of scrap mica which was accepted by industry.

OP 202-68. Models of All-Gas and All-Electric Economies, by William A. Vogely. Ch. in Energy: Proc. 7th Biennial Gas Dynamics Symp., Northwestern Univ., Aug. 23-27, 1967, Evanston, Ill., 1968, pp. 63-82. Ten contingency models of the energy economy were developed. A conventional model, reporting the actual 1966 situation and a probability forecast for 1980 and 2000, was the starting point of the analysis. Three all-gas models and six all-electric models were derived. The most efficient, in resource use sense, was the all-gas model utilizing small hydrocarbon air fuel cells for onsite generation of electrical power. The least efficient were oil-fired central generating plants with all energy used in the form of electricity. Of course, the actual energy mix in the future will be determined by economic factors, not absolute efficiency criteria.

OP 203-68. Technological Change in the Markets for Bituminous Coal, by William A. Vogely. Proc. Illinois Mining Institute Annual Meeting, Springfield, Ill., Nov. 15, 1965, pp. 99-101. Technological change in the markets for bituminous coal is the major contributor to the shifts in those consuming industries. Coal's share of the energy market has declined in all areas except electric utilities, and its hope of increasing its market will depend on major technological breakthroughs.

OP 204-68. Basic Minerals (Mineral Industry Faces a Critical Year), by William A. Vogely and Barbara Lloyd. Chem. and Eng. News, v. 44, No. 36, Sept. 5, 1966, pp. 44A-48A. In 1966 there will be heavy demand for minerals because of a high level of demand for consumer goods, the needs of the military, and the growing requirements for mineral products to make the machinery needed for the domestic capital expansion program. Government activities in the mineral industry have had mixed success in stabilizing prices, restricting product demand, and assuring adequate supplies. The mineral industry is in turmoil because of changing technology and the ever-present concern with pollution.

OP 205-68. Patterns of U.S. Energy Consumption to 1980, by William A. Vogely and Warren E. Morrison. IEEE Spectrum, v. 4, No. 9, September 1967, pp. 81-86. The total consumption of energy in the United States in the year 1980 is expected to be equivalent to 93 x 10^{18} joules or 63 percent greater than in 1965. Coal consumption in 1980 is projected at 612 to 677 million tons, natural gas at 696 billion cubic meters, and petroleum products demand at 899 million tons. Nuclear power generation will be 723 million Mwh; conventional fuel-burning plants will provide up to 1,941 million Mwh of energy.

OP 206-68. Pattern of Energy Consumption in the United States, 1947 to 1965 and 1980 Projected, by William A. Vogely and Warren E. Morrison. World Power Conf., Tokyo Sectional Meeting, Oct. 16-20, 1966, Paper 83, 24 pp. Based on preliminary data for 1965, the total national consumption of energy was equivalent to 13,639 trillion kilogram calories, almost two-thirds greater than consumption in 1947. For the next 15 years it is anticipated that increasing quantities of energy will be needed for the expanding economy. In the forecast made for this paper, total consumption of energy in the United States in the year 1980 is expected to be equivalent to 22,196 trillion kilogram calories, or 63 percent greater than in 1965. Coal consumption in 1980 is projected at 677 million metric tons, natural gas at 696 billion cubic meters, and petroleum products demand, including natural gas liquids, at 809 million metric tons. Net generation of utility electricity in the forecast year is projected at 2,739 billion kilowatt-hours.

OP 1-69. The Hannay Diamonds, by E. P. Flint. Chem. and Ind., No. 47, Nov. 23, 1968, pp. 1618-1627. A review is given of the history of the diamond specimens presented to the British Museum, London, by James B. Hannay in 1880. Evidence is presented which indicates that the specimens may be of synthetic origin as claimed by Hannay.

OP 2-69. Thermochemistry of Ethylenimine and Some Diamines, by W. D. Good, H. L. Finke, J. F. Messerly, G. B. Guthrie, R. H. Harrison, and D. R. Douslin. Proc. Thermochemistry Working Group Symp., Douglas Advanced Research Laboratory, Mar. 25-27, 1968, Huntington Beach, Calif., CPIA Pub 173, August 1968, pp. 81-91. A comprehensive study of the chemical thermodynamic properties of ethylenimine and determination of the enthalpies of formation of four diamines was carried out by means of oxygen-bomb calorimetry, low-temperature calorimetry, and vapor-pressure measurements.

OP 3-69. Quick Way To Find Reservoir Pressure Distribution, by R. V. Higgins and A. J. Leighton. Oil and Gas J., v. 67, No. 1, Jan. 6, 1969, pp. 67-70. A time-saving electronic computer method to find pressure distribution between wells for various well patterns has been developed by Bureau of Mines engineers.

OP 4-69. Cohesion Index of Coal for Gravity Flow Through Orifices, by W. R. Huff. Combustion, v. 40, No. 2, August 1968, pp. 28-30. Cohesion indices and packed bed densities are extremely important factors in predicting the behavior of solids flowing from storage to use through orifices. These factors were determined for lignite, high-volatile A bituminous coal, and anthracite of different sizes and total moisture concentrations. Indices for lignite and bituminous coal generally increased and packed bed densities decreased with increase in total moisture content; in the case of anthracite, neither factor changed significantly. Indices for lignite and bituminous coal increased with increase in particle size; for anthracite, the index decreased. Packed bed densities for bituminous coal and anthracite were higher for larger particles; for lignite they decreased.

OP 5-69. Preparation of Cobalt-Rare-Earth Alloys by Electrolysis, by E. Morrice, E. S. Shedd, M. M. Wong, and T. A. Henrie. J. Metals, v. 21, No. 1, January 1969, pp. 34-37. An electrolytic method for preparation of alloys of cobalt and various rare-earth metals is described. The method consisted of electrowinning rare-earth metal from its oxide in a fluoride electrolyte using a consumable cobalt cathode. As the temperature of operation was above the melting point of the eutectic formed between the cobalt and rare earth, the alloy dripped off the cathode and was collected on a skull of frozen electrolyte in the bottom of the cell. The rare-earth content of the product was in the range of 64 to 89 weight-percent.

OP 6-69. Cycles for Generation of Electricity From Coal, by Harry Perry, James McGee, and Donald Strimbeck. Combustion, v. 40, No. 6, December 1968, pp. 25-36. Further economic increases in electric generating efficiency of the conventional coal-burning steam powerplant are presently impossible. This, plus competition from nuclear power and air and thermal water pollution, leads to new power schemes.

Some methods for converting coal to electricity, in light of their promise for increased efficiency and reliability, reduced air and thermal water pollution, and solvable development problems, may be practical before 1980. These are (1) an improved Rankine cycle, either from metals permitting increased steam temperatures or from new working fluids replacing steam or permitting topping of the steam cycle; (2) cycles combining high-temperature gas turbines with the steam plant, fueled by gas made from coal and cleaned of fly ash and sulfur; and (3) the magneto-hydrodynamic-steam combined cycle. Thermoelectric and thermionic generators are considered too inefficient and impractical for large-scale plants. Fuel cells may be efficient, but presently appear unsuited for large plants. Many questions about electrogas dynamics must be answered before it can be reasonably evaluated.

OP 7-69. Oil Shale Utilization—When and How? by J. Wade Watkins. Western Oil Reporter, v. 24, No. 7, July 1967, pp. 18-22. Technology is available to produce shale oil from Green River oil shale by conventional mining, crushing, and retorting methods. The economics of shale oil production, however, have not been demonstrated to be favorable. Research on in situ retorting is yielding promising results, but this method has not been demonstrated to be technically feasible on a large scale. The present level of effort by both Government and industry, the five-point oil-shale development program of the Department of the Interior, and other considerations lead to the conclusion that there will be some commercial production of shale oil by 1980 and that production may be appreciable by the end of the century.

OP 8-69. Summary of Oil Shale Activity, by J. Wade Watkins. Internat. Oil Scouts Assoc., v. 7, No. 9, September 1967, 5 pp. Oil shale technical activities can be divided into the following major areas: Surface retorting research, in situ retorting research, characterization studies, and mineral extraction. Past and present activities in each of these areas are briefly reviewed, and a discussion on oil shale's future emphasizes the technical problems.

OP 9-69. Scanning Electron Microscope, by Robert J. Willard. Geotimes, v. 13, No. 7, September 1968, pp. 16-18. The scanning electron microscope (SEM) is described briefly and compared with light and transmission electron microscopes. A portion of a thermally spalled surface of quartzite is shown in a series of micrographs at several levels of magnification to illustrate the microscope's role in rock disintegration research at the Twin Cities Mining Research Center.

OP 10-69. Electrowinning of Beryllium, by M. M. Wong, D. E. Couch, and D. A. O'Keefe. J. Metals, v. 21, No. 1, January 1969, pp. 43-45. Beryllium metal of approximately 99-percent purity was produced by electrolysis of BeO (beryllium oxide) in a fluoride mixture at 700° C with an applied voltage of 2.6 v. The deposited metal and salt were subsequently heated to 1,300° C in an induction furnace. Beryllium metal was coalesced and recovered as spheres from 1 to 10 mm in diameter.

OP 11-69. Reactions of Coal and Related Materials in Microwave Discharges in Hydrogen, Water Vapour, and Argon, by Yuan C. Fu and Bernard D. Blaustein. Fuel, v. 47, No. 6, November 1968, pp. 463-474. In a microwave discharge in hydrogen, water vapor, or argon, coal produces gaseous products such as acetylene, methane, and carbon oxides, in addition to tar and residual char.

OP 12-69. Electrostatic Distortion of Ion Beam Eliminated by Metal Coating Fluorocarbon Valve Seats, by A. Visnapuu and J. W. Jensen. Rev. Sci. Instr., v. 39, No. 12, December 1968, p. 1963. This note reports the successful elimination of an ion beam instability in a mass spectrometer by depositing a conductive coating on a Teflon valve seat.

OP 13-69. Silicate Reactions—A Review, by A. Gene Collins and L. R. Fisher. Office of Saline Water, R&D Progress Rept. 307, 1969, 99 pp. This review contains short discussions and annotated bibliographies of subjects relating to silicate reactions: Methods of analyzing silicates, buffering in aqueous solutions, diagenesis and weathering, hydrothermal reactions in nonsaline and saline aqueous media, and corrosion prevention. An author index is included.

OP 14-69. New Approaches to Solid Mineral Wastes, by K. C. Dean, H. Dolezal, and R. Havens. Min. Eng., v. 21, No. 3, March 1969, pp. 59-62. Use or stabilization of mineral wastes comprises the only viable means for minimizing pollution from them. Utilization of the wastes is preferable to stabilization, because it both eliminates waste and broadens the mineral resource base, and some methods of utilization are summarized. However, the bulk of the solid wastes comprises immense tonnages of discarded materials that rarely can be of any further use. Physical, chemical, vegetative, and combination methods are practical stabilization procedures for existing wastes, and some of these methods are described.

OP 15-69. Reactivity of AN-FO Mixtures With Pyrite-Bearing Ores, by D. R. Forshey, T. C. Ruhe, and C. M. Mason. Min. Cong. J., v. 55, No. 1, January 1969, pp. 34-35. To determine the extent of self-heating between AN-FO and sulfide ores, the Explosives Research Center of the Bureau of Mines studied the reactivity of AN-FO with a number of samples of pyrite-bearing ores, using a differential thermal analysis and experimental simulation of borehole conditions that might be experienced in the AN-FO charge.

OP 16-69. Mechanisms Relevant to the Initiation of Low-Velocity Detonations, by J. E. Hay and Richard R. Watson. Ann. New York Acad. Sci., v. 152, Art. 1, Oct. 28, 1968, pp. 621-635. The fundamental mechanism pertaining to low-velocity detonations in liquid explosives is described; methods and means for elucidating the role of cavitational phenomena in the low-velocitv detonation regime are presented.

OP 17-69. Evaluation of the Factors Affecting the Performance of a Peripheral Waterflood, by Freddie J. Hensley. Thesis, Univ. Tulsa, 1968, 128 pp. Four waterflood tests were made on the heterogeneous flank model at the University of Tulsa to study factors affecting peripheral waterflood performance.

OP 18-69. Vapor-Flow Calorimetry, by John P. McCullough and Guy Waddington. Ch. 10 in Experimental Thermodynamics, v. I, Calorimetry of Non-Reacting Systems. Butterworths and Co., Ltd., London, 1968, pp. 369-394. Methods of semiadiabatic vapor flow calorimetry are described for the accurate determination of vapor heat capacity in the temperature range from ambient to 250° C and pressure range from 1/8 to 2 atmospheres.

OP 19-69. Separation of the Neon Isotopes by Cryogenic Chromatography, by A. Purer, R. L. Kaplan, and D. R. Smith. Advances in Chromatography 1969, ed. by A. Zlatkis. Preston Technical Abstracts Co., v. 5, 1969, pp. 57-60. The separation of the neon isotopes was achieved by utilizing a soft-glass capillary column with an etched internal surface, operating at cryogenic temperatures, with a mixed carrier gas.

OP 20-69. A Wedge Technique for Evaluation of Detonation Hazards of Liquid Explosives, by John Ribovich. Ann. New York Acad. Sci., v. 152, Art. 1, Oct. 28, 1968, pp. 766-772. A technique is described that permits the evaluation of the detonation propagation characteristics of liquid explosives and liquid explosive systems. The thicknesses, that are related to sensitivity of the materials, at which transition from high- to low-velocity and, in some cases, from low- to high-velocity detonations as well as propagation failures are determined. This information, when correlated with card-gap and projectile impact sensitivity measurements, provides a stronger insight into the hazards involved in the manufacture, handling, and use of energetic liquid systems.

OP 21-69. A Case History of Two Steam-Injection Pilot Tests in Pennsylvania, by T. E. Sterner and G. G. Campbell. Producers Monthly, v. 32, No. 10, October 1968, pp. 10-14. Continuous steam-injection pilot tests were conducted in the Triumph field, Warren County, Pa., and the Shamburg field, Venango County, Pa., during 1965-66 by Miami Oil Producers, Inc., of Abilene, Tex. The object horizon in both tests was the Venango Third sand. Steam was injected in wells on the Dennis Run lease (Triumph field) from April 29 to November 15, 1965. The project was then converted to hot-water injection which was terminated on January 31, 1966. Steam was injected in wells on the Foggan lease (Shamburg field) from May 18, 1965, until March 3, 1966. During the injection, the generator was off the line 14 percent of the time. In the last 72 days of operation the steam generated was seldom above 40 percent quality. The slight increase in oil production in these test sites could not be attributed to steam injection.

OP 22-69. Checks and Balances of a Helium Pipe Line System, by A. H. Taquard. Pipe Line Industry, v. 30, No. 2, February 1969, pp. 31-33. A pipeline system materials balance and control chart and statistical tests have been beneficial to the Helium Activity in noting the performance of the measurement of crude helium.

OP 23-69. Large-Scale Investigations of Sympathetic Detonation, by Robert W. Van Dolah. Ann. New York Acad. Sci., v. 152, Art. 1, Oct. 28, 1968, pp. 792-801. The widespread use of ammonium nitrate-fuel oil as a commercial blasting agent and its common association with very large stocks of raw ammonium nitrate stimulated an investigation into the problem of sympathetic detonation of these materials. Large charges (between 200 and 5,400 pounds AN-FO fired against AN, AN-FO, or dynamite acceptor charges of 1,600 to 5,000 pounds) were sympathetically initiated over air gaps as large as 4 to 8 charge diameters for AN and as large as about 30 charge diameters for AN-FO. The data developed in this program are used in tables of safe separation distances for AN and AN-FO.

OP 24-69. Adiabatic Low-Temperature Calorimetry, by Edgar F. Westrum, George T. Furukawa, and John P. McCullough. Experimental Thermodynamics, ch. 5, in v. I, Calorimetry of Non-Reacting Systems, ed. by J. P. McCullough and D. W. Scott. Butterworths and Co., Ltd., London, 1968, pp. 136-217. Methods of adiabatic low-temperature calorimetry are described for accurate determination of heat capacities, heats of transition, transition temperatures, and third law entropies.

OP 25-69. Microstructural Techniques in the Study of Physical Properties of Rock, by R. J. Willard and J. R. McWilliams. Internat. J. Rock Mech. Min. Sci.,

v. 6, No. 1, 1969, pp. 1-12. Techniques have been developed to further understanding of rock behavior in terms of its microstructure. The techniques include (1) diametric mineralogical analysis, (2) defect analysis, (3) grain elongation analysis, (4) macrogrid analysis, and (5) transgranular-intergranular analysis. Physical properties of granite and limestone are compared with their fabric properties obtained through these techniques.

OP 26-69. A Lunar Drill Concept, by W. George Woo, J. Bensko, L. Lindelof, and J. Paone. Proc. Industrial Diamond Conf., 1967, pp. 257-274. This report describes one concept of a drill system which will be capable of taking core samples at depths of several hundred feet on the moon.

OP 27-69. Stress Required To Initiate Core Disking, by A. J. Durelli, Leonard Obert, and V. J. Parks. Trans. Soc. Min. Eng., AIME, v. 241, September 1968, pp. 269-276. The state of stress in the region where core disking initiates has been investigated through the use of three-dimensional photoelastic models, and the results of this study have been compared with those of a previous investigation of rock models. This comparison showed that disking initiates at a point of maximum shear stress, but that the magnitude of the shear stress, as determined photoelastically, is much larger than the shear strength of the rock as determined from conventional triaxial testing. Moreover the shear stress required to produce disking is not constant, but depends on the applied stress field. Possible explanations for these effects are included in this article.

OP 28-69. Bureau of Mines Research on Lunar Resource Utilization, by Thomas C. Atchison and Clifford W. Schultz. Proc. 6th Ann. Meeting of Working Group on Extraterrestrial Resources, Brooks Air Force Base, San Antonio, Tex., Feb. 19-21, 1968, NASA SP-177, pp. 65-74. The Bureau of Mines is cooperating with the National Aeronautics and Space Administration to provide, through a program of multidisciplinary research, the basic scientific and engineering knowledge that will be needed to utilize extraterrestrial mineral resources for support of future space missions. The concept, scope, and present status of the Bureau's program are described in this paper.

OP 29-69. Ore Deposits in Volcanic Rocks on Earth With Lunar Extrapolation, by Rolland L. Blake. Proc. 6th Ann. Meeting of Working Group on Extraterrestrial Resources, Brooks Air Force Base, San Antonio, Tex., Feb. 19-21, 1968, NASA SP-177, pp. 97-106. A literature search was made on the origin of ore deposits in volcanic rocks on Earth. The close association between mineralization of the rocks in a region and the later stages of volcanism is well established. Also recognized is the prominent role of magmatic solutions composed mostly of juvenile water, but frequently supplemented with ground water, in the formation of mineral deposits by such processes as hydrothermal deposition and sublimation. Ten ore-forming processes were recognized, and eight of these form ore deposits in Earth volcanic rocks. Effects of the inferred lunar environment on processes forming ore deposits were also studied. Mineral deposits thought to exist in volcanic rocks on the Moon, in order of decreasing amount and likelihood, are those formed by the following six processes: Hydrothermal deposition, sublimation, combined eruption and exhalation, volcanic eruption, and, rarely, metasomatism and evaporation. The Moon is viewed by the writer as a still dynamic body with some volcanism likely.

OP 30-69. A Nuclear Magnetic Resonance Study of the Association of Porphyrins in Chloroform Solution. Mesoporphyrin IX Dimethyl Ester and Its Nickel Chelate, by Daryl A. Doughty and C. W. Dwiggins, Jr. J. Phys. Chem., v. 73, No. 2, February 1969, pp. 423-426. The nuclear magnetic resonance spectra of the porphyrins studied are concentration dependent. The concentration dependence is caused by association between porphyrin molecules. Chemical shifts, association constants, and the spacings between porphyrin molecules in the dimer were determined.

OP 31-69. Development of Standard Procedures for Testing Fuel Briquets, by J. W. Eckerd. Proc. 10th Biennial Conf., Institute for Briquetting and Agglomeration, Aug. 15-17, 1967, Albuquerque, N. Mex., 1969, pp. 95-99. A test that will give a measure of the relative ease of igniting barbecue briquets has been developed and adopted as a tentative method. However, this test is not designed to provide information on burning rate, temperature attained, heat release, or length of burning; all of these are important characteristics of barbecue briquets from the viewpoint of the consumer. Tests for these characteristics would be desirable. Tests should also be devised and standardized for determining (1) the deterioration (breakage and abrasion) of briquets on handling and (2) the strength of the bags or packages in which briquets are sold. Degree of water absorption and shelf life probably should also be determined. Quality control tests such as the preceding are, for all practical purposes, more important to the consumer than to the producer. Tests of characteristics important to the producer can and probably should also be standardized. This decision rests with the barbecue briquet industry.

OP 32-69. Correction of X-Ray Diffraction Profiles for Instrumental Broadening in Transmission Geometry, by Sabri Ergun. J. Appl. Phys., v. 40, No. 1, January 1969, pp. 293-296. When polychromatic radiation is used in X-ray diffraction, the instrumental broadening changes with the scattering angle. It is shown that when transmission geometry is used, the instrumental broadening can be expressed in terms of the profile of the primary beam and its wavelength distribution. Consequently, it becomes possible to correct the entire intensity profile for instrumental broadening. The correction is made by successive foldings of the observed profile and is demonstrated using the intensity profiles of raw and heat-treated carbon black.

OP 33-69. Factors Affecting the Optimum Speeding Level of Coal- or Char-Fired, Open-Cycle MHD Power Plants, by H. F. Feldmann, W. H. Simons, and D. Bienstock. In Electricity From MHD, 1968. International Atomic Energy Agency, Vienna, Austria, v. 4, 1968, pp. 2097-2117. Factors affecting the optimum seeding level of coal- or char-fired, open-cycle magnetohydrodynamic power plants are (1) the air-fuel level, (2) the nature of the fuel, (3) the sulfur level of the fuel, (4) the silica content of the fuel, (5) the seeding level, (6) the type of seed, and (7) the separation temperature of the bulk of the liquid slag from the combustion products.

OP 34-69. An Improved Process for Making Prereduced Iron Ore Pellets, by M. M. Fine and R. B. Schluter. Trans. SME, v. 244, March 1969, pp. 71-77. Processes for manufacturing prereduced pellets have heretofore required temperatures of 2,100° F or higher. Sulfides will accelerate the liquid-phase sintering of metallic iron, yet do not deter the reduction of iron oxides. The sulfides may be introduced as gases to the kiln atmosphere or as solids in the reductants. The net result is that well metallized iron pellets with good crushing strength can now be produced at a little over 1,800° F.

OP 35-69. Simulated Lunar Rocks, by David E. Fogelson. Proc. 6th Ann. Meeting of Working Group on Extraterrestrial Resources, Brooks Air Force Base, San Antonio, Tex., Feb. 19-21, 1968, NASA SP-177, pp. 75-95. This paper describes the selection of rock materials for use by the Bureau of Mines in its extraterrestrial resource utilization studies which are designed to simulate the range of materials likely to be found on the Moon. It includes preliminary results of the measurement of the engineering properties of these materials.

OP 36-69. Reflectors Substitute for Trip Lights, by Richard Oitto and Alex O'Rourke. Coal Age, v. 73, No. 11, November 1968, pp. 96-98. To determine whether reflectors could substitute for trip lights, the Bureau of Mines compared reflectors to lights under simulated haulageway conditions. Reflectors were found suitable for use as a trip safety device.

OP 37-69. Lunar Drilling, by James Paone and R. L. Schmidt. Proc. 6th Ann. Meeting of Working Group on Extraterrestrial Resources, Brooks Air Force Base, San Antonio, Tex., Feb. 19-21, 1968, NASA SP-177, pp. 107-117. The association of the Bureau of Mines with lunar-drill programs since 1964 includes (1) advising and consulting with the National Aeronautics and Space Administration and with contractors making prototype drills and (2) conducting laboratory investigations of problems related to drilling in ultrahigh vacuum, at lunar extreme temperatures, and in reduced gravity. This paper reviews problems related to lunar drilling, data from Bureau drilling tests for lunar applications, and possible methods for predicting drillability of lunar materials from their engineering properties.

OP 38-69. Wyoming Corehole No. 1—A Potential Site for Production of Shale Oil in Place, by John Ward Smith and Laurence G. Trudell. Colorado Sch. Mines Quart., v. 63, No. 4, October 1968, pp. 55-69. Bureau of Mines Colorado Corehole No. 1 drilled near Eden in Wyoming's Green River basin sampled Green River Formation oil shales representing a potential of 200 million barrels of oil per square mile. In general properties and gross mineralogy the sampled oil shales strongly resemble Mahogany-zone oil shales of Colorado and Utah. Alternating thin beds of tough, rich oil shale and brittle, lean oil shale at depths less than 700 feet may offer advantages to in-place shale oil production techniques, providing possible access to at least 100,000 barrels of oil per acre in an area greater than 100,000 acres.

OP 39-69. Natural Gas, by Charles H. Atkinson. McGraw-Hill Yearbook of Science and Technology, 1969. McGraw-Hill Book Co., New York, 1969, pp. 228-23. The article discusses the application of underground nuclear explosions for stimulating production from low-permeability natural gas reservoirs. Project Gasbuggy is described and the potential of the technique for increasing natural gas reserves in the United States is considered.

OP 40-69. Velocity Errors in Cemented Specimens, by T. R. Bur, J. R. McWilliams, and K. E. Hjelmstad. Internat. J. Rock Mech. Min. Sci., v. 6, No. 2, March 1969, pp. 203-209. The bar, torsional, and longitudinal pulse velocities were measured on rock specimens and aluminum standard specimens consisting of up to seven segments together. The maximum error was about 1 percent, which is larger than can be predicted from the expected traveltime in the cement.

OP 41-69. Wettability Determination and Its Effect on Recovery Efficiency, by Erle C. Donaldson, Rex D. Thomas, and Philip B. Lorenz. SPE J., v. 9, No. 1, March 1969, pp. 13-20. A quantitative method for measuring the wettability of crude oil-brine-rock systems was developed, and some of the effects of wettability on oil production are shown.

OP 42-69. Reactions in the Cobalt-60 Irradiation of Pyridine and Methylpyridines, by J. J. Duvall and H. B. Jensen. J. Phys. Chem., v. 72, No. 13, December 1968, pp. 4528-4534. γ irradiation of nitrogen bases found in shale oil has been studied as a possible means of enhancing their value. Pyridine, 2-methylpyridine, 3-methylpyridine, 4-methylpyridine, and 2,6-dimethylpyridine were subjected to cobalt-60 irradiation with total dosages of 2 x 10^7 to 2 x 10^8 rads. *G* values for hydrogen, methane, acetylene, methylacetylene, and polymer, as determined by gas-liquid partition chromatography and mass spectroscopy, are reported. Products resulting from rupture of bonds external to the ring, rupture of ring bonds, aromatic substitution, and intramolecular rearrangement are reported. Respective examples of each of the above reactions on irradiation of 2-methylpyridine are the formation of methane, acetylene, 2,4-dimethylpyridine, and 3-methylpyridine. Possible reaction mechanisms are discussed. Dealkylation of methylpyridines occurred but not in significant amounts.

OP 43-69. Selective Separation of "Nonbasic" Nitrogen Compounds From Petroleum by Anion Exchange of Ferric Chloride Complexes, by D. M. Jewell and R. E. Snyder. J. Chromatography, v. 38, December 1968, pp. 351-354. "Nonbasic" nitrogen compounds in petroleum products are quantitatively removed from hydrocarbons and other nonhydrocarbons by complex formation with ferric chloride supported on kaolin. The colored complexes remaining adsorbed on the kaolin are easily desorbed with 1,2-dichloroethane and other polar organic solvents. The free nitrogen compounds are quantitatively recovered by contacting a dichloroethane solution of the complexes with a strong anion exchange resin of the quaternary ammonium hydroxide type.

OP 44-69. Designing an Alkalized Alumina Pilot Plant for Sulfur Dioxide Removal, by R. C. Kurtzrock, D. H. McCrea, and G. J. Cinquegrane. Proc. Extractive Met. Division Symp., AIME 1967 Operating Met. Conf., Dec. 11-13, 1967, Chicago, Ill., 1968, pp. 251-268. Design of a continuous pilot plant for the removal of sulfur oxides is discussed, including design parameters, description of equipment, some operating experiences, and a general conclusion.

OP 45-69. Cycles for Generation of Electricity From Coal, by Harry Perry, James McGee, and Donald Strimbeck. Proc. Am. Power Conf., v. 30, 1968, pp. 633-648; discussion, pp. 649-653. Methods of generating electricity from coal, including some still under development, are discussed. The relative performance characteristics and economics of the various methods are compared.

OP 46-69. Stationary Phases for Separation of Basic and Nonbasic Nitrogen Compounds or Hydrocarbons by Gas-Liquid Chromatography, by R. E. Poulson. J. Chromatographic Sci., v. 7, March 1969, pp. 152-157. Relative retention values were determined for some basic and nonbasic nitrogen compounds, and some hydrocarbons on polyethylene glycol (Carbowax 20M), polyethylene glycol terminated with terephthalic acid (Carbowax 20M-TPA), octylphenoxy-polyethoxy ethanol (Triton X-305), and purified Apiezon L doped with Carbowax 20M-TPA. Retention data were obtained at 180° and 220° C on the polar liquid phases. Triton X-305 was found to show more alkyl character than Carbowax 20M. Column bleed rates were measured with 5 percent liquid phase at 220° C, the maximum temperature found appropriate for extended use of the polar columns. The Carbowax 20M bleed rate was 0.10 μg hydrocarbon-equivalent/min with very slightly less for the Carbowax 20M-TPA, while the Apiezon L rate was 0.01 μg/min, all at 73 ml/min (25° C, 1 atm) flow rate. An Apiezon L column doped wth 5 percent Carbowax 20M to reduce tailing exhibited a bleed rate characteristic of Carbowax 20M. Hydrogen flame response factors were determined for several heterocyclic nitrogen compounds. By the agreement of hydrogen flame response factors for samples put through polar and nonpolar columns it was concluded that the polar columns do not destroy the relatively unstable indole-type nitrogen compounds although they are strongly retained.

OP 47-69. Design of an Open-Cycle, Vortex MHD Generator, by J. R. Thalimer, R. C. Kurtzrock, W. H. Simons, D. Bienstock, and W. F. Hughes. In Electricity From MHD, 1968. International Atomic Energy Agency, Vienna, Austria, v. 4, 1968, pp. 2601-2612. The Bureau of Mines built a vortex magnetohydrodynamic generator which combines the combustor-nozzle-duct combination into one integral unit. The vortex MHD generator consists of a cyclone burner, 7½ inches in diameter and 21 inches long, with the inner wall used as one electrode together with a coaxial center electrode. Power is obtained by impressing an axial field of 3,000 G from an air solenoid magnet. Electrical output is expected to be 1 kilowatt. For the initial runs natural gas will be burned in oxygen-enriched preheated air with a subsequent change to coal as a fuel. A theoretical analysis has been completed which predicts the velocity profiles and the electrical output characteristics of the generator. The analysis assumes variations in the radial and axial directions for all variables, steady state inviscid flow, constant electrical conductivity, and a small magnetic Reynolds number.

OP 48-69. An Automated Ultrasonic Pulse Measurement System, by Richard A. Thill and Thomas R. Bur. Geophysics, v. 34, No. 1, February 1969, pp. 101-105. The automated ultrasonic pulse measurement system can be used to obtain information simultaneously on velocity changes and rock noise while the rock is being loaded. The system is automated to the extent that, once set up, it can record independently of an operator for extended periods of time.

OP 49-69. Use of Carbonic Acid To Concentrate Kerogen in Oil Shale, by Rex D. Thomas. Fuel, v. 48, January 1969, pp. 75-80. A new method of concentration of the organic material in oil shale using carbonic acid was investigated. Carbonic acid was selected because it dissolves the major mineral constituents (carbonates), yet should not attack the organic material. Results show that the best separation is obtained with a carbon dioxide pressure of 200 psig and oil shale particles smaller than 150 mesh. All of the calcium and magnesium in the oil shales, along with some iron and aluminum, is removed and the organic carbon content of the shale is not affected by this treatment. Centrifuging the treated oil shale in aqueous calcium chloride solution gives a high yield of organic material which has a reduced amount of ash.

OP 50-69. The Sociological Impact of Mechanization on Coal Miners and Their Families, by Helen M. Lewis and Edward E. Knipe. Proc. Council of Economics, AIME, 1969, pp. 268-307. This paper is concerned with the effect of mechanization on the coal miner, his family, and the community in which he lives. The study was confined to the Virginia coalfields which are located in Buchanan, Dickenson, Wise, Lee, Tazewell, and Russell Counties.

OP 51-69. Quantitative Aspects of Nuclear Quadrupole Resonance Spectrometry of Inorganics and Minerals, by Harry D. Schultz and Clarence Karr, Jr. Anal. Chem., v. 41, No. 4, April 1969, pp. 661-664. NQR quantitative analyses performed on 18 samples from constructed calibration curves gave results that were comparable to other spectroscopic techniques in reproducibility and accuracy.

OP 52-69. Radioisotopic X-Ray Analytical Techniques for Gold and Silver Ores, by P. G. Burkhalter. Proc. Symp. on Use of Nuclear Techniques in the Prospecting and Development of Mineral Resources, Buenos Aires, Argentina, No. 5-9, 1968. Internat. Atomic Energy Agency, Vienna, Austria, v. 1, 1968, pp. 365-379. The purpose of this investigation was to determine the sensitivity of radioisotopic, energy dispersion X-ray techniques using semiconductor detectors for silver and gold ores. The excellent pulse resolution of the semiportable silicon and germanium (Li-drifted) semiconductor detectors offer a rapid and sensitive method for on-line X-ray analysis of drill hole cores, ocean sediments, and ore processing concentrates.

OP 53-69. Chemistry of Some Anadarko Basin Brines Containing High Concentrations of Iodide, by A. Gene Collins. Chem. Geol., v. 4, Special Issue, No. 1/2, March 1969, pp. 169-187. The chemistry of some petroleum-associated waters from Mississippian and Pennsylvanian age sediments was determined. The waters were a Na-Ca-Cl type which were altered by diagenesis and contained up to 1,400 mg/l of iodide. Collected evidence indicated that the iodide was solubilized from the sediments.

OP 54-69. Potentiometric Determination of Ammonium Nitrogen in Oilfield Brines, by A. Gene Collins, Joe L. Castagno, and V. M. Marcy. Environmental Sci. and Tech., v. 3, No. 3, March 1969, pp. 274-275. A potentiometric method utilizing the reaction of formaldehyde with the ammonium ion was developed. The ammonium nitrogen in a saline water can be determined in less than 30 minutes with a single laboratory relative standard deviation of 1 percent and relative error of −2.8 percent with a 77.5 mg per liter concentration of NH_4N in the presence of sodium chloride.

OP 55-69. Evaluation of Diaphragm Materials for Electrowinning High-Purity Titanium, by D. E. Couch, O. Q. Leone, R. S. Lang, and D. D. Blue. Design of Metal Producing Processes, Proc. Extractive Metallurgy Division Symp., AIME, Chicago, Ill., Dec. 11-13, 1967, 1969, pp. 309-323. Titanium with a Brinell hardness of 70 was electrowon from $TiCl_4$ fed into a LiCl-KCl-$TiCl_2$ electrolyte maintained at 520° C. The cells were operated on a continuous basis using commercial ceramic diaphragms composed of alumina with a silica bond. Methods of supporting the anode diaphragm and materials of construction were studied.

OP 56-69. Hydroformylation of Unsaturated Fatty Esters, by E. N. Frankel, S. Metlin, W. K. Rohwedder, and I. Wender. J. Am. Oil Chemists' Soc., v. 46, No. 3, March 1969, pp. 133-138. Unsaturated fatty esters and vegetable oils were hydroformylated with H_2 and CO(3500-4600 psi) and $Co_2(Co)_8$ to give fatty aldehydes at 100°-110° C and fatty alcohols at 175°-190° C. Yields of distillable C_{19} oxo products varied from 42 to 84 percent. Distilled products contained from 50 to 90 percent branched isomers and from 4 to 16 percent linear isomers.

OP 57-69. Merits of Decline Equations Based on Production History of 90 Reservoirs, by R. V. Higgins and J. H. Lechtenberg. Rocky Mountain Regional Meeting, SPE, AIME, Denver, Colo., May 25-27, 1969, Preprint SPE 2450, 12 pp. Four different equations were tested to determine which would fit the history and result in the best prediction of future performance of 90 California fields. Two equations proved to have the best merits.

OP 58-69. Identification of Alkyl Aryl Sulfides in Wasson, Texas, Crude Oil, by R. L. Hopkins, R. F. Kendall, C. J. Thompson, and H. J. Coleman. Anal. Chem., v. 41, No. 2, February 1969, pp. 362-365. This paper describes the isolation and the positive identification of (2-methyl-1-thiabutyl) benzene (phenyl *sec*-butyl sulfides), the tentative identification of three other alkyl aryl sulfides, and establishes for the first time the presence of this class of sulfur compounds in petroleum.

OP 59-69. Developing an In-House Writing Course for Engineers and Scientists, by Bill Linville. Proc. 16th Internat. Tech. Communications Conf., Soc. Tech. Writers and Publishers, Washington, D.C., May 14-17, 1969, v. 16, pp. B152-B161. An in-house training program in technical writing for engineers and scientists of the Bureau of Mines Petroleum Research Center in Bartlesville, Okla., is described. Simultaneous instruction in English composition and technical writing techniques provides a unique approach to short-course teaching methods. The course is effective in improving the quality of the internal and external written communications of the enrollees. Objectives and an outline of the course are given. Teaching methods are described.

OP 60-69. Spark Ignition—Ignition of Flammable Mixtures as a Consequence of Gaseous Electronic Discharge, by Elton L. Litchfield. Nat. Air Transportation Meeting, Soc. Automotive Eng., New York, Apr. 21-24, 1969, Preprint 690439, 5 pp. The concept of minimum energy for spark ignition is summarized and then applied to the question of ignition hazard from triboelectrified fluids. It is shown that if certain auxiliary conditions are satisfied, assurance of safety can be given if, and only if, the electric field strength is maintained below the dielectric breakdown strength of the flammable air-vapor mixture.

OP 61-69. Plastic Coatings Preserve Shale Samples, by R. H. Oitto and A. Zona. Coal Mining & Processing, v. 6, No. 5, May 1969, pp. 42-43. A new proprietary plastic coating can be melted in the field and used to coat rock samples to maintain them in field condition for off-location analyses and experiments.

OP 62-69. Sensitivity of Optical Data Processing to Changes in Rock Fabric. Part III—Rock Fabrics, by H. J. Pincus. Internat. J. Rock Mech. Min. Sci., v. 6, pp. 259-268. Idealized geometric patterns have been used as input test data to determine the sensitivity of optical data processing to changes in fabric. Useful test results have been obtained for separating input components of different directions or different spatial frequencies, measuring elongation of simulated grains and determining their stacking geometry, and filtering for band-pass and high-cut outputs. All of the operations performed here and the results obtained are directly transferable to rock fabric inputs.

OP 63-69. Vehicle Emissions vs. Fuel Composition, API-Bureau of Mines—Part II, by R. K. Stone and B. H. Eccleston. API Division of Refining Midyear Meeting, Chicago, Ill., May 13, 1969, Preprint 41-69, 29 pp.; Proc. API, December 1969, v. 49, pp. 651-690. Results showed that volatility reduction reduced both the quantitative total of exhaust and evaporative losses and the photochemical effect from these emissions. Replacing the olefin in the front end of the fuel with no change in volatility did not change the quantity of total hydrocarbon emissions but did reduce the photochemical effect of these emissions.

OP 64-69. Research at the Pittsburgh Coal Research Center, United States Department of the Interior, Bureau of Mines, by D. E. Wolfson and M. D. Schlesinger. AIME Annual Meeting, Washington, D.C., Feb. 16-20, 1969, Preprint 69-F-40, 5 pp. Presents a brief discussion of basic and applied research work at the Pittsburgh Coal Research Center of the U.S. Bureau of Mines.

OP 65-69. Vapor Pressure of the Cadmium Chloride-Lead Chloride System, by L. C. George, Robert M. Doerr, and Aarne Visnapuu. J. Chem. and Eng. Data, v. 14, No. 1, January 1969, pp. 23-26. Vapor pressures of mixtures in the binary system $CdCl_2$-$PbCl_2$ were measured by the static-pressure method. Vapor presure isotherms showed positive and negative deviations from additivity, with a pronounced discontinuity at the composition 9 $CdCl_2 \cdot 2\ PbCl_2$. This suggests that a mixed-salt complex of this composition is present in the molten mixtures. Vapor pressure equations for all mixtures of $CdCl_2$ and $PbCl_2$ investigated, and derived values of heat of vaporization and free energy of vaporization for high-purity $CdCl_2$ and $PbCl_2$ are presented.

OP 66-69. Scanning Electron Microscope Gives Researchers a Closer Look at Rock Fractures, by Robert J. Willard. Min. Eng., v. 21, No. 6, June 1969, pp. 88-90. In rock mechanics research, the SEM should prove a useful basic tool in characterizing rock fracture on a very small scale and thus contribute to a better understanding of rock behavior at large scales. This article presents one example of how the SEM is being applied to such research by the Bureau of Mines.

OP 67-69. Analytical Uses of Energy Balances, by William A. Vogely. IEEE Spectrum, v. 6, No. 5, May 1969, pp. 57-63. Energy balances necessitate energy requirements and sources to be expressed in commensurate units—usually heat. If these balances are complete, the flow of energy through the economy can be traced in such units, and the transformation functions of one form or source of energy to another can be specified. Thus, energy balances permit analysis of the entire energy sector on a whole, rather than on a commodity by commodity, basis. As such, they are capable of being used analytically to solve a number of problems that would otherwise be beyond comprehensive analysis. In this article, four such analytical uses are described and applied.

OP 68-69. The Role of Wire Size in Negative Electrical Discharge at High Temperature, by C. C. Shale and J. H. Holden. IEEE Trans. on Industry and General Applications, v. IGA-5, No. 1, January-February, 1969, pp. 34-39. Negative corona onset and sparkover voltages in air are shown to be affected by temperature, density, and the pipe-to-wire ratio of radii when using concentric cylindrical electrodes. Use of large wires at high temperatures demonstrates that onset of electrical discharge occurs at voltages significantly less than those predictable by earlier theory and that sparkover occurs at voltages considerably greater than those anticipated. Theory is presented to account for the results obtained.

OP 69-69. A Valance Force Field for Aliphatic Sulfur Compounds: Alkanethiols and Thiaalkanes, by Donald W. Scott and M. Zaki El-Sabban. J. Molecular Spectroscopy, v. 30, No. 2, May 1969, pp. 317-337. In a vibrational analysis of alkanethiols and thiaalkanes, a force field was derived from wavenumbers of 11 compounds and tested with wavenumbers of four additional compounds.

OP 70-69. Application of Electrometallurgy in Processing of Minerals, by Joe B. Rosenbaum. J. Metals, March 1969, pp. 18-20; Proc. Extractive Metallurgy Division Symp. Electrometallurgy, AIME, Cleveland, Ohio, Dec. 2-3, 1968, pp. 43-51. Paper explains why electrometallurgical procedures are used in the production of most metals; shows how electricity is used and the incremental cost of the electricity in electrometallurgy; and points out some targets for expanded use of electrometallurgical techniques.

OP 71-69. Electrowinning of Metals, by Joe B. Rosenbaum. Proc. Abundant Nuclear Energy Symp., Gatlinburg, Tenn., Aug. 26-29, 1968, pp. 197-201. The relation between cost of energy for electrowinning and the selling price of selected metals is presented to illustrate the incremental benefit of cheaper power. The outlook for uses of electricity in electrometallurgy is discussed.

OP 72-69. Enthalpies of Combustion of Toluene, Benzene, Cyclohexane, Cyclohexene, Methylcyclopentane, 1-Methylcyclopentene, and n-Hexane, by W. D. Good and N. K. Smith. J. Chem. and Eng. Data, January 1969, v. 14, No. 1, pp. 102-106. The enthalpies of combustion of toluene, benzene, cyclohexane, cyclohexene, methylcyclopentane, 1-methylcyclopentene, and n-hexane were measured in a bomb calorimeter. Values, in kilocalories per mole based on the mass of samples, for the enthalpies of combustion, $\triangle Hc^{\circ}_{298.15}$, of the liquid hydrocarbons in gaseous oxygen to form gaseous carbon dioxide and liquid water are toluene, -934.49 ± 0.12; benzene, -780.95 ± 0.10; cyclohexane, -936.87 ± 0.13; cyclohexene, -896.75 ± 0.12; methylcyclopentane, -941.28 ± 0.14; 1-methylcyclopentene, -897.17 ± 0.13; and n-hexane, -995.03 ± 0.13. Values of the enthalpy of formation of the liquids were derived. They were compared to existing hydrocarbon data and can be used to check the internal consistency of the existing selections of data for the several families of hydrocarbons. The best means of measuring the amount of reaction in combustion calorimetry were reconsidered. Both sample mass and carbon dioxide recovery were used as measures of the amount of reaction. A new carbon dioxide absorbent was used and was superior to older absorbents.

OP 73-69. Process Evaluation as a Guide for Magnesium Research, by Douglas A. Elkins and Paul L. Placek. Proc. Extractive Metallurgy Division Symp., AIME, Chicago, Ill., Dec. 11-13, 1967, pp. 240-250. Process economic evaluation is commonly employed to determine probable costs for newly developed metallurgical processes. Examples drawn from experience in research on magnesium production methods by the Bureau of Mines demonstrate how evaluation can also be used to advantage in examining existing technology prior to research and for many purposes during research. Cost estimation required can be simplified by the use of a digital computer. Information provided can help to insure that planning decisions are made objectively and that the research produces proper, meaningful, and adequate data needed for eventual application of the processes.

OP 74-69. Special Situation Planning for the Mesabi Iron Pits, by David B. Brooks. Landscape Architecture, v. 59, No. 3, April 1969, pp. 194-197. Environmental problems created by open-pit iron mining in Minnesota are local not regional and, therefore, they are more susceptible to control by zoning and land-use planning rather than by broad-brush regulation.

OP 75-69. Titanium Electrorefining, by Don H. Baker, Jr. Ch. 15 in High Temperature Refractory Metals, Gordon and Breach Science Publishers, Ltd., London, v. 1, July 1969, pp. 223-233. The development of the molten-salt electrorefining of titanium is traced from the early laboratory stages to the operation of a 10,000-ampere cell. The influences of electrolyte composition, temperature, feed material, and current density on the quality of the product are discussed. The effects of cell design and materials of construction are also described. Electrorefining is extremely effective for separating interstitial impurities from titanium. The transfer and controlled codeposition of selected metallic elements for titanium alloy preparation is outlined.

OP 76-69. Detection Limit for Silver by Energy-Dispersion X-Ray Analysis Using Radioisotopes, by P. G. Burkhalter. Internat. J. of Applied Radiation and Isotopes, v. 20, May 1969, pp. 353-362. The purpose of this study was to determine the sensitivity for silver in silica using radioisotopic X-ray sources, electronic discrimination with a single-channel analyzer, and scintillation detectors. The sensitivity for silver was determined as a function of excitation energy. Using monoenergetic K-spectra X-ray sources Sb, Te, and Ba, a normalized detection limit ranging from 21 to 13 ppm was obtained for 100-sec counting intervals. With an annular ^{125}I source as a detection limit of 15 ppm silver was measured. The effect on the detection limit of heavy metals common to silver ores was also investigated. A detection liimt of 25 ppm or less was still obtained when 5-percent concentrations were present in the silica matrix provided X-ray interferences with the Ag K α radiation did not exist. The need for accurate background measurements for analysis in the parts-per-million range was emphasized. The sensitivities found in this work indicate that a portable radioisotopic X-ray analyzer could be designed for low-grade silver ores.

OP 77-69. Separation of Crude Oil Fractions by Gel Permeation Chromatography, by H. J. Coleman, D. E. Hirsch, and J. E. Dooley. Anal. Chem., v. 41, No. 6, May 1969, pp. 800-804. This study was undertaken by the Bureau of Mines to investigate, extend, and apply gel permeation chromatographic (GPC) techniques to the fractionation of high-boiling petroleum samples. The use of GPC with specially built columns and appropriate size polystyrene gel successfully effected the separation of several diverse petroleum samples. In general, these separations were made by molecular size. Analytical data such as molecular weight, nuclear magnetic resonance (NMR) spectra, mass spectra, and percent sulfur on the GPC subfractions provided a measure of the separations attainable. These data establish GPC as a useful supplementary method for separating high-boiling petroleum fractions without exposing the samples to the thermal hazards of distillation.

OP 78-69. Preparation and Evaluation of Rhenium and Rhenium-Base Alloys, by C. E. Armantrout and H. Kato. Trans. 1968 Internat. Met. Conf., Beverly Hills, Calif., June 10-13, 1968, pp. 439-462. To determine selected mechanical properties, pure rhenium and rhenium-base alloys consolidated by arc melting using nonconsumable electrodes were fabricated to sheet and rod. An optimum cold-working procedure was developed that utilized cold-press forging with reductions of up to 40 percent, annealing, and then cold rolling using multiple pass reductions to a total reduction of 20 to 30 percent between each anneal. The repeated cold working and annealing of cast rhenium ingots resulted in an appreciable increase in hardness from Rockwell A 42-43 to Rockwell A 58-62; however, no further hardening was noted with additional working and annealing steps.

Tensile strengths were 109,000 to 130,000 psi, yield strengths 16,100 to 17,700 psi, and modulus of elasticity 54 x 10^6 psi for pure rhenium. The alloys that were amenable to cold working and that were subsequently tested in tension were of the solid-solution type or were amenable to heat treating in a solid-solution range. The alloy additions that strengthened through solid-solution mechanisms had high tensile strengths, up to 231,000 psi, yield strengths up to 119,000 psi with elongations near 20 percent, and modulus of elasticity near 60 x 10^6 psi.

OP 79-69. The Impact of Surface Mine Regulation on the Coal Industry: The Case of Kentucky, by David B. Brooks. Proc. Council of Economics, AIME, 1969, pp. 65-92. The purpose of this study was to analyze certain effects of surface mine regulation on the coal industry of Kentucky where surface mining has been regulated since 1954. It was calculated that the short-run opportunity cost under the conditions found in Kentucky amounts to about 25 percent in terms of output and employment lost because of reclamation requirements. It was also found that firms increased the scale and concentration of production in order to become more efficient. Technologic advances in reclamation practices were also introduced so that productivity did not generally lag for more than a year or so following passage of stricter reclamation requirements. The impact of regulation has been most important in those areas, such as east Kentucky, where a combination of physical conditions and industry structure limits the flexibility of response. On the other hand, as evidenced by the post-1954 response in east Kentucky, reclamation costs are not so large as to deter increases in production when other forces, like a growing demand for low-sulfur coal, work in the opposite direction.

OP 80-69. Stacking Distribution on a Carbon Black, by Sabri Ergun and Theodore J. Gifford. J. Chim. Phys., 1969, pp. 99-103. The distribution of the number of layers in stacks formed by parallel and equidistant layer domains has been analyzed from the profiles of the (002) reflections using the Warren-Bodenstein equations. The analysis revealed that the distribution follows the Maxwell-Boltzmann law. According to this distribution the probability of finding q parallel and equidistant layer domains decreases exponentially with q. The coefficient of the exponent completely defines the profiles of the (002) reflections.

OP 81-69. Potential Hazards of Propargyl Halides and Allene, by D. R. Forshey, J. C. Cooper, G. H. Martindill, and J. M. Kuchta. Fire Technology, v. 5, No. 2, May 1969, pp. 100-111. The combustion characteristics and detonability of propargyl bromide, propargyl chloride, and allene were investigated as a means to evaluate their hazard in storage, use, and transportation. All three will undergo monopropellant burning, but their ignitibility and tendency toward monopropellant burning were reduced by dilution with toluene.

OP 82-69. USBM-CCI Cooperative Research on Flotation of Nonmagnetic Taconites of Marquette Range, by D. W. Frommer. 30th Ann. Mining Symp. and 42d Ann. Meeting Minnesota Sec., AIME, University of Minnesota, Duluth, Minn., Jan. 13-15, 1969, pp. 189-198; Blast Furnace and Steel Plant, v. 57, No. 5, May 1969, pp. 380-388. The hematitic-martitic-goethitic jaspers of the Marquette range can be beneficiated by flotation to yield concentrates of excellent quality with good recoveries. An essential part of the treatment is the selective flocculation and desliming that precedes the flotation step. Although excellent progress has been made through the 900-pound-per-hour pilot plant, the future of the proposed methods depends on their effective adaptation to unit operations of commercial size.

OP 83-69. High-Temperature Drop Calorimetry, by Thomas B. Douglas and Edward G. King. Ch. 8 in Calorimetry of Non-Reacting Systems, ed. by John P. McCullough and Donald W. Scott. Experimental Thermodynamics, v. 1, Butterworths, London, 1968, pp. 293-331. The general requirements for accurate drop calorimetry are considered in terms of the composition of the sample and the design and operation of the furnace and calorimeter. Methods of correcting the data to standard conditions, smoothing and representing enthalpy values, and derivation of other thermodynamic properties are discussed.

OP 84-69. Pyrolysis of Coals in a Microwave Discharge, by Yuan C. Fu and Bernard D. Blaustein. I&EC Process Design and Development, v. 8, No. 2, April 1969, pp. 257-262. Pyrolysis of coals of different ranks in a microwave discharge yields gaseous products containing hydrogen, carbon oxides, and hydrocarbons, with acetylene as the main hydrocarbon. The discharge pyrolysis of coal, except for lignite, occurs in three stages: partial carbonization to produce tar, rapid gasification to produce gaseous products, and slow degasing of residual char. When the gas products are cooled with liquid nitrogen as they form during the discharge pyrolysis, the hydrocarbon yield increases markedly and the extent of volatilization in terms of carbon gasified rises. The initial presence of argon increases the rate of gas evolution and appears to yield greater amounts of smaller fragments as the primary gasification products.

OP 85-69. System Analysis for Truck and Shovel Selection, by L. W. Gibbs, J. R. Gross, and E. P. Pfleider. Trans. SME, December 1967, pp. 354-359. A method using computer techniques is described for the comparative evaluation of truck performance over any given haul road using readily obtainable manufacturers' data. An additional computer program is utilized to calculate individual cycle times for each truck and shovel combination, fleet requirements for any desired production rate, and to estimate comparative costs.

The introduction of a large number of variables into the program permits management to determine the critical system factors having the greatest bearing on costs. Thus, the method described can be used not only for analysis of needs for a new surface mine but for cost improvement in existing mines where changes in truck and shovel operations are contemplated.

OP 86-69. Enthalpies of Combustion and Formation of 11 Isomeric Nonanes, by William D. Good. J. Chem. and Eng. Data, v. 14, No. 2, April 1969, pp. 231-235. The enthalpies of combustion of 11 isomeric nonanes were determined by oxygen-bomb combustion calorimetry. Enthalpies of combustion were computed from measurements of mass of samples burned and mass of carbon dioxide produced. The following values, in kilocalories per mole based on the mass of sample, are reported for the standard enthalpy of combustion, $\Delta Hc^{\circ}_{298.15}$, of these compounds in the liquid state: *n*-nonane, -1463.96 ± 0.13; 2,2-dimethylheptane, -1460.74 ± 0.20; 2,2,3-trimethylhexane, -1462.05 ± 0.18; 2,2,4-trimethylhexane, -1462.1 ± 0.20; 2,2,5-trimethylhexane, -1459.50 ± 0.20; 2,3,3-trimethylhexane, -1462.43 ± 0.20; 2,3,5-trimethylhexane, -1461.73 ± 0.20; 2,4,4-trimethylhexane, -1462.65 ± 0.18; 3,3,4-trimethylhexane, -1463.28 ± 0.18; 2,2-dimethyl-3-ethylpentane, -1464.44 ± 0.18; and 2,4-dimethyl-3-ethylpentane, -1465.15 ± 0.18. The experimental results for these compounds were compared to values predicted by current correlative procedures.

OP 87-69. Estimation of Fluid-Bed Operation by a Graphical Method, by J. P. Hansen and I. L. Feld. The Design of Metal Producing Processes, Proc. Extractive Metallurgy Div. Symp., AIME, Chicago, Ill., Dec. 11-13, 1967, 1969, pp. 144-157. A graphical method is presented for predicting the degree of reduction and gas composition after each stage of a multiple fluid-bed reduction of iron ore. Using a pseudo equililibrium derived from equilibrium and operational characteristics of the fluid beds, and an operating line dependent on the desired reduction of the final product, the composition of the entering gas, and the ore-to-gas ratio, the percent reduction, and gas composition after each stage can be predicted.

Since a multistage fluid bed was not available at the Tuscaloosa Metallurgy Research Laboratory, the graphical method was modified to predict the results of multiple reduction passes through a single-stage fluid bed. The percent reduction predicted after each pass was within 3 percent of the experimental results, which is considered well within the experimental error.

OP 88-69. The Farm Revolution and the Demand for Fertilizer, by Olman Hee. Proc. Council of Economics, AIME, 1969, pp. 189-218. The main objective of this paper is to estimate the contribution of user technology in explaining the consumption of fertilizer. Statistical relations are formulated which specify price of each fertilizer component, consumer income (proxy for farm output), and level of user technology as the explanatory variables. A set of equations is fitted to data for the specified variables to explain past patterns of consumption of each fertilizer component. The estimating equations also are used to project consumption of the respective fertilizer components into future years.

OP 89-69. Extractive Metallurgy of Titanium, by T. A. Henrie. Ch. 11 in High Temperature Refractory Metals. Gordon and Breach Science Publishers, Ltd., London, v. 1, July 1969, pp. 134-154. The technology involved in the reduction of titanium compounds is reviewed. Physical-chemical factors are discussed for separating titanium metal from the oxide minerals. Various chemical schemes are presented for processing impure oxides through intermediate compounds to high-purity metal. Technical evaluations are made of the energy potentials of selected reducing agents for effecting complete reduction. Product quality of titanium from commercial and potential processes is compared.

OP 90-69. Vapor-Phase Deposition of Tungsten From Tungsten Hexafluoride and Hydrogen, by F. W. Hoertel. Ch. in High Temperature Refractory Metals. Gordon and Breach Science Publishers, Inc., New York, v. 34, pt. 1, 1965, pp. 519-537. High-purity tungsten having a columnar grain structure, with Knoop microhardness values with a 100-gram load ranging from 240 to 714 and an average density of 19,249, was vapor deposited on various substrates by reducing commercial WF_6 with hydrogen. Deposition temperatures ranged from 300° to 700° C. Bonding of the tungsten to the various substrates was mechanical. Exceptionally adherent bonding to copper was achieved. A table of average values of detectable impurities, a schematic diagram of the apparatus used, two photomicrographs of grain structure, and three photographs and one X-ray photograph of deposits are included.

OP 91-69. Oil Shale as a Potential Source of Liquid Fuels, by Sidney Katell. Proc. Council of Economics, AIME, 1969, pp. 147-155. Oil shale is a potential source of liquid fuels, and the vast known reserves in the West have served as an impetus for utilizing this reserve. The economics of a system using oil shale in the production of liquid products is examined in this paper. Included are mining, retorting, and refining to produce the salable product. Capital cost, operating costs, and a financial analysis are detailed.

OP 92-69. Effects of Interstitial Impurities on Twinning and Low-Temperature Mechanical Properties of Electrorefined Vanadium, by G. H. Keith and D. R. Mathews. In Refractory Metals and Alloys IV. Gordon and Breach Science Publishers, Ltd., London, v. 1, 1969, pp. 247-264. Nitrogen and oxygen have substantially greater solubilities in vanadium than carbon and boron, and the amount of strengthening which can be achieved by addition of these elements appears to be primarily dependent upon the quantity of the elements in solid solution. Where low solubility exists, very little strengthening occurs. The occurrence of second-phase carbides and borides in the quantities and temperature range studied does not seriously affect ductility. The initial deformation mode changed from slip to twinning as temperature changed from 123° to 77° K. Oxygen or nitrogen in solution suppressed twinning in vanadium when in excess of a critical concentration; carbon or boron, precipitated as a second phase, had little effect. High ductility was associated with profuse twinning, and conversely, when twinning was suppressed or inhibited the material became embrittled.

OP 93-69. Rock Mechanics—Its Role in Oil Recovery, by C. A. Komar. Producers Monthly, v. 32, No. 11, November 1968, pp. 2-7. A state-of-the-art report on the role of rock mechanics in oil recovery was prepared to formulate plans for experimentally determining if subsurface formation fractures may be oriented along a preferred azimuthal direction. This report combines the conclusions, experimental observations, and inferences from 43 references to show why oriented fractures are important in the recovery of oil; to summarize pertinent theory on causes of fractures; and to make available current knowledge on joint surfaces, fractured reservoirs, and rock mechanics. Conclusions evolving from this study suggest that oriented cores can be subjected to laboratory tensile tests, directional flow studies, sound velocity studies, and petrographic microscopic examinations to ascertain if particular rock properties or rock composition and structure are indicators of the preferred direction of fracture. Whenever impression-packer surveys, stress-field analyses, and surface-joint measurements are available for the formation tested, a comparison can be made of the conditions existing for fractures induced in the laboratory and those observed in the field. When establishing flooding patterns for maximum sweep efficiency, such information would determine which wells should be fractured.

OP 94-69. Physical Properties of Some Sulfur and Nitrogen Compounds, by W. J. Lanum and J. C. Morris. J. Chem. and Eng. Data, v. 14, No. 1, January 1969, pp. 93-98. Physical properties were determined on purified samples of 38 organic sulfur compounds and 18 organic nitrogen compounds. Most of the compounds were donated by interested laboratories for augmenting the spectral data on these types of compounds. Special handling techniques to prevent contamination or decomposition were employed during purification, storage, and property measurement. Boiling point, freezing point, density at 20° C, and refractive index (sodium *D* and mercury *g* lines) at 20° C were determined. Derived functions calculated are refractivity intercept, specific dispersion, and molecular refraction.

OP 95-69. Irmay's Saturation Factor as an Indication of an Immobile Fraction of Pore Water in Saturated Permeable Sandstone, by G. E. Manger, R. A. Cadigan, and G. L. Gates. J. Sedimentary Petrology, v. 39, No. 1, March 1969, pp. 12-17. The permeability of moderately permeable Jurassic sandstone from the Colorado Plateau as calculated from grain size and other textural parameters agrees reasonably well with that determined experimentally, if calculated permeability is reduced by a factor that reflects fractional saturation with capillary water. This result tends to confirm a conclusion by Irmay that in saturated permeable media a fraction of pore water is shut off from flow of water. Applicability of a saturation factor to poorly permeable sandstone is obscured where acid-soluble contents are high; apparent inapplicability results at very fine grain size perhaps because calculated permeability is not valid where based on very fine grain diameter.

OP 96-69. Tatman Formation, by W. L. Rohrer and John Ward Smith. Wyoming Geol. Assoc. Guidebook, 1969, pp. 49-54. Stratigraphy and characteristics of organic matter in the lacustrine sediments of Wyoming's Eocene Tatman Formation are described.

OP 97-69. Vapor Pressure Relations for the Seven Pentadienes, by Ann G. Osborn and Donald R. Douslin. J. Chem. and Eng. Data, v. 14, No. 2, April 1969, pp. 208-209. Experimental values of vapor pressure for the seven isomeric pentadienes were measured in the range 2 to 25 mm of Hg by means of the included-piston deadweight gage.

OP 98-69. China's Mineral Industries in 1967: Victims of the Cultural Revolution, by Kung-Lee Wang. Asian Survey, v. 9, No. 6, June 1969, pp. 425-437. The Cultural Revolution took a heavy toll from China's economy in 1967. The mineral industries were hit the hardest. The estimated total 1967 China mineral output suffered a significant decline of 30 percent from that estimated for 1966.

OP 99-69. Effect of Loading Rate on Transgranular-Intergranular Fracture in Charcoal Gray Granite, by R. J. Willard and J. R. McWilliams. Internat. J. Rock Mech. Min. Sci., v. 6, 1969, pp. 415-421. An inverse relation was found between rate of loading and transgranular-intergranular fracture in Charcoal gray granite disks loaded to failure at four different loading rates by the point load test. An empirical equation was developed to express the dependence of strain energy dissipation on the degree to which favorably oriented defects dilate under different loading rates.

OP 100-69. Solubilities of Some Silicate Minerals in Saline Waters, by A. Gene Collins. Office of Saline Water Research and Development Progress Report 427, August 1969, 27 pp. In the systems H_2O, H_2O-$CaCl_2$, H_2O-$MgCl_2$, H_2O-$NaCl$, and H_2O-$NaHCO_3$, the solubilities of illite, kaolinite, montmorillonite, nontronite, and a serpentine were determined as a function of time at ambient temperatures and pressures. The solubility of a serpentine was also determined in H_2O-$CaCl_2$ and H_2O-$NaCl$ systems from 30° to 200° C and from 2,500 to 15,000 psi. The experimental data are illustrated with smoothed curves plotted from silicon molality versus hours. Empirical equations were derived from the smoothed data.

OP 101-69. Preparation of Carbon Metallurgical Electrodes From Low-Temperature Lignite Coke and Lignite Pitch Binder, by John S. Berber and Richard L. Rice. I&EC Product Research and Development, v. 8, No. 2, June 1969, pp. 188-193. Carbon electrodes were prepared from materials produced by low-temperature carbonization of lignite. Coke aggregate for the electrodes was produced by thermal cracking or by delayed coking of pitch obtained from distillation of low-temperature lignite tar; the pitch served as electrode binder. Electrodes prepared from these materials compared favorably with high-purity electrodes found in commerce.

OP 102-69. Far-Infrared Spectroscopy of Mineral and Inorganics, by Clarence Karr, Jr., and John J. Kovach. Appl. Spectroscopy, v. 23, No. 3, May-June 1969, pp. 219-223. Far-infrared spectroscopic analysis of minerals and inorganics was investigated.

Far-infrared spectra, 200 to 500 cm^{-1} (50 to 200 μ), were obtained for 18 different minerals and inorganics, including eight sulfides, three oxides, three carbonates, and four sulfates, many for the first time. Original analytical applications were made on samples of practical interest. These included the identification of cinnabar in a high-quartz ore, cuprite and tenorite in a mixture, calcite and dolomite in a coal refuse sample, dawsonite and dolomite in an oil shale, thenardite in a boiler deposit, and ferrous sulfate in the surface film on pyrite.

OP 103-69. Solid and Gaseous Fuels, by R. F. Abernethy and J. G. Walters. Anal. Chem., Ann. Rev., v. 41, No. 5, April 1969, pp. 308R-322R. This two-part report is a technical literature survey on the improved and new methods of sampling and analyzing coal and coke, and the methods used for testing blast-furnace top, carbureted water, coal, coke-oven, liquefied petroleum, sludge, manufactured, natural, producer, synthesis, and water gases.

OP 104-69. Principles and Practices of Incineration, ed. by Richard C. Corey. John Wiley & Sons, Inc., New York, 1969, 297 pp. This book is a detailed treatment of incineration technology intended as a guide for air pollution and waste disposal officials and technologists, industry, consulting firms, and students in environmental control engineering. All of the important aspects of incineration are covered, from the theory of combustion and gas cleaning to testing their performance as regards specifications for discharge of particular matter to the atmosphere.

OP 105-69. Electrodeposition of Palladium and Platinum From Aqueous Electrolytes, by Stephen D. Cramer and David Schlain. Plating, v. 56, No. 5, May 1969, pp. 1-7. Techniques for plating thick, adherent, and coherent electrodeposits of palladium and platinum from aqueous electrolytes are described. Palladium and platinum were deposited on molybdenum, nickel, niobium (columbium), and tungsten; in addition, palladium was deposited on titanium. Successful deposition on the refractory metals was accomplished using a cathodic pretreatment salt bath containing salts of a platinum-group metal. Deposit-substrate specimens were heat treated at temperatures up to 1,250° C. Microhardness measurements and electron probe analyses were conducted to determine the effect of heat treatment.

OP 106-69. Design of a Facility for Marine Mining Systems Research, by Michael J. Cruickshank and Ian J. Collins. Proc. Offshore Technol. Conf., OTC 1034, 1969, pp. 1305-1310. The paper describes existing and proposed facilities for marine mining systems research at the Marine Minerals Technology Center of the Bureau of Mines at Tiburon, Calif. Present facilities include a hydraulic laboratory and an environmental mechanics laboratory for study of the interrelationships between the mining process and marine mineral deposits. In the design stage is a simulator facility for the dynamic testing of marine mining systems components under controlled conditions in a real or simulated environment. The simulator will consist of a tank approximately 150 ft long by 15 ft wide by 10 ft deep, with viewing ports and a moving instrumented test carriage. Deposits will be simulated in removable containers, and other ancillary facilities will include a materials handling and analysis facility, a sea state generator, a directional current generator, and a simulated beach with adjustable slope. Proposed uses, and associated design problems are discussed.

OP 107-69. Reduction of the Benzene Ring and of the Olefinic Double Bond by Electrolytically Generated Electrons, by Heinz W. Sternberg, Raymond E. Markby, Irving Wender, and David M. Mohilner. J. Am. Chem. Soc., v. 91, No. 15, July 16, 1969, pp. 4191-4194. Benzene and olefins can be reduced electrochemically in ethanol containing hexamethylphosphoramide (HMPA). The reduction of these substrates is believed to be due to electrochemically generated solvated electrons. The relative amounts of cyclohexadiene, cyclohexene, and cyclohexane obtained in the reduction of benzene depend on ethanol concentration, current density, and temperature in a manner consistent with the proposed mechanism. Benzene can also be reduced electrochemically in pure ethanol. In the absence of HMPA, however, the current efficiency is only of the order of 1 pct as compared to a current efficiency of 95 pct in ethanol-HMPA.

OP 108-69. Pressure-Volume-Temperature Relations of Hexafluorobenzene, by D. R. Douslin, R. H. Harrison, and R. T. Moore. J. Chem. Thermodynamics, v. 1, 1969, pp. 305-319. A comprehensive investigation of PVT properties of hexafluorobenzene provided definitive results which characterized its intermolecular behavior.

OP 109-69. Principles of Cleaning Combustion Products, by Joseph H. Field. Ch. 3 in Principles and Practices of Incineration, ed. by R. C. Corey. John Wiley & Sons, Inc., New York, 1969, pp. 34-73. In relation to particulate matter discharged from incinerators, the chapter describes particle dynamics, devices for separating particulate matter and their applications, and odor control. Examples are given to illustrate certain principles.

OP 110-69. High-Temperature Evaluation of Iron Ore Pellets, by M. M. Fine. 30th Ann. Mining Symp. and 42d Ann. Meeting, Minnesota Sec., AIME, University of Minnesota, Duluth, Minn., Jan. 13-15, 1969, pp. 133-141. A number of diagnostic procedures have been developed for evaluation of indurated iron ore pellets at elevated temperatures. In general these tests are designed to reveal the effects of blast furnace operation upon specific physical and chemical properties. This report reviews a number of high-temperature tests such as hot compression, reducibility, swelling and reduction degradation. Although these are only estimates derived under simulated blast furnace environments, they can play a role in improving iron ore pellet quality.

OP 111-69. Impressions Gained on a Visit to Lenin Mining and Metallurgical Complex at Almalyk, Uzbekistan, U.S.S.R., by D. W. Frommer. 30th Ann. Mining Symp. and 42d Ann. Meeting, Minnesota Sec., AIME, University of Minnesota, Duluth, Minn., Jan. 13-15, 1969, pp. 39-44. One of the U.S.S.R.'s largest copper producing facilitites, having an estimated annual output in excess of 60,000 tons per year, was visited as part of a post-VIII International Minerals Processing Congress tour. The mine, mill, and smelter are located at Almalyk in Uzbekistan, Central Asia. Various technical aspects of the operation are discussed, as they appeared to the author, including size of equipment, and tonnages treated, along with apparent discrepancies between the author's observations and the limited published data. Reagent use is given and the author's conception of the flotation and grinding flowsheet is presented and discussed.

OP 112-69. A New Way to Handle Nonmagnetic Taconite, by D. W. Frommer. Eng. and Min. J., v. 170, No. 8, August 1969, pp. 92-97. This article gives typical results of cooperative flotation research on nonmagnetic taconites of the Marquette range, including the development of approaches to filtration and water reclamation.

OP 113-69. Mergers in the Mineral Industry, by Annette Graham and David B. Brooks. Min. Eng., v. 21, No. 8, August 1969, p. 84. This article explores the participation of nonfuel mineral companies in the merger movement of 1967-68. Total merger activity in 1967-68. resulted in record years for the industry. Nonfuel mineral companies also gained attention by the sizes of the companies acquiring and being acquired.

OP 114-69. The Vibrational Spectrum of 2,2,5,5-Tetramethyl-3,4-Dithiahexane, by J. H. S. Green, D. J. Harrison, W. Kynaston, and D. W. Scott. Spectrochim. Acta, v. 25A, No. 7, July 1969, pp. 1313-1314. A vibrational assignment for 2,2,5,5-tetramethyl-3,4-dithiahexane was based on molecular spectral data obtained with a highly purified sample.

OP 115-69. Technologic Gaps in Exploration and Exploitation of Sub-Sea Mineral Resources, by Frank H. Wang and Michael J. Cruickshank. Proc. Offshore Technol. Conf., OTC 1031, 1969, pp. I286-I298. Progress in marine hard mineral exploration and exploitation has been severely restricted by technologic gaps and the lack of discovery of deposits that can be exploited at a competitive price in the world markets. Immediate needs include improved techniques of placer drilling to permit more reliable evaluation of in situ deposits and improved systems of dredging and processing in greater depths of water and in heavier seas. New exploration techniques for locating and characterizing the subsurface deposits, and breakthroughs in low-cost methods for rapid detailed three-dimensional mapping of the seafloor relief, similar to the photogrammetry breakthrough on land, would offer new incentives to industry. Advances in solution mining, in situ extraction techniques, and rapid excavation with the possibilities of sub-sea entry, could eventually shift the emphasis in ocean mining from near shore placers to large-scale exploitation of deeply buried consolidated deposits.

OP 116-69. Techniques for Diesel Emissions Measurement, by R. W. Hurn and W. F. Marshall. Trans. 1968 SAE, v. 77, No. 680418, 1969, pp. 1492-1500. Methods used in diesel emissions measurement at the Bartlesville Petroleum Research Center are described; limitations, adequacy, and needs for further development of each are discussed. Smoke measurements are reported from work with the Hartridge meter, as well as newly developed instruments that are used to view smoke plumes directly, and which seem to offer advantage over smokemeters previously used. Experience in odor assessment by a human panel using reference odor materials is reported as encouraging. Odor intensity is judged with much greater reliability than odor quality; capability to assess the latter remains wholly inadequate.

Results in application of the methods for measuring diesel emissions are intended to illustrate the use of experimental techniques to reveal engine and fuel factors as they influence the character, amount, and air-polluting effect of diesel emissions. Although the data do not permit reliable assessment of any of the factors, they are useful in showing orders of magnitude and possible relative significance of the respective emissions in the several categories.

OP 117-69. An Independent's Struggle With Steam, by F. Sam Johnson, Abdo F. Bayazeed, and Harold Dutcher. Independent Petroleum Monthly, v. 40, No. 3, July 1969, pp. 2-8. For over three years Dubros, Inc., intermittently steamflooded a 280-foot-deep, 27-foot-thick Peru sand reservoir containing 29° API gravity oil. The project was stopped in February 1969 when the coil in the last steam generator developed a leak. Insufficient data prevent a technical evaluation of the steamflood results, but operational problems were the main reason that steam injection failed. Some of the problems experienced and the solutions found are presented for the benefit of others attempting steamflooding.

OP 118-69. Ignition and Flammability Properties of Lubricants, by J. M. Kutchta and R. J. Cato. SAE Proc., No. 680323, 1968, pp. 1008-1020. The ignition temperature and flammability properties of combustible fluids are useful in determining safety guidelines and in assessing the fire or explosion hazard that may exist in the environment where the fluids are employed. This report is a compilation and review of such information for over 90 lubricants and hydraulic fluids. Particular emphasis is given to those fluids used in aircraft applications. Data are presented for petroleum base fluids and purely synthetic fluids in air, oxygen, and oxygen-nitrogen atmospheres at pressures from ⅛ to 1,000 atm.

OP 119-69. Solvent Extraction in the Presence of Emulsion-Forming Residues—Application to the Atomic Absorption Determination of Gold in Low Grade Ores, by Stephen L. Law and Thomas E. Green. Anal. Chem., v. 41, No. 8, July 1969, pp. 1008-1011. Extraction in the presence of insoluble residues caused a serious emulsion problem in the development of an aqua regia, methyl isobutyl ketone extraction, atomic absorption method for determining microgram quantities of gold in ore samples weighing up to 500 grams. A study of factors affecting the change in volume of ketone during the extraction showed that, under proper conditions, atomic absorption analysis of the small quantity of ketone which separated as a clean phase provided quantitative results. The use of solvent extraction in the presence of insolubule residues which cause the formation of large emulsions has not been previously reported. This technique should have general application in many other extraction methods of analysis.

OP 120-69. Electrodeposition of Molybdenum Coatings, by Frank X. McCawley, Charlie Wyche, and David Schlain. J. Electrochem. Soc., v. 116, No. 7, July 1969, pp. 1028-1033. The electrodeposition of coatings of molybdenum from a sodium and lithium metaborate-molybdate-molybdenum oxide fused-salt system was investigated. Coatings up to 16 mils thick were deposited on Inconel, Carpenter 20 stainless steel, nickel, copper, and graphite at current densities of 3.1-6.2A dm^{-2} (0.2-0.4A in^{-2}) and 900° C under an argon atmosphere. The composition of the electrolyte is critical; deposits are obtained only when the electrolyte contains between 1.0 and 3.3 percent molybdenum.

OP 121-69. Homogeneous Catalytic Deuteration of Olefinic Double Bonds, by J. R. Morandi and H. B. Jensen. J. Org. Chem., v. 34, No. 6, June 1969, pp.

1889-1891. The specific deuteration of olefins using tris(triphenylphosphine)rhodium(I) chloride (A) as a homogeneous catalyst has been investigated. Seventeen *n*-monoolefins were deuterated and the distribution and the vicinal positions of the deuterium atoms were located by mass spectrometry. Deuterium adds specifically across the double bonds in *n*-monoolefins and the reaction proceeds to completion in a reasonable time. The mass spectral fragmentation patterns for the deuterioalkanes formed by this specific labeling technique can be used to locate the deuterium atoms and thus to determine the position of the double bond in the original olefin.

OP 122-69. Nonmetal Elements and Compounds, by J. C. Morris, D. R. Latham, and W. E. Haines. Anal. Chem., v. 41, No. 5, April 1969, pp. 170R-176R. This is the ninth in a series of reviews of analytical chemistry as used in the petroleum industry. It reviews the progress of analytical chemistry for sulfur, nitrogen, oxygen, phosphorus, and halogens in petroleum. It covers essentially the period 1966-67.

OP 123-69. Separating Intermediate Phases From Zinc-Base Alloys, by L. A. Neumeier and J. S. Risbeck. Metallography, v. 2, No. 1, March 1969, pp. 107-108. A method is described for electrolytically extracting intermediate phase particles from zinc-base alloys containing no more than 3 wt pct Cu and 1 wt pct Ti. The zinc solid-solution matrix is selectively dissolved in an electrolyte of CrO_3 in water at about 40 volts dc, and the insoluble phase particles settle to the bottom of the cell, are washed, dried, and analyzed by X-ray diffraction.

OP 124-69. Roasting Nonmagnetic Taconites With Scrap Iron as a Reductant, by Charles Prasky and R. E. Peterson. 30th Ann. Mining Symp. and 42d Ann Meeting of the Minnesota Sec., AIME, University of Minnesota, Jan. 13-15, 1969, Duluth, Minn., pp. 183-188; Blast Furnace and Steel Plant, v. 57, No. 7, July 1969, pp. 570-576. Recent advancements are described in the pilot plant development of the Bureau of Mines' process for roasting iron ores with ferrous scrap as the primary reductant to obtain artificial magnetite. Quality magnetic concentrates containing about 68 percent Fe and 6 percent SiO_2 with iron recoveries of about 90 percent were obtained after roasting fine-grained nonmagnetic taconites (32 percent Fe) with sheared automobile hulks in a rotary kiln. The relatively more thorough destruction of the lighter gage metal in the automobile by oxidation during roasting resulted in a metallic coproduct of unconsumed scrap consisting somewhat selectively of the heavier gage metal. This tailored scrap is potentially useful as a heavy melting material which is more valuable than the original scrap.

OP 125-69. Electrodeposition of Rhodium From a Molten Sodium Cyanide Electrolyte, by G. R. Smith, C. B. Kenahan, R. L. Andrews, and David Schlain. Plating, v. 56, No. 7, July 1969, pp. 805-808. A method for electrodepositing thick, protective coatings of rhodium from a fused-salt electrolyte was developed. The electrolyte was made by dissolving rhodium in molten sodium cyanide. The cell was operated at 600° C under an atmosphere of argon with anodes of rhodium or graphite and a cathode made of one of several substrate materials. Deposits as thick as 7.8 mils were obtained. Evidently rhodium has a valence of +1 in the ion which is discharged at the cathode. When electrodeposition was carried out in the presence of air the bath deteriorated within a few hours. The rhodium coatings protected molybdenum from oxidation at temperatures up to 1,270° C, 700° C above the normal oxidation temperature of the metal; tungsten was protected up to 1,330° C, 600° C above its oxidation temperature.

OP 126-69. SMRL Soil Stress Cell, by Robert C. Bates. Proc. 7th Ann. Engineering Geology and Soils Engineering Symp., Apr. 9-11, 1969, University of Idaho, Moscow, Idaho, 1969, pp. 9-32. A soil stress cell developed at the Bureau of Mines Spokane Mining Research Laboratory is described. The construction techniques, calibration procedures, and inclusion effects are detailed.

OP 127-69. The Economics of Mined-Land Reclamation, by David B. Brooks. Proc. Mining Environmental Conf., Apr. 16-18, 1969, University of Missouri, Rolla, Mo., 1969, pp. 85-96. This paper discusses the use by government of benefit-cost analysis in evaluating and comparing various possible antipollution actions. Although it requires the estimation of damage functions (which relate the occurrence of pollutants to the damages they cause) and of cost functions (which relate the reduction of pollutants to control costs), benefit-cost analysis can often indicate, at least approximately, the net gains to be expected from proposed public actions.

OP 128-69. Explosive Detonation Tested in Hydraulically Fractured Gas Wells, by W. D. Howell and J. B. Hille. 44th Ann. Fall Meeting, Soc. Petrol. Eng., AIME, Denver, Colo., Sept. 29, 1969, SPE 2605, 8 pp. A procedure and technique for stimulating low-permeability gas reservoirs by chemical explosive fracturing was investigated by the Bureau of Mines.

OP 129-69. Air Pollution and the Compression-Ignition Engine, by R. W. Hurn. 12th Internat. Symp. on Combustion, University of Poitiers, France, July 14-20, 1968. Combustion Institute, Pittsburgh, Pa., 1969, pp. 677-687. Except for the problems of odor and of oxides of nitrogen, it would appear that the combustion processes of the diesel engine are inherently favorable toward engine design and operation for reduction in pollutants to meet environmental needs.

OP 130-69. BuMines Research Center Aids Efficient Use of Oil, by Bill Linville. Oil Daily, Suppl., No. 4,565, Aug. 25, 1969, pp. 4 and 24. For more than 50 years, the Bureau of Mines Bartlesville Petroleum Research Center in Bartlesville, Okla., has worked closely with the petroleum industry of Tulsa and other areas. This article describes some of the accomplishments of the research center and its current research program. The six research groups described include basic production research, petroleum engineering, petroleum chemistry and refining, thermodynamics, fuels combustion, and properties and flow of reservoir fluids. The physical plant of the research center is also briefly described.

OP 131-69. Design of Cylindrical Channel Flame Arrestors, by Elton L. Litchfield and Joseph M. Kuchta. Instrument Soc. of America, ISA Monograph 112, 1969, pp. 70-74. The various steps involved in designing a cylindrical channel flame arrestor for instrumentation application are considered. For conservative design, the principal uncertainties relate to the quantitative prediction of the cooling of the combustion products in the cylindrical channel.

OP 132-69. Conservation of Mineral Resources, by Charles W. Merrill. Min. Cong. J., v. 55, No. 8, August 1969, pp. 65-69. An examination of the complex problem of applying our best conservation efforts to assure that the United States experiences neither wanton waste of our mineral resources nor deprivation through hoarding.

OP 133-69. A Discounted Cash Flow Model for Evaluating the Cost of Producing Iron Ore Pellets From Magnetic Taconite, by R. W. Michelson and H. J. Polta. In a Decade of Digital Computing in the Mineral Industry, ed. by Alfred Weiss. American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, 1969, pp. 111-140. Discounted cash flow analysis is commonly used to evaluate the profit making potential of a business venture. The same method can be used to analyze the effects of varying physical and economic conditions upon the real cost of supplying a mineral commodity. If a fixed rate of return on a capital investment is specified, and the flow of cash, discounted at that rate, is just adequate to repay the investment over the life of the venture, the net present value of the venture is zero. At this condition it is possible to evaluate the unit cost of producing the mineral. It will be exactly equal to the selling price required to calculate a zero present value.

Increasing a particular cost factor will not always increase the cost of supply by the same amount. For example, in iron production from magnetic taconite, an increased cost per ton associated with beneficiation would be integrated into the discounted cash flow model along with local, State, and Federal taxes, depletion and depreciation allowances, resultant increased unit recoveries, and all of the other related component cost factors. Rather than adding to the cost, the factor may have a positive, instead of negative, effect on the discounted cash flow and cause a decreased cost of supply. This value can be determined by a computer model which iterates the necessary selling price until the net present value is essentially zero. The discounted cash flow evaluation model lends itself particularly well to an application of the Monte Carlo simulation method for calculating a probability distribution of iron unit cost resulting from the probability distributions of the component cost factors.

OP 134-69. Natural and Induced Systems and Their Application to Petroleum Production, by J. Pasini III and W. K. Overby, Jr. 44th Ann. Fall Meeting, Soc. Petrol. Eng., AIME, Denver, Colo., Sept. 28-Oct. 1, 1969, SPE 2565, 5 pp. The Bureau of Mines is investigating the orientation of hydraulically induced fractures in petroleum reservoirs. The results of analyses of surface and subsurface information show a definite correlation between surface lineations and azimuths of hydraulically induced fractures. Joint systems determined from remote sensing imagery and/or surface surveys have been correlated with subsurface fracture orientations to depths of 3,000 feet and used to predict the bearing of hydraulically induced fractures in the Appalachian basin. Possible applications of fracture orientation prediction to petroleum production are also discussed.

OP 135-69. Separation of the Neon Isotopes by Cryogenic Chromatography, by A. Purer, R. L. Kaplan, and D. R. Smith. J. Chromatographic Sci., v. 7, August 1969, pp. 504-507. A gas chromatographic system for the separation of the neon isotopes is described. Separation was obtained by using a soft-glass capillary column with an etched internal surface operating at established critical working conditions. The desired α values for this type of separation exist only at cryogenic temperatures; therefore, a helium refrigerator was used to obtain column temperatures of 15° to 25° K. At these operating temperatures the column's adsorptive affinity for small neon samples became so great that neon would not pass through the column. Therefore, it was necessary to cover the more highly active adsorption areas with a material that had no interaction with the neon sample. This was done by using hydrogen as a deactivating gas mixed with the helium carrier gas. The high resolution obtained for the separation of Ne^{20} and Ne^{22} indicates that it should also be possible to separate Ne^{21}. The value of these purified neon isotopes warrants additional development of this method on a preparative scale.

OP 136-69. Utilization and Stabilization of Solid Mineral Wastes, by Joe B. Rosenbaum and Karl C. Dean. Proc. Engineering Foundation Research Conf., Solid Waste Research and Development, II, Wayland Acad., Beaver Dam, Wisc., July 22-26, 1968. Preprint C-13, 4 pp. This report reviews the work in progress at the Salt Lake City Metallurgy Research Center on selected mineral waste accumulations under both utilization and stabilization categories.

OP 137-69. Gold in Sea Water—Fact or Fancy, by Joe B. Rosenbaum, Joan T. May, and J. M. Riley. Mines Magazine, v. 5, No. 9, September 1969, pp. 14-17. This brief experiment by the Bureau of Mines to determine a threshold values for the gold in sea water employed solvent extraction for initial concentration, evaporation of the gold loaded organic for further concentration, and atomic absorption analysis of the gold in the concentrated organic. Radioactive gold was used as a tracer for monitoring the gold through the concentration and analytical steps. Our method established that sea water contains about 11 parts of gold per trillion parts sea water or 0.001 cent worth per ton. This agrees closely with results of recent studies by other investigators employing ion exchange resins and neutron activation techniques.

OP 138-69. The Effect of a Siemens Ozonizer Discharge on the Reaction of Carbon Monoxide and Steam, by T. C. Ruppel, P. F. Mossbauer, and D. Bienstock. In Chemical Reactions in Electrical Discharges. Adv. in Chem. Ser. 80, 1969, pp. 214-231. The gas-phase reaction of carbon monoxide and steam to produce carbon dioxide and hydrogen has been studied in the presence of a Siemens ozonizer discharge. The effect of process variables on carbon monoxide conversion was investigated.

OP 139-69. Electrodeposition of Titanium Diboride Coatings, by David Schlain, Frank X. McCawley, and Charlie Wyche. J. Electrochem. Soc., v. 116, No. 9, September 1969, pp. 1227-1228. Adherent, smooth coatings of titanium diboride, metallic in appearance and 3 to 6 mils in thickness, were electrodeposited on Inconel from a molten-salt electrolyte at 900° C. The electrolyte consisted chiefly of $NaBO_2$ and $LiBO_2$ with smaller amounts of Na_2TiO_3, Li_2TiO_3, and TiO_2. The electrolytic cell was operated under an argon atmosphere at cathode and anode current densities of approximately 0.4 A per in² (6.2 A per dm²). The coating was formed at the rate of about 1 mil per hr. The soluble titanium anode was stationary and the cathode was rotated at 250 rpm. The cell voltage was approximately 0.3 volt.

OP 140-69. **The Structure of Low-Velocity Detonation Waves,** by Richard W. Watson. 12th Internat. Symp. on Combustion, University of Poitiers, France, July 14-20, 1968. Combustion Institute, Pittsburgh, Pa., 1969, pp. 723-729. High-speed photographic and radiographic evidence is presented in support of a previously developed model of low-velocity detonation showing the existence of a cavitation field between the shock front and the reaction zone.

OP 141-69. **Incineration of Radioactively Contaminated Combustible Wastes,** by Richard C. Corey, Ch. 10 in Principles and Practices of Incineration, ed. by R. C. Corey. John Wiley & Sons, Inc., New York, 1969, pp. 239-253. This chapter on the safe, economical disposal of radioactively contaminated solid wastes, generated by institutional, commercial, and industrial users of radioisotopes discusses the selection of a suitable size and type of incinerator, the protection of personnel handling raw wastes and solid incinerator residues, the precention of contamination of the public domain by excessive radioactivity in the gaseous and particulate emissions from the incinerator stack, and the technology of each step in the system.

OP 142-69. **A Valence Force Field for Aliphatic Sulfur Compounds: Dithiaalkanes,** by Donald W. Scott and M. Zaki El-Sabban. J. Molecular Spectroscopy, v. 31, No. 3, September 1969, pp. 362-367. To obtain reliable vibrational assignments for use in statistical thermodynamic calculations for dithiaalkanes, the valence force field reported earlier for alkanethiols and thiaalkanes was extended to include the dithiaalkanes. The six additional force constants involved in the potential function of the dithiaalkanes were evaluated from observed wavenumbers of the following four molecules: 2,3-dithiabutane, 2,3-dithiapentane, 3,4-dithiahexane, and 2,2,5,5-tetramethyl-3,4-dithiahexane. The mean deviation of the calculated wavenumbers from the observed ones is 12.3 cm^{-1} or 1.1 percent, only slightly larger than for the alkanethiols and thiaalkanes. Previous assignments for the four investigated molecules were critically examined in the course of the molecular vibrational analysis and revised as necessary, and the probable conformations in which they can exist are presented and discussed.

OP 143-69. **A Valence Force Field for Thiophene and Its Deuterium and Methyl Derivatives,** by Donald W. Scott, J. Molecular Spectroscopy, v. 31, No. 3, September 1969, pp. 451-463. To obtain reliable vibrational assignments for use in statistical thermodynamic calculations, a valence force field was derived from 300 observed vibrational wavenumbers of thiophene, 8 deuterium derivatives, and 6 methyl derivatives. Of the 45 force constants, 25 were adjusted to fit the a_1, b_1, and a' fundamentals; 14 were adjusted to fit the a_2, b_2, and a'' fundamentals; and 6 pertaining to the methyl group were transferred from other molecules. The mean deviation of the calculated wavenumbers from the observed ones was 7.3 cm^{-1} or 0.73 percent for the a_1, b_1, and a' species and 2.6 cm^{-1} or 0.46 percent for the a_2, b_2, and a'' species. A vibrational assignment proposed in the literature for the parent compound was substantiated, and reliable vibrational assignments were obtained for the two monomethyl and four dimethyl derivatives.

OP 144-69. **Simultaneous DTA-TG-MSA Apparatus for Thermal Study of Natural Fuels,** by John Ward Smith and Donald R. Johnson. Proc. 2d Internat. Conf. on Thermal Analysis, Holy Cross College, Worcester, Mass., Aug. 18-23, 1968, v. 2, 1969, pp. 1251-1268. Quadrupole equipment added to apparatus designed expressly for thermal analysis of natural fuels like oil shale provides continuous mass spectrometric analysis (MSA) of evolving gases, differential thermal analysis (DTA), and thermogravimetry (TG) simultaneously on a single sample. Described is tested apparatus developed specifically to solve problems inherent in thermal analysis of solid fuels. Key to this solution is the use of thin, flat pans as sample holders. Adaptation of the quadrupole euipment to sample and analyze evolving gases in a carrier stream is described. Because gases evolve rapidly from the thin sample layer, the resulting gas analysis corresponds closely with DTA and TG results. Tests run on Green River Formation oil-shale minerals demonstrate the value of the MSA data generated by the quadrupole gas analyzer.

OP 145-69. **Controlled Low-Temperature Pyrolysis of Benzene-Extracted Green River Oil Shale,** by J. J. Cummins and W. E. Robinson. Div. Petrol. Chem., ACS, Preprints, v. 12, No. 4, September 1968, pp. 41-47. Green River oil-shale kerogen was pyrolyzed at 300° and 350° C and the order, rate, and activation energy of the thermal reaction were determined. The composition of the pyrolytic products was determined.

OP 146-69. **Thermal Properties of Barium Chloride From 300° to 1350° K,** by T. Estelle Gardner and Arthur R. Taylor, Jr. J. of Chem. and Eng. Data, v. 14, No. 3, July 1969, pp. 281-283. The heat contents of $BaCl_2$ have been determined from 300° to 1,350° K using an ice calorimeter. The results of this investigation were correlated with low-temperature heat-capacity data on a sample from the same batch of material. A transition at 1,198° K with ΔH_T = 4.05 kcal per mole and a melting point of 1,235° K with ΔH_f = 3.82 kcal per mole were found for the sample.

OP 147-69. **Rock Mechanics Can Help Underground Blasting Practice,** by James J. Olson and David E. Fogelson. Min. Eng., v. 21, No. 9, September 1969, pp. 89-92. The Bureau of Mines undertook a research program in cooperation with White Pine Copper Co., Mich., to determine how rock adjacent to a newly opened underground working could be left as undisturbed as possible, leaving a competent structure which would tend to limit rock falls. Geophysical techniques were used to study rock properties (resistivity and seismic velocities) in a tunnel excavated with a pilot bore driven with explosives. The differences in vibration levels due to size of charge, type of explosive (AN-FO or 60 percent ammonia dynamite), and structural flaws in the mine roof were investigated. It was found that reducing the zero delay charge would effectively limit vibrations transmitted to already weakened roof rock. Differences due to explosive type were found to be larger than the differences due to structure of the roof. Scaling by the square root of the V-cut charge weight did the best job of grouping the data. The empirical propagation equation $AW^{1/2}$ 50,000 $(R/W^{1/2})^{-2.2}$ where A is the peak-to-peak acceleration in gravities, W is the zero delay charge weight in pounds, and R is the distance from the blast in feet, may be used to estimate the maximum accelerations from underground mine blasts.

OP 148-69. Some Surface Variations Resulting From Additives in the Electrowinning of Zinc, by H. Fukubayashi, T. J. O'Keefe, H. Kenworthy, and L. W. Higley. Proc. 2d Ann. Symp. on Scanning Electron Microscopy, IIT Research Institute, Apr. 29-May 1, 1969, Chicago, Ill., 1969, pp. 285-294. An examination by the Bureau of Mines of the surface structure of zinc electrodeposited from an acid sulfate solution was made by scanning electron microscopy techniques. The starting solutions were in a range of acid and zinc concentrations commonly used in commercial practice. Changes in morphology resulting from additives such as animal glue, gum arabic, and sodium silicate are compared.

OP 149-69. Reclaiming Refractory Carbides and Cobalt From Cemented-Carbide Scrap, by P. G. Barnard, A. G. Starliper, and H. Kenworthy. Secondary Raw Materials, v. 7, No. 9, September 1969, pp. 19-21. The Rolla Metallurgy Research Center of the Bureau of Mines has developed a new method for reclaiming refractory carbides and cobalt from cemented-carbide scrap involving the use of molten zinc which tends to disintegrate the carbide mass by forming an alloy with the cobalt binder. Subsequently, the zinc is recovered by distillation. Refractory carbides and the cobalt remain in a mass which can be ground to desired particle size and be totally reused. This method can be used to recover costly materials that are now being discarded. The patent on this method is pending.

OP 150-69. Discrete Averaging of X-Ray Diffraction Data Using a Multichannel Analyzer, by Martin Berman and Sabri Ergun. Rev. Sci. Instr., v. 40, No. 9, pp. 1144-1145. A system is described in which a multichannel analyzer is used to repeatedly scan a powder X-ray diffraction spectrum in discrete intervals. Counts are recorded at a given angle for the required dwell time. A preset indexer actuated by the multichannel analyzer drives a stepping motor the required increment in angle. The channel memory is advanced by one and the above process is repeated until the end of a scan. The indexer then drives the diffractometer back to the starting angle. Scans are repeated until sufficient data are accumulated. All the scans are made in the same direction to avoid backlash errors. The system prints out the contents of the memory at definite intervals (usually every 12 hours) so that in the event of a malfunction only the data taken since the last printout are lost. Other advantages and some disadvantages of the system are described.

OP 151-69. Flotation of Southeastern Kyanite Ore, by James S. Browning. Trans. SME, AIME, v. 244, September 1969, pp. 283-287. The Bureau of Mines conducted laboratory and small scale continuous tests of kyanite ore from Georgia and South Carolina to determine the technical feasibility of recovering commercial-grade kyanite concentrates by flotation. The research indicated that combinations of sulfuric acid and petroleum sulfonate may be used effectively for flotation of kyanite from quartzite-kyanite ore. This report summarizes the results of these tests and demonstrates the feasibility of producing commercial-grade concentrates with a high recovery of the contained kyanite.

OP 152-69. Principles of Rock Cutting Applied to Mechanical Boring Machines, by William E. Bruce and Roger J. Morrell. Proc. 2d Symp. Rapid Excavation, "Progress Toward Goals," ed. by H. L. Hartmann. Sponsored by School of Engineering, Sacramento State College, Sacramento, Calif., Oct. 16-17, 1969, pp. 3-1 through 3-43. The Mechanical Fragmentation Laboratory at the Twin Cities Mining Research Center of the Bureau of Mines is conducting research directed toward more efficient tunneling to be achieved through more precise application of boring machines to rocks as well as through better understanding of the parameters influencing design of suitable boring machines. Research equipment includes a multipurpose boring unit equipped with tunneling machine cutters to simulate the action of a shaft-drilling or tunnel-boring operation. Another device being used to study the operation of cutters is called a linear-cutter apparatus. Results obtained with the linear-cutter apparatus are presented here with suggestions as to possible applications by those industry personnel skilled in boring machine design.

OP 153-69. The Activity of Zinc in Liquid Zn-Al Alloys From Isopiestic Measurements, by Pedro Bolsaitis and Paul M. Sullivan. Trans. Met. Soc., AIME, v. 245, July 1969, pp. 1435-1438. The activities of zinc in liquid Zn-Al alloys in the temperature range of 1,000° to 1,160° K were determined by means of the isopiestic technique. The results are in reasonable agreement with the previous values determined by the radioactive tracer dewpoint method. Slightly negative excess entropies of mixing were found. The measured activities suggest that the α function for these alloys is not a constant, as has frequently been assumed, but is better represented by two straight line segments of different slopes.

OP 154-69. Mining and Mineral Recovery, by Michael J. Cruickshank. Ch. 6 in UnderSea Technology Handbook Directory 1969. Compass Publications, Inc., Arlington, Va., pp. A45-A55. This literature survey presents, in summary and tabular form, the current activities in mining and mineral recovery from the oceans and comments on some of the more salient happenings for 1968. For more detailed information on specific points the reader is referred to appropriate publications in the bibliography.

OP 155-69. Thermodynamic Anomalies of a van der Waals Helium-Nitrogen Solution at the Critical Point of Pure Nitrogen, by B. J. Dalton and Robert E. Barieu. J. Chem. Physics, v. 51, No. 7, Oct. 1, 1969, pp. 2920-2924. For a van der Waals He-N_2 solution, it is shown that in the limit of the infinitely dilute solution of He in N_2 (with the exception of the heat capacity at constant volume which is zero everywhere for a van der Waals fluid) all relative partial molal thermodynamic properties of He are infinite at the critical point of pure N_2; all relative partial molal thermodynamic properties of N_2 with the exception of the chemical potential and the heat capacity at constant pressure, exhibit a finite, nonzero singularity at the critical point of pure N_2, and the limiting value of the singularity, as a function of the concentration of He, depends on the path by which this critical point is approached. It is also shown that these same general conclusions are valid for any van der Waals binary mixture and are expressible in terms of the constants appearing in the equation of state itself.

OP 156-69. Evaluating Blasting Techniques in Frozen Gravel, by Richard A. Dick. Min. Cong., J., v. 55, No. 9, September 1969, pp. 30-36. Effects of blast design, delay type, and explosive type were studied in a factorial experiment performed in a 7- by 12-foot tunnel in frozen gravel. Results of a statistical analysis are presented.

OP 157-69. Silylation of Asphalts Within Gas-Liquid Chromatographic Columns, by S. M. Dorrence and J. C. Petersen. Anal. Chem., v. 41, No. 10, August 1969, pp. 1240-1243. Silylation of asphalts within inverse gas-liquid chromatographic (IGLC) columns offers a convenient means to study asphalt functionality. This technique was demonstrated to be effective in blocking phenolic and carboxylic acid OH functional groups in asphalts. This was confirmed by infrared spectra of silylated asphalts. It is suggested that these OH groups interact strongly with both phenol and propionic acid in inverse interaction coefficients for both test compounds. IGLC data on silylated asphalts indicated that formamide interacts strongly with carbonyl groups in asphalts.

OP 158-69. Detonability of the Nitromethane-Hydrazine-Methanol System, by D. R. Forshey, J. C. Cooper, and W. J. Doyak. Explosivstoffe, v. 6, June 1969, pp. 125-129. A study of the detonability of binary and ternary mixtures of nitromethane, hydrazine, and methanol revealed that hydrazine strongly sensitizes nitromethane and nitromethane-methanol mixtures to detonation.

OP 159-69. Separation of Asphaltic Materials by Reversed Phase Partition and Adsorption Chromatography, by R. V. Helm. Anal. Chem., v. 41, No. 10, August 1969, pp. 1342-1344. This preliminary report describes the use of a nonaqueous reversed-phase partition chromatography system followed by silica gel chromatography to separate a molecular distillation fraction from a Wilmington (California) asphalt. In addition, the separation of the same fraction on silica gel only is reported, and a comparison of the separated materials is made by infrared spectrometry.

OP 160-69. Fuel: A Factor in Internal Combustion Engine Emissions, by R. W. Hurn. ASME Winter Annual Meeting, Los Angeles, Calif., Nov. 16-20, 1969, Preprint 69-WA/APC-8, 5 pp. Characteristics of fuel used in an internal combustion engine influence both the amount and the nature of air pollutants associated with engine use. Fuel composition directly governs the amount and character of pollutants from the fuel system and exerts varying influence upon the products of combustion. Fuels could be changed (from typical current practice) to reduce the pollution that results from their use; however, comparable or greater reduction could also be realized through mechanical or engine design changes. The fuel factor is, therefore, only one of several factors that should be considered. But it is important that fuel characteristics be considered in any concept of emission control.

OP 161-69. New Requirements for Self-Contained Breathing Apparatus, by E. J. Kloos. Environmental Control Management, v. 138, No. 4, October 1969, pp. 51-54. This article describes the major changes in the Bureau of Mines revised schedule for self-contained breathing apparatus. Schedule 13E, and explains their significance.

OP 162-69. Induced Oxidation-Precipitation of Iron From Aqueous Solutions of $MnSO_4$-$FeSO_4$, by Vance G. Leak and M. M. Fine. I&EC Fundamentals, v. 8, No. 3, August 1969, pp. 411-414. The oxidation-precipitation reaction rate of iron(II) in sulfate solutions was measured over the range 110° to 200° C and 90 to 365 psia oxygen to determine its dependence on the temperature and oxygen pressure. Both the intrinsic rate of oxidation-precipitation of iron from iron(II) sulfate and the induced reaction rate in binary manganese(II) and iron(II) sulfate solutions were examined. The reaction in either case is second-order with respect to the iron(II) concentration and first-order with respect to the oxygen partial pressure. However, the rate is greatly enhanced by the presence of the manganese(II) ion. The activation energies are 16.5 kcal per mole for the intrinsic case and 39.4 kcal per mole for the binary case.

OP 163-69. Removal of Sulfur and Nitrogen Oxides From Stack Gases by Ammonia, by C. C. Shale, D. G. Simpson and P. S. Lewis. Proc. Symp. on Important Chemical Reactions in Air Pollution Control. Pt. II, AIChE, Washington, D.C., Nov. 16-20, 1969, Preprint 13b, 17 pp. Complete removal of SO_2 and partial removal of NO_x impurities from a simulated stack gas mixture was effected in laboratory experiments by vapor phase reaction with ammonia. A cyclic process utilizing ammonia involves recovery of the chemical reaction products by condensation and regeneration of the feeds by thermal decomposition and reaction of acidic constituents with ZnO. Ammonia is separated for recycle, and essentially pure SO_2 is recovered as a byproduct. Ash particles not removed by mechanical separation are trapped in the condensate. A flow diagram for commercial application of this conceptual process is discussed.

OP 164-69. Respirator Testing and Approval, by Robert H. Schutz. Safety Standards, v. 18, No. 6, November-December 1969, pp. 6-8. This article describes operation to the Bureau of Mines Respirator Approval program and its proposed expansion.

OP 165-69. Use of Sodium Sulfate for Copper Removal From Molten Iron, by Harry V. Makar and Beverly W. Dunning, Jr. J. Metals, v. 21, No. 7, July 1969, pp. 19-22. Use of sodium sulfate (Na_2SO_4) for removing copper and other residual elements from molten iron has been studied at the Bureau of Mines as a possible approach to upgrading low-quality ferrous scrap, such as auto bodies. Earlier studies have shown that a substantial amount of copper can be removed by this process and the amount removed is essentially a function of the amount of Na_2SO_4 added. Final copper concentrations down to <0.002 percent can be achieved, but excessive amounts of Na_2SO_4 are required. Additional studies were undertaken to evaluate possible approaches towards increasing the efficiency of the Na_2SO_4 process. This work included making additions of Na_2SO_4 in different physical forms, adding mixtures of sulfates, recycling used slag, and lance injection and stirring. Efficiency of removal of copper was improved and the data indicate that additional improvement may be possible. Evaluation of these results suggest research areas where more intensive studies would be worthwhile.

OP 166-69. Electrowinning of Hafnium From Hafnium Tetrachloride, by G. M. Martinez, M. M. Wong, and D. E. Couch. Trans. Met. Soc., AIME, v. 245, October 1969, pp. 2237-2242. The Bureau of Mines electrowon hafnium metal with an average oxygen content of 150 ppm at 700° C from an electrolyte containing 27 wt pct LiCl, 62 wt pct RbCl, and 11 wt pct $HfCl_4$. The average anode and cathode current efficiencies were 90 pct at anode and initial cathode current densities of 86 amp per sq ft. Hafnium metal with an average oxygen content of 440 ppm was electrowon at 800° C from an electrolyte containing 90 wt pct KCl and 10 wt pct $HfCl_4$. The average anode and cathode current efficiences were similar to those obtained in the LiCl-RbCl-$HfCl_4$ electrolyte. The chlorine was given off at the graphite anode was vented through either a silica or a graphite tube to prevent cell corrosion.

OP 167-69. Sintered Fly Ash as a Soil Modifier, by J. C. Patterson, Jr., P. R. Henderlong, and L. M. Adams. Proc. West Virginia Academy of Science, v. 40, April 1968, pp. 151-159. Field and laboratory studies are being conducted to evaluate the feasibility of utilizing sintered fly ash as a soil modifier or amendment. Sintered fly ash was applied in 13 different particle size and rate combinations to a poorly drained turf grass area. Incorporation of sintered fly ash with the upper 6 inches of soil generally increased water infiltration and overall soil drainage. As a result of the improved soil drainage, aeration should also be improved and soil compaction reduced. Root penetration and growth should be improved. This should lead to the development of a more vigorous and dense turf or sod cover. Addition of sintered fly ash did not alter the textural classification of the soil, but increased the pH from 6.8 to 7.4. The sintered fly ash apparently acts much like a sponge and tends to absorb large quantities of water. Also, the sorbed water appeared to be retained less vigorously by the sintered fly ash than by the unmodified soil during periods of moisture stress. In general, the soil moisture and moisture tension data supported this hypothesis.

OP 168-69. The Preparation of Low-Ash-Content Anthracite, by W. S. Sanner. Trans. SME, AIME, v. 244, September 1969, pp. 268-276. Experiments were conducted to determine the quantity and purity of ultraclean anthracite that could be prepared in the laboratory, using conventional separating techniques. A low-, a medium-, and a high-volatile anthracite were studied. Specific gravity separation followed by grinding, screening, and refloating at lighter specific gravities yielded small quantities of material purified to 1.0 percent ash, as follows: from low-volatile anthracite, 0.7 percent; from medium-volatile coal, 1.0 percent; and from high-volatile coal, 2.3 percent. The reduction in ash had no appreciable effect on the volatile matter or sulfur content of the coal. The limited quantities of material containing 1.0 percent or less ash obtainable indicate that if ultraclean coal is desired, a practical approach should include the processing units as an integral part of a conventional dense-media washing plant.

OP 169-69. Geochemistry of Oil-Shale Genesis, Green River Formation, Wyoming, by John Ward Smith. Wyoming Geol. Assoc. Guidebook, 1969, pp. 185-190. The chemical conditions of deposition and the mechanics of deposition postulated for Wyoming's Green River Formation oil shales explain development of oil shale containing relatively large amounts of hydrogen-rich organic matter; uniform, minute, and angular mineral particles; and the existence of the minute annual markings called varves. Lateral persistence of lamina is a natural consequence of the manner of development.

OP 170-69. The Effect of Time and Depth of Burial on the Naphtha and Gas Oil Content of Crude Oil, by Harold M. Smith and John S. Ball. Div. Petrol. Chem., ACS, Preprints, v. 14, No. 4, September 1969, pp. E5-E15. The amounts of the naphtha and gas oil fractions of more than 6,000 crude oils were correlated with depth and geologic age of the producing formation.

OP 171-69. Physical and Chemical Beneficiation of Metal and Mineral Values Contained in Incinerator Residue, by Martin H. Stanczyk and Paul M. Sullivan. Soc. Min. Eng., AIME, Ann. Meeting, Washington, D.C., Feb. 16-20, 1969, Preprint 69-B-54, 12 pp. The Bureau of Mines initiated research on reclaiming and recycling metal and mineral values contained in incinerator residues on a continuous basis, using existing mineral engineering technology.

OP 172-69. Correlation of Longitudinal Velocity Variation With Rock Fabric, by R. E. Thill, R. J. Willard, and T. R. Bur. J. Geophys. Res., v. 74, No. 20, Sept. 15, 1969, pp. 4897-4909. In the petrophysical method described, longitudinal wave velocities are measured omnidirectionally in rock spheres, plotted and contoured on Schmidt equal area nets, and compared with structural subfabrics of the rocks. Velocity anisotropy is correlated with the structural preferred orientation of (1) calcite *c*-axes in Yule Marble, (2) elongate vesicles in Newberry Crater pumice, and (3) microfractures in quartz in the Salisbury Granite.

OP 173-69. A New Technique for Preparing Rock Spheres, by B. L. Vickers and R. E. Thill. J. Sci. Instr., v. 2, No. 2, October 1969, pp. 901-902. A new sphere preparation technique which reduces sphere preparation time to about half that required by conventional techniques was developed at the Bureau of Mines Twin Cities Mining Research Center. In the new technique, the rock specimen is core drilled in three mutually orthogonal directions and its remaining edges and corners ground on a grinding wheel, before being placed in a sphere grinding machine for final grinding and polishing. The new technique permits closer control of specimen diameter than was possible by former sawing procedures.

OP 174-69. An Improved Torsion Pendulum for Measuring Internal Damping, by A. E. Schwaneke and R. W. Nash. Rev. Sci. Instr., v. 40, No. 11, November 1969, pp. 1450-1453. A new torsion pendulum for measuring internal damping of metals and alloys is described. Improvements over earlier apparatus of this type include (1) a more convenient specimen shape, (2) an electromechanical transducer to measure angular deflections, (3) automatic compensation for eccentric vibrations when operated in the bearing-free mode, and (4) a continuous range of over 500:1 in strain amplitudes with a signal-to-noise ratio of better than 2:1 at a strain of less than 6×10^{-6}. Specific damping capacities ranging from 80 percent (log decrement, 0.81) to 0.01 percent (log decrement, 5×10^{-5}) have been measured, and stresses as high as 1,970 kg/cm^{-2} have been used.

OP 175-69. Low-Resolution Mass Spectrometric Determination of Aromatic Fractions From Petroleum, by C. J. Robinson and Glenn L. Cook. Anal. Chem., v. 41, No. 12, October 1969, pp. 1548-1554. A mass spectrometric procedure for determining up to 21 compound types in petroleum aromatic fractions is described. The entire composition of any sample is accounted for in terms of 12 hydrocarbon types, three thiophenol types, and six unidentified groups. Inclusion of the unidentified components avoids the difficulties encountered in earlier methods which described composition in terms of a fixed number of named types.

OP 176-69. The Isolation of Steranes From Green River Oil Shale, by P. C. Anderson, P. M. Gardner, E. V. Whitehead, D. E. Anders, and W. E. Robinson. Geochim. et Cosmochim. Acta, 1969, v. 33, pp. 1304-

1307. The C_{29} sterane was identified and the presence of the C_{27} steranes in Green River oil shale was confirmed. This was accomplished by comparison of the spectra of the isolated components with authentic standards.

OP 177-69. Some Fundamental Properties of Rock Noises, by Wilson Blake and Wilbur I. Duvall. Trans. SME, AIME, v. 244, September 1969, pp. 288-290. A study of self-generated rock noises by a broad-band microseismic system has revealed two important fundamental properties which can be utilized to make the microseismic method of detecting and delineating unstable rock much more useful than it is in its present form: (1) the frequency spectrum of rock noises is very broad and (2) both *P* and *S* waves are readily identifiable on high-speed rock noise accelerograms.

To take advantage of these properties microseismic equipment should be broad-band with the combination of high sensitivity and high resonant frequency in the geophone so that it will respond to signals of all frequencies, thus permitting recognition of both *P* and *S* waves on microseismic recordings. Such equipment makes possible the source location of rock noises by the *S-P* method.

OP 178-69. 3-Methyl-1,2-butadiene: Enthalpies of Combustion and Formation, by William Good. J. Chem. and Eng. Data, v. 14, No. 4, October 1969, pp. 480-481. The enthalpy of combustion of liquid 3-methyl-1,2-butadiene was measured in an oxygen-bomb calorimeter. The enthalpy of formation was derived. The following values, in kcal per mole at 298.15° K, are reported for liquid 3-methyl-1,2-butadiene: $\Delta Hc^\circ = -767.70 \pm 0.10$, $\Delta Hf^\circ = 24.18 \pm 0.12$.

OP 179-69. Gas Chromatographic Analysis of Vehicular Exhaust Emissions, by Basil Dimitriades, C. F. Ellis, and D. E. Seizinger. Ch. in Advances in Chromatography, ed. by J. C. Giddings and R. A. Keller. Marcel Dekker, Inc., New York, 1969, v. 8, pp. 327-362. Procedures are described for sampling and analysis of automotive exhaust emissions. Emphasis is on hydrocarbons and oxygenated hydrocarbon derivatives. Procedures include sampling, chromatographic separation, and generation and treatment of quantitative data.

OP 180-69. Surface Conductance and Electrokinetic Properties of Kaolinite Beds, by Philip B. Lorenz. Clays and Minerals, v. 17, No. 4, October 1969, pp. 223-231. Electrokinetic measurements were made on kaolinite in the sodium, calcium, and acid forms. The results shed light on the structure of the mineral surface.

OP 181-69. Conversion of Coal to Gasoline, by G. Alex Mills. Ind. and Eng. Chem., v. 61, No. 7, July 1969, pp. 6-17. This paper describes certain new concepts in catalytic chemistry which have potential for a major contribution to coal-to-gasoline technology. Most of these have been investigated by the Bureau of Mines in its exploratory basic research program and have not yet been developed into practical utility, although work on this phase is actively in progress.

OP 182-69. Prediction of Gasoline Storage Stability, by F. G. Schwartz, C. S. Allbright, and C. C. Ward. National Combined Fuels and Lubricants and Transportation Meetings, SAE, Houston, Tex., Nov. 4-7, 1969, SAE paper 690760, 9 pp. A 16-hour accelerated aging test is described which provides data for predicting the amounts of gum and lead precipitate that will form in a gasoline during storage.

OP 183-69. How to Effect a Cost Reduction in Diamond Drilling, by K. C. Strebig, C. W. Schultz, and A. A. Selim. Min. Eng., v. 21, No. 10, October 1969, pp. 73-75. An investigation of the diamond drilling of quartzite with impregnated bits showed that organic additives can reduce total drilling costs 30 percent.

OP 184-69. Equations of State: A Review for Engineering Applications, by C. Tsonopoulos and J. M. Prausnitz. Cyrogenics, v. 9, No. 5, October 1969, pp. 315-327. No one equation of state can hope to satisfy all the conditions required of it for a variety of fluids. Equations of state are therefore numerous. This article discusses those equations which are useful for engineering applications, particularly cryogenic engineering. Special reference is made in each case to the practical use of the equations discussed.

OP 185-69. Approximate Correction for Unsteady Pressure Differential in a Capillary-Tube Gas Viscosimeter, by K. R. Van Doren, R. A. Guereca, H. P. Richardson, and D. Cummins. J. Appl. Mech., v. 36, No. 2, June 1969, pp. 171-180. Equations are developed which satisfactorily describe the change in the pressure differential with time for a closed, constant-volume system which utilizes a coiled-capillary tube and a constant-rate pump to determine gas viscosities. Viscosities are computed at transient, unsteady, and apparent-steady-state conditions. As long as the flow rates are not too high and the pressure level is not too low, the computed viscosities appear to be reliable.

OP 186-69. Amino Acids as Retaining Agents in Displacement Chromatography of the Rare-Earth Elements, by J. O. Winget and R. E. Lindstrom. Separation Science, v. 4, No. 3, June 1969, pp. 209-216. The feasibility of using amino acids as retaining agents with ethylenediaminetetraacetic acid (EDTA) eluents in displacement chromatography of the rare-earth elements was studied at 85° to 90° C. Hydroxyethylethylenediaminetraacetic acid (HEDTA) and diethylenetriaminepentaacetic acid (DTPA) were the most effective retaining agents investigated.

INDEX OF BUREAU OF MINES PUBLICATIONS

ABBREVIATIONS

B	Bulletin.
CMS	Handbook.
BPA	Bonneville Power Administration, U.S. Department of the Interior.
GS	Geological Survey, U.S. Department of the Interior.
IC	Information Circular.
KNR	Kentucky Geological Survey.
M	Monograph.
MISC	Miscellaneous Publication.
MNR	Maryland Geological Survey.
MY*	Minerals Yearbook.
NCNR	North Carolina Division of Mineral Resources, Department of Conservation and Development.
NMNR	New Mexico Bureau of Mines and Mineral Resources.
OFR	Open-File Report.
OP	Outside Publication.
P	Patent.
PNR	Bureau of Topographic and Geologic Survey, Commonwealth of Pennsylvania.
PPS	Petroleum Products Survey.
RI	Report of Investigations.
S	Schedule.
SCNR	South Carolina State Development Board, Division of Geology.
SP	Special Publication.
TNR	State of Tennessee, Department of Conservation, Division of Geology.
TPR	Technical Progress Report.
VNR	Virginia Department of Conservation and Economic Development, Division of Mineral Resources.

* MY 1968 (v. I–II)—Minerals Yearbook Metals, Minerals, and Fuels, Volume I–II, 1968; MY 1968 (v. III)—Minerals Yearbook, Area Reports: Domestic, Volume III, 1968; MY 1968 (v. IV)—Minerals Yearbook, Area Reports: International Volume IV, 1968.

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