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ADVANCED TECHNOLOGY APPLICATIONS FOR SECOND AND THIRD GENERATION COAL GASIFICATION SYSTEMS

JULY 10, 1980

SRS/SE TR80-11

SRS NAS8-33846

spectra research systems

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NASA CONTRACT: NAS8-33846

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I. INTRODUCTION

This final report is submitted to the George C. Marshall Space Flight Center (MSFC), National Aeronautics and Space Administration (NASA), by Spectra Research Systems, 500 Wynn Drive, Suite 319, Huntsville, AL 35805. It provides a synopsis, in briefing chart format, of the results of a four-month study contract (NAS8-33846) conducted under the technical guidance of Mr. Lott W. Brantley (MSFC) as part of the NASA Headquarters - Energy Systems Division's Energy Technology Program.

The major objectives of this effort were:

- o the establishment of a technical and programmatic data base on second and third generation coal gaisifier systems,
- o analysis of requirements for equipment and component-improvements and advanced technology applications,
- o and the formulation of recommendations for technology development.

Additional activities accomplished included the planning and definition of approaches for detailed investigations and assessments of commercial coal gasification plant startup and operational experience and supporting technology development.

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I. INTRODUCTION

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II. HISTORICAL BACKGROUND OF COAL CONVERSION

COAL GASIFICATION PROCESS DEVELOPMENT CATAGORIES

- FIRST GENERATION
  - PROCESSES DEVELOPED PRIOR TO WWII AND OPERATING COMMERCIALLY
  - FIXED BED LURGI/FLUIDIZED BED WINKLER/ENTRAINED FLOW KOPPERS - TOTZEK

- SECOND GENERATION
  - PROCESSES WHICH INCORPORATE IMPROVED TECHNOLOGY TO INCREASE CONVERSION EFFICIENCY/REDUCE CAPITAL COSTS
  - MOST HAVE BEEN DEMONSTRATED IN PILOT PLANT OPERATIONS BUT HAVE NOT OPERATED ON A COMMERCIAL SCALE
  - TEXACO/SLAGGING LURGI/HIGAS/U-GAS

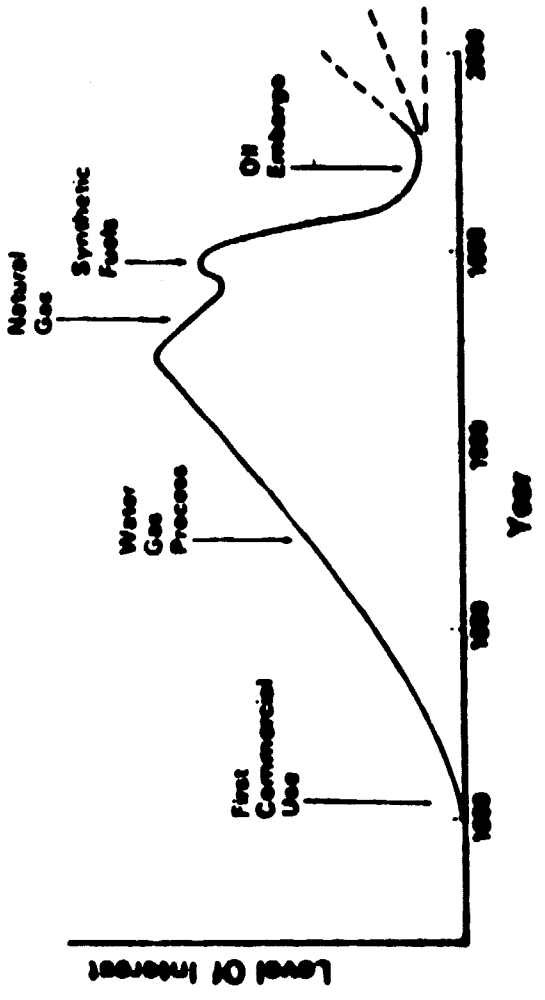
- THIRD GENERATION
  - INCORPORATE ADVANCED TECHNOLOGY THAT OFFERS SIGNIFICANT ADVANTAGES TO IMPROVE PROCESS EFFICIENCY/ECONOMICS
  - REQUIRE FURTHER DEVELOPMENT FOR SCALEUP TO PILOT PLANT OPERATION
  - EXXON CATALYTIC/HYDROGASIFICATION/MOLTEN SALT

HISTORICAL BACKGROUND OF COAL CONVERSION

GASIFICATION

- KNOWN AS EARLY AS 1670 (REVEREND JOHN CLAYTON) THAT GAS COULD BE PRODUCED BY HEATING COAL IN A RETORT
  - 100 YEARS LATER MANUFACTURED GAS INDUSTRY HAD ITS BEGINNING IN ENGLAND (WILLIAM MURDOCH ILLUMINATED HIS HOME IN 1792)
  - LONDON BRIDGE LIT BY COAL GAS IN 1813/WHITE HOUSE in 1848 (FIRST COAL GAS COMPANY IN U. S. STARTED IN BALTIMORE IN 1816)
  - CYCLIC CARBURETTED WATER GAS PROCESS DEVELOPED IN 1875, BUNSEN'S INVENTION OF ATMOSPHERIC GAS BURNER IN 1855 HAD OPENED HEATING MARKET
- DURING 19TH AND 20TH CENTURIES GAS FROM COAL PRODUCED IN U. S. AND EUROPE FOR LIGHTING/COOKING/INDUSTRIAL PURPOSED
  - NEARLY EVERY MAJOR EASTERN U. S. CITY ONCE HAD A COAL GAS PLANT AND ACCOMPANYING CYLINDRICAL STORAGE TANKS
  - BY MID 1920'S APPROX. 11,000 PLANTS WERE OPERATING IN U. S.(6500 IN STEEL PLANTS, 1500 IN GLASS, 1500 IN CERAMICS, 1000 IN GAS UTILITIES, 500 IN METALLURGICAL/CHEMICAL)
  - PRIMARY FEEDSTOCK WAS BITUMINOUS COAL
- PLANTS GRADUALLY DISAPPEARED IN U. S. AFTER WWII DUE TO "CHEAP" NATURAL GAS DISTRIBUTION BY PIPELINE
- INCENTIVE EXISTED IN EUROPE TO CONTINUE TO DEVELOP IMPROVED PROCESSES BECAUSE COAL WAS THE MAJOR AVAILABLE FUEL

HISTORICAL PATTERN OF DEVELOPMENT OF COAL GASIFICATION



PROPERTIES OF COAL-DERIVED GASES

- "PRODUCER GAS" HAS RELATIVELY LOW HEATING VALUE (100-160 BTU/SCF) AND IS PRODUCED BY COMPLETELY CONVERTING COAL OR COKE TO GAS BY CONTINOUS REACTION WITH STEAM AND AIR
- DEVELOPMENT OF CYCLIC WATER-GAS PROCESS PERMITTED CONTINUOUS PRODUCTION OF HIGHER THERMAL CONTENT GAS (300-350 BTU/SCF)
  - ADDING OIL TO REACTOR INCREASES HEAT CONTENT (500-550 BTU/SCF)
  - THIS WAS STANDARD DISTRIBUTED GAS FOR USE IN HOMES/COMMERCIAL ESTABLISHMENTS
  - FIRST SUCCESSFUL SYNTHETIC AMMONIA PLANT BUILT BY TVA IN MUSCLE SHOALS, AL. USED COKE-FED WATER GAS GENERATORS TO PRODUCE REQUIRED SYNTHESIS GAS (BY 1945 STEAM REFORMING OF NATURAL GAS TO PRODUCE H_2 WAS UNDERWAY)

	COKE OVEN GAS	PRODUCER GAS	WATER GAS	CARBURETTED WATER GAS	SYNTHETIC NATURAL GAS
REACTANT SYSTEM	THERMAL HEATING	AIR PLUS STEAM	STEAM (CYCLIC WITH AIR)	STEAM (CYCLIC WITH AIR PLUS OIL)	OXYGEN PLUS STEAM AT PRESSURE
ANALYSIS, VOLUME %[a]					
CARBON MONOXIDE, CO	6.8	27.0	42.8	33.4	0.1
HYDROGEN, H_2	47.3	14.0	49.9	34.6	2.5
METHANE, CH_4	33.9	3.0	0.5	10.4	94.2
CARBON DIOXIDE, CO_2	2.2	4.5	3.0	3.9	0.4
NITROGEN, N_2	6.0	50.9	3.3	7.9	2.8
OTHER[b]	3.8	0.5	0.5	9.8	-
FUEL VALUE, BTU/FT^3	590	150	308	536	962
USES	FUEL CHEMICALS	FUEL	FUEL SYNTHESIS CHEMICALS	FUEL	FUEL SYNTHESIS CHEMICALS

[a] ANALYSES WILL VARY DEPENDING ON TYPE OF COAL AND OPERATING CONDITIONS.
[b] OTHER COMPONENTS INCLUDE HYDROCARBON GASES, HYDROGEN SULFIDE, AND SMALL AMOUNTS OF OTHER IMPURITIES.

HISTORICAL BACKGROUND OF COAL CONVERSION (CONT'D)

GASIFICATION

- WINKLER PROCESS DEVELOPMENT BEGAN IN 1921 AND LED TO CONSTRUCTION OF AIR-BLOWN GASIFIER IN 1926 AT LEUNA, GERMANY
  - EXPANDED TO FIVE GENERATORS BY 1929 PRODUCING 10 MILLION SCF/HR.
  - THREE UNITS CONVERTED TO USE OXYGEN IN 1933
  - 16 PLANTS HAD BEEN CONSTRUCTED UTILIZING 36 GENERATORS BY 1960 (6 PLANTS IN GERMANY, 4-JAPAN, 2-SPAIN, OTHERS IN CZECHOSLOVAKIA, YYGOSLAVIA, TURKEY, INDIA)
- LURGI PROCESS FOR PRESSURE GASIFICATION USING OXYGEN DEVELOPED TO MANUFACTURE AN EQUIVALENT TO COKE-OVEN GAS FROM BROWN COAL IN AREAS WHERE NO CAKING COAL FOR USE IN COKE OVENS WAS AVAILABLE
  - PILOT PLANT BUILT IN 1930 LED TO FIRST INDUSTRIAL PLANT IN HIRSCHFEDLDE, GERMANY IN 1936 (1 MILLION SCF/DAY OF TOWN GAS FROM LIGNITE IN TWO GASIFIERS)
  - 1950-1954 PILOT PLANT AT HOLTEN USFD TO DEVELOP TECHNIQUES TO HANDLE BITUMINOUS (INCLUDING CAKING) COALS TO PRODUCE SYNTHESIS GAS IN ADDITION TO TOWN GAS
  - 13 PLANTS UTILIZING 55 GASIFIERS BUILT BY 1966 IN EUROPE, ENGLAND, AUSTRALIA, PAKISTAN
  - AIR BLOWN PLANT WITH FIVE GASIFIERS BUILT IN 1969 AT ESSEN TO PRODUCE POWER PLANT FUEL
- HEINRICH KOPPERS OF GERMANY ANNOUNCED IN 1942 THE KOPPERS-TOTZEK PROCESS BASED ON PILOT PLANT WORK INITIATED IN 1938
  - FIRST INDUSTRIAL PLANT BUILT IN 1949 IN FRANCE TO PRODUCE SYNTHESIS GAS FOR AMMONIA/METHANOL PRODUCTION
  - TOTAL OF 50 PLANTS HAD BEEN CONSTRUCTED BY MID 1970'S IN EUROPE, JAPAN, FINLAND, UNITED ARAB REPUBLIC, THAILAND, TURKEY, ZAMBIA, SOUTH AFRICA, AND INDIA (APPROX. 20 CURRENTLY IN OPERATION)
  - MOST ARE OXYGEN BLOWN TO PRODUCE SYNTHESIS GAS FOR AMMONIA PRODUCTION

HISTORICAL BACKGROUND OF COAL CONVERSION (CONT'D)

LIQUEFACTION

- PRODUCTION OF LIQUIDS FROM COAL BY DIRECT HYDROGENATION HAD ITS EARLY DEVELOPMENT IN GERMANY (HYDROGASIFICATION FIRST REPORTED BY BRITISH GAS COUNCIL IN 1937)
- BERGIUS DEVELOPED PROCESS TO INTRODUCE PUMPABLE GROUND COAL AND OIL PASTE INTO HIGH-PRESSURE REACTOR
  - PILOT PLANT OPERATION BEGUN IN 1921 WHICH CONVERTED 30-50% OF THE COAL TO OIL AT H_2 PRESSURES OF 1500-3000 PSI, 750-900°F
  - PROCESS IMPROVED IN 1924 BY INTRODUCTION OF CATALYSTS IN FORM OF SULFIDES AND OXIDES (OF MOLYBDENUM, TUNGSTEN, COBALT, IRON) AND SEPARATION INTO TWO STEPS (PARTIAL HYDROGENATION IN LIQUID PHASE PRODUCED HEAVY OIL, VOLATILE PRODUCTS THEN CATALYTICALLY TREATED IN VAPOR PHASE TO PRODUCE GASOLINE AND OTHER LIGHT PRODUCTS)
  - 300 TONS/DAY COMMERCIAL PLANT TO PROCESS BROWN COAL BUILT IN 1926
  - GERMAN PLANTS PRODUCED 25,000 BBL/DAY BY 1939 FROM BITUMINOUS, BROWN COAL, COAL TARS
- "FOR THE LAST 34 YEARS THE DIRECT HYDROGENATION (BERGIUS) PROCESS HAS NOT BEEN USED AND IT IS QUESTIONABLE WHETHER THE TECHNICAL KNOW HOW STILL EXISTS TO UTILIZE THE PROCESS WITHOUT REINVENTING MANY OF THE DETAILS OF ITS OPERATION"

NOTE: THE LIFE OF PRESSURE LET-DOWN VALVES FOR THE BERGIUS PLANTS OPERATED IN GERMANY DURING WAR II WAS IN THE RANGE OF ONE TO 60 DAYS. CURRENT U.S. PILOT PLANT EXPERIENCE INDICATES A PROBABLE MEAN OPERATING LIFE FOR THE INTERNALS OF LET-DOWN VALVES OF APPROXIMATELY 45 DAYS AND FOR VALVE BODIES OF ONE YEAR. THE LONGEST REPORTED LIFE IS ONLY 4,000 HOURS. THE RESULT IS A REQUIREMENT TO INSTALL MULTIPLE LET-DOWN VALVES IN PARELLEL, EACH ACCOMPANIED BY COMPANION STOP VALVES AND CONTROL SYSTEMS TO ASSURE CONTINUITY OF PLANT OPERATION WHEN REPLACING VALVE BODIES AND INTERNALS. A FURTHER COMPLICATION IS THAT, FOR PERSONNEL PROTECTION REASONS, THE LIQUIDS FLOWING THROUGH THE VALVES ARE PREFERABLY CAREFULLY FLUSHED PRIOR TO CLEARANCE FOR ACCESS BY MAINTENANCE PERSONNEL. THE OVERALL RESULTS ARE HIGHER CAPITAL INVESTMENT AND OPERATING COSTS AND A POTENTIAL NEGATIVE EFFECT ON PLANT AVAILABILITY.

HISTORICAL BACKGROUND OF COAL CONVERSION (CONT'D)

LIQUEFACTION

- DIRECT HYDROGENATION PLANT CONPLETED IN ENGLAND IN 1937 (OPERATED ABOUT 2 YEARS THEN SHUT DOWN AT START OF WW II)
- U.S. BUREAU OF MINES CONDUCTED SMALL-SCALE HYDROGENATION EXPERIMENTS DURING 1930'S
  - 100 LB/DAY CONTINUOUS FEED PILOT PLANT CONSTRUCTED IN 1937
  - DURING 1947-1953 200 BBL/DAY DEMONSTRATION PLANT CONSTRUCTED AND OPERATED AT LOUISIANA, MO. (10,000 PSI, 850°F)
  - CONSIDERABLE MECHANICAL PROBLEMS, E.G. EROSION, ENCOUNTERED BUT DEMO CONSIDERED TO BE SUCCESS (VARIETY COAL FEEDSTOCK USED)
  - ACTIVITY NOT CONTINUED DUE TO SUFFICIENT CRUDE OIL RESERVES
- INDIRECT FISCHER-TROPSCH PROCESS FIRST ANNOUNCED IN GERMANY IN 1923
  - COMBINED H_2 AND CO AT 1500 PSI, 750°F OVER NON ALKALI CATALYST
  - PILOT PLANT OPERATIONAL IN 1932 AND 20 BBL/DAY PRODUCED IN 1933
  - NINE PLANTS OPERATIONAL IN GERMANY BY 1939 PRODUCING 16,000 BBL/DAY (USED COBALT CATALYST, ATMOSPHERIC - 300 PSI)
- BY 1945 GERMANY PRODUCED 36% OF ITS TOTAL USAGE
  - 75,000 BBL/DAY FROM BERGIUS PROCESS
  - 16,000 BBL/DAY F-T
- FISCHER-TROPSCH PLANTS BUILT IN OTHER COUNTRIES
  - FRANCE (1937 AND 1952)
  - JAPAN (3 PLANTS 1939-1943)
  - MANCHURIA (1939)
- F-T LABORATORY CATALYST WORK PERFORMED DURING 1930'S BY U.S. BUREAU OF MINES AT BRUCETON, PA
  - 1 BBL/DAY PILOT PLANT BUILT AS PROCESS IMPROVEMENTS TOOL
  - 80 BBL/DAY DEMO PLANT OPERATED DURING 1949-1953 AT LOUISIANA, MO. PARALLELING HYDROGENATION PLANT

HISTORICAL BACKGROUND OF COAL CONVERSION (CONT'D)

LIQUEFACTION

- CARTHAGE HYDROCOL PLANT AT BROWNSVILLE, TEXAS BASED ON F-T PROCESS BEGAN OPERATION IN 1949
  - DESIGN CAPACITY OF 7700 BBL/DAY WITH SYNTHETIC GAS PRODUCED BY PARTIAL OXIDATION OF NATURAL GAS
  - PLANT REACHED 30% CAPACITY AND SHUT DOWN IN 1953
  - MODIFICATIONS MADE AND OPERATIONS RESUMED IN 1956
  - TECHNICAL PROBLEMS REPORTED SOLVED BUT PLANT SHUT DOWN PERMANENTLY IN 1957 DUE TO UNCOMPETITIVENESS WITH CRUDE OIL PRICES

- CONSOLIDATION COAL CO. CONDUCTED INDEPENDENT RESEARCH ON THE MANUFACTURE OF GASOLINE AND LIGHT HYDROCARBONS FROM COAL DURING 1950-1962 PERIOD
  - PROCESS USED COAL-DERIVED SOLVENT WHICH SERVED AS HYDROGEN DONOR
  - OFFICE OF COAL RESEARCH SPONSORED 20 TON/DAY PILOT PLANT CONSTRUCTION AT CRESAP, W. VA.
  - PLANT OPERATED FOR 40 MONTHS DURING 1967-1970
  - OPERATIONS LIMITED BECAUSE OF RECURRING EQUIPMENT FAILURES.

HISTORICAL BACKGROUND OF COAL CONVERSION (CONT'D)

LIQUEFACTION: OIL FROM COAL IN SOUTH AFRICA

- ANGLO TRANSVAAL CONSOLIDATED INVESTMENT COMPANY ACQUIRED THE S. A. RIGHTS TO F-T PROCESS IN 1935 AND PILOT PLANT TESTING CONDUCTED UNTIL OUTBREAK OF WW II IN 1939

- U. S. ENGINEERS WERE FREQUENT VISITORS TO GERMANY DURING 1930'S AND U. S. (AMERICAN KELLOGG, LATE 1940'S) VARIATION OF F-T PROCESS DEVELOPED USING A MOVING POWDERED CATALYST RATHER THAN PELLITIZED CATALYST DEVELOPED BY GERMANS

- F-T PLANT STARTED OPERATIONS AT SASOLBURG, S.A. IN 1955 BY S.A. COAL, OIL, AND GAS CORP. (SASOL) USING PRESSURIZED LURGI GASIFIERS TO PRODUCE SYNTHESIS GAS
  - SASOL I DESIGNED TO PRODUCE APPROX. 5000 BBL/DAY OF GASOLINE AND HEAVIER PETROLEUM FRACTIONS FROM SUBBITUMINOUS COAL (5 MILLION TONS/YR.)
  - PRODUCTION COSTS NOW AVERAGE APPROX. $17/BBL (CAPITAL INVESTMENT $450 MILLION)
  - LOW PRICE HELPED BY ABUNDANCE OF CHEAP LABOR AND LOW COST COAL

- SASOL I CONSTRUCTION SUPERVISED BY KELLOGG INTERNATIONAL CORP. AND MOST EQUIPMENT CAME FROM THE U. S. AND GERMANY

- SOUTH AFRICA HAS LOW GRADE COAL RESERVES OF 25 BILLION TONS (NO OIL HAS EVER BEEN FOUND)
  - CURRENTLY 80% OF COUNTRIES ENERGY NEEDS MET BY COAL (VERSUS 10% OR LESS IN U. S.)
  - SASOL I, II, III WILL PROVIDE A TOTAL OF 112,000 BBL/DAY OR ABOUT HALF OF COUNTRY'S NEEDS (CURRENT PUMP PRICE OF GASOLINE $2.40/GAL.)

HISTORICAL BACKGROUND OF COAL CONVERSION (CONT'D)

LIQUEFACTION: OIL FROM COAL IN SOUTH AFRICA

- COMMISSIONING OF FIRST SYNTHESIS UNITS IN SASOL I BEGAN IN 1955
  - APPEARED IMMEDIATELY THAT FLUID BED F-T TECHNOLOGY WAS NOT DEVELOPED FAR ENOUGH FOR INDUSTRIAL APPLICATION (GERMAN PELLETIZED CATALYST F-T ALSO EMPLOYED)
  - TOOK "A COUPLE" OF YEARS TO ACHIEVE SUCCESSFUL OPERATION

- SASOL I IS A LARGE COMPLEX WHICH IS PRESENTLY THE WORLD'S ONLY FULLY INTEGRATED COMMERCIAL SYN FUELS FROM COAL PLANT (OIL-FROM-COAL PLANT + REFINERY + FACILITIES FOR INDUSTRIAL PETROCHEMICAL PRODUCTION)
  - GERMAN F-T PROCESS PRODUCES MAINLY HIGHER BOILING POINT MATERIALS (E.G. WAXES, DIESEL OILS, LIQUEFIED PETROLEUM GAS, CHEMICALS, SOME GASOLINE)
  - U. S. F-T PROCESS PRODUCES LOW BOILING POINT MATERIALS (E.G. GASOLINE, CHEMICALS SUCH AS ALCOHOL, ACETONE)
  - MAJOR SUPPLIER OF INDUSTRIAL GAS VIA A HIGH-PRESSURE PIPELINE TO INDUSTRIAL AREAS (CAPACITY OF GASIFICATION PLANT INCREASED 40% IN 1975 TO DOUBLE SUPPLY)

- SASOL I PRETAX PROFITS FOR 1978 WERE $140 MILLION ON SALES OF $1 BILLION (GASOLINE SALES REPRESENTED 7% OF MARKET)

- S. A. GOVERNMENT ANNOUNCED IN 1974 THAT IT WOULD BUILD A SECOND COMPLEX SASOL II (RESULT OF ARAB OIL BOYCOTT IN 1973 AND YOM KIPPUR WAR IN 1974)
  - SASOL II TO BE THREE TIMES DESIGN CAPACITY OF SASOL I (14 MILLION TONS/YR. COAL CONSUMPTION)
  - EMPLOYS SAME TECHNOLOGY (LURGI GASIFIERS + FLUID BED FT)
  - CONSTRUCTION INITIATED IN 1976 WITH COMPLETION SCHEDULED FOR 1980

HISTORICAL BACKGROUND OF COAL CONVERSION (CONT'D)

LIQUEFACTION: OIL FROM COAL IN SOUTH AFRICA

- S. A. GOVERNMENT ANNOUNCED IN 1979 THAT SASOL III WOULD BE CONSTRUCTED ALONGSIDF SASOL II (RESULT OF DOWNFALL OF SHAH OF IRAN AND NEW IRANIAN REVOLUTIONARY GOVERNMENT DECISION TO CUT OFF OIL SHIPMENTS TO S. A.)
  - WILL BE ALMOST EXACT COPY OF SASOL II TO SAVE ON DESIGN COSTS (ESTIMATED COST $3.8 BILLION)
  - SCHEDULED OPERATIONAL DATE 1984
- FULL OPERATION OF SASOL I/II/III WILL PRODUCE ABOUT 112,000 BARRELS OF OIL PER DAY OR APPROX. HALF OF SOUTH AFRICA'S NEEDS IN THE 1980"S
- "THE DREAM OF LICENSING SASOL TECHNOLOGY IS ALREADY PARTLY IN THE PIPELINE AND THE AGE HAS ARRIVED WHEN SOUTH AFRICA MAY SELL TECHNOLOGY TO THE UNITED STATES."

OBSERVATIONS

- OIL FROM COAL IS VIABLE IN S. A. BECAUSE OF A UNIQUE SET OF FACTORS INCLUDING
  - LARGE RESERVES OF LOW COST COAL
  - SCARCITY OF DOMESTIC PETROLEUM RESERVES
  - ABUNDANCE OF CHEAP LABOR
  - GOVERNMENT POLICY
  - S. A. IS BOYCOTTED BY MOST OF OPEC
- DOUBTS EXIST ABOUT ECONOMIC VIABILITY OF SASOL - LIKE PLANTS IN U. S.
  - COSTS OF COAL, CONSTRUCTION, LABOR, CAPITAL
  - ESTIMATES OF COST RANGE FROM $27 TO $45 BBL IN U. S.
- CONSIDERING SOUTH AFRICA'S GROSS NATIONAL PRODUCT AND ENERGY CONSUMPTION ITS EFFORT IS COMPARABLE TO A $300 BILLION CRASH PROGRAM FOR THE U. S.

II. WORLD WAR II SYNTHETIC RUBBER EFFORT

WORLD WAR II SYNTHETIC RUBBER EFFORT

MAY 1940	INITIAL COMMITTEE ON SYNTHETIC RUBBER FORMED
JUNE 28, 1940	RUBBER RESERVE COMMITTEE FORMED
DECEMBER, 1940	RFP FOR CONSTRUCTION OF SYNTHETIC RUBBER PLANTS
MAY, 1941	CONTRACTS ISSUED TO FOUR MANUFACTURERS TO DESIGN CONSTRUCT, AND OPERATE PLANTS
APRIL, 1942 TO NOVEMBER, 1942	FIRST FOUR PLANTS ON STREAM AT DESIGN CAPACITY OF 15,000 TPY EACH
OCTOBER, 1942	MAJOR RUBBER CONSERVATION PROGRAM OUTLINED
DECEMBER, 1944	51 PLANTS OPERATING WITH 21,713 EMPLOYEES
DECEMBER, 1945	PRODUCTION WAS 719,414 TONS IN 1945

- EXPEDITING PROCEDURES IMPLEMENTED:
  - PATENTS AND KNOW-HOW WERE EXCHANGED BETWEEN COMPANIES
  - A COOPERATIVE EFFORT WAS ESTABLISHED WITH CANADA
  - SYNTHETIC RUBBER PROCESS, EQUIPMENT, AND OPERATING CONDITIONS WERE STANDARIZED
  - ANY CHANGES HAD TO BE JUSTIFIED AND APPLICABLE TO ALL INSTALLATIONS
- ESTIMATED TOTAL COST OF PLANTS WAS $750 MILLION (EQUIVALENT TO $2.5 BILLION CURRENT DOLLARS)

IV. PROGRAMMATIC STATUS

DOE TEST/DEMONSTRATION FACILITIES

DIFFERENTIATED BY THE KIND OF INFORMATION TO BE OBTAINED - NOT NECESSARILY BY AMOUNTS OF RAW MATERIAL PROCESSED

- LABORATORY BENCH EXPERIMENTS CONFIRM KEY PROCESS STEPS
- PROCESS DEVELOPMENT UNITS (PDU's)
  - OPERATE CONTINUOUSLY AND PROCESS MINIMUM AMOUNT OF RAW MATERIAL TO TEST PROCESS FEASIBILITY
  - ELEMENTS OR COMPONENTS OF EXISTING FACILITIES
- PILOT PLANTS
  - ESTABLISHES INTEGRATED PROCESS FEASIBILITY BY COMBINING COMMERCIAL TYPE (NOT SIZE) COMPONENTS INTO SMALL MODEL PLANT
  - TEST/EVALUATE CRITICAL DESIGN/PERFORMANCE PARAMETERS OF SCALEUP
  - IDENTIFY COMPONENTS/SUBSYSTEMS FOR SCALEUP
  - ASSESS ECONOMIC FEASIBILITY AND DESIGN OF LARGER NEAR-COMMERCIAL SIZE PLANT SYSTEMS
- DEMONSTRATION PLANTS
  - ESTABLISHES ECONOMIC/ENVIRONMENTAL/PRODUCTIVE CAPACITY OF COMMERCIAL-SIZE PLANT
  - INTEGRATES AND OPERATES A SINGLE DEVELOPMENTAL MODULAR UNIT OF COMMERCIAL-SIZED COMPONENTS
  - PLANNED TO BE EXPANDED TO BECOME PART OF THE COMMERCIAL PLANT

MAJOR COAL GASIFICATION PILOT AND DEMONSTRATION PLANTS

PROJECT			STATUS		PLANT				DOE FUNDING	
NAME	LOCATION	DEVELOPER/ CONTRACTOR	PLANT SCALE*	DEVELOPMENT PHASE**	GASIFICATION PROCESS	COAL CONSUMPTION (TONS/DAY)	PRODUCT GAS	ESTIMATED PRODUCTION	YES	NO
GREAT PLAINS	MERCER CO. N D.	COLUMBIA GAS TRANSMISSION CO	C	P/D	LURGI FIXED BED	20,000	HIGH-BTU	175 MMSCF/D		X
TVA	NO. ALABAMA	TVA	C	D	TEXACO? ENTRAINED FLOW	20,000	MED-BTU	1000 " "		X
COGAS	PERRY CO. ILLINOIS	ILLINOIS COAL & GASIFICATION GROUP	D	D	COGAS FLUIDIZED BED	2,300	HIGH-BTU	20 " "	X	
CONOCO	NOBLE CO., OHIO	CONOCO	D	D	BRITISH GAS/ SLAGGING LURGI	3,000	HIGH-BTU	50 " "	X	
W.R. GRACE	BASKETT KY	W R. GRACE & CO EBASCO	C	D	TEXACO MOBIL-M	20,000	HIGH-OCTANE GASOLINE	10,000 BBL/D	X	
HYGAS		PROCON	D	P.D	HYGAS FLUIDIZED BED	7,340	HIGH-BTU LIQUID	85 MMSCF/D 1000 BBL/D	X	
MEMPHIS	MEMPHIS,TN	MEMPHIS LIGHT FOSTER WHEELER	D	D	U-GAS FLUIDIZED BED	1,700	MED-BTU	175 MMSCF/D	X	
COLD WATER COAL GASI	BARSTOW,CA	SO CALIF EDISON	D	P	TEXACO	1,000	MED-BTU	40 " "		X
KILN GAS	EAST ALTON, ILL	GILBERT COMMONWEALTH	D	D	ALLIS CHALMERS KILN GAS	800	LOW BTU	90 " "		X
BI-GAS	HUMEH CITY, PA.	PHILLIPS PETR	P	D	BI-GAS ENTRAINED FLOW	120	HIGH-BTU	3.6 " "	X	
HYGAS	CHICAGO ILL	IGT	P	D	HYGAS FLUID BED	75	HIGH-BTU	1.5 " "	X	
COGAS	LEATHERHEAD ENGLAND	COGAS DEVEL CO	P	D	COGAS FLUID BED	80	MED-BTU	2.5 " "		X
SHELL KOPPERS	HAMBURG W. GERMANY	SHELL INT. KRUPP-KOPPERS	P	D	SHELL KOPPERS ENTRAINED FLOW	100	MED-BTU	3.5 " "		X
MOLTEN SALT	SANTA SUSANA CA.	ROCKWELL	P	D	ROCKETDYNE	100 TPD	GAS/LIQUID	- -	X	
BRITISH GAS SLAG LURGI	ENGLAND	BRITISH GAS CORP	P	P	FIXED BED/ SLAG LURGI	100 TPD	MED-BTU	0.8 MMSCF/D		X
TVA AMMONIA	MUSCLE SHOALS AL	TVA/ BROWN & ROOT	P	C/D	TEXACO ENTRAINED FLOW	170 TPD	HIGH-BTU	0.8 "		X
COMBUST. ENGRNG	WINDSOR CONN	COMBUSTION ENGINEERING	P	D	CE TWO STAGE ENTRAINED	120 "	LOW-BTU	16.8 "	X	
TEXACO	MONTEBELLO, CA.	TEXACO	P	D	TEXACO ENTRAINED FLOW	15	MED-BTU	0.9 "	X	X
METC STIRRED FIXED BED	MORGANTOWN W.V.	METC	P	D	METC SFB	20	LOW-BTU	2.3 "	X	
HRI FAST FLUID BED	LAWRENCE TOWNSHIP NJ	HYDROCARBON RESEARCH INC	PDU	D	HRI FFB	9	LOW-BTU	1.03 "		
MOLTEN SALT	SANTA SUSANA CA	ROCKWELL INT	PDU	D	RI MOLTEN SALT	24	LOW-BTU	3.5 "		X
CO_2 ACCEPTOR	RAPID CITY S.D	CONSOLIDATED COAL	P	COMPL OPERA	CO_2 ACCEPTOR FLUIDIZED BED	30	MED-BTU	1.4 "	X	
SHELL KOPPERS	AMSTERDAM, NETH	SHELL INT KRUPP-KOPPERS	P	D	SHELL KOPPERS ENTRAINED FLOW	6	MED-BTU	0.35 "		X
WESTING HOUSE	WALTZ MILL PA	WESTINGHOUSE	P	D	WESTINGHOUSE FLUIDIZED BED	15	LOW-BTU	2.5 "	X	
EXXON CATALYTIC	BAYTOWN TX	EXXON	PDU	C	EXXON CAT FLUID BED	1	HIGH-BTU	0.05 "	X	
BELL HIGH MASS FLUX	BUFFALO N Y	BELL AEROSP	P	D	HI MASS FLUX ENTRAINED FLOW	12	MED-BTU	0.77 "	X	
HYDROGASIFICATION	SANTA SUSANA,CA	ROCKWELL INT	PDU	D	HYDROGASIFICATION ENTRAINED FLOW	6	HIGH BTU	0.35 "	X	
GFETC SLAGGER	GRAND FORKS ENERGY TECH CTR	GFETC/ STEARNS ROGER	P	C/D	SLAGGING FIXED BED	24	MED BTU	1.46 "	X	
U-GAS	CHICAGO ILL	IGT	P	D	U-GAS FLUID BED	6	MED-BTU	0.384 "	X	
GEGAS	SCHENECTADY N Y	GENERAL ELECTRIC	P	D	GE ATMOS FIXED BED	24	LOW-BTU	3.1 "		X
TOSCOAL	GOLDEN CO., UTAH	TOSCO CORP	P	D	TOSCOAL PYROLYSIS	25	MED-BTU	1.7 "		X
TRI GAS	MONROEVILLE, PA	BITUMINOUS COAL RESEARCH	PDU	D	BCR TRI-GAS FLUID BED GASIF.	1.2	LOW-BTU	0.2 "	X	
MOUNTAIN FUEL GAS	SALT LAKE CITY UTAH	MOUNTAIN FUEL RESOURCES, INC	PDU	D	MT FUEL/FORD,BACON & DAVIS ENTRAINED FL	30	MED-BTU	1.9 "		X
CHEMICAL ACTIVE FLUID BED	SAN BINITO TX	EXXON/CENTRAL POWER & LIGHT	P	D	EXXON CHEM ACTIVE FLUID BED	5-10	LOW-BTU	1.3 "		X

* PLANT SCALE C- COMMERCIAL, D- DEMONSTRATION, P- PILOT, PDU- PROCESS DEVELOPMENT UNIT

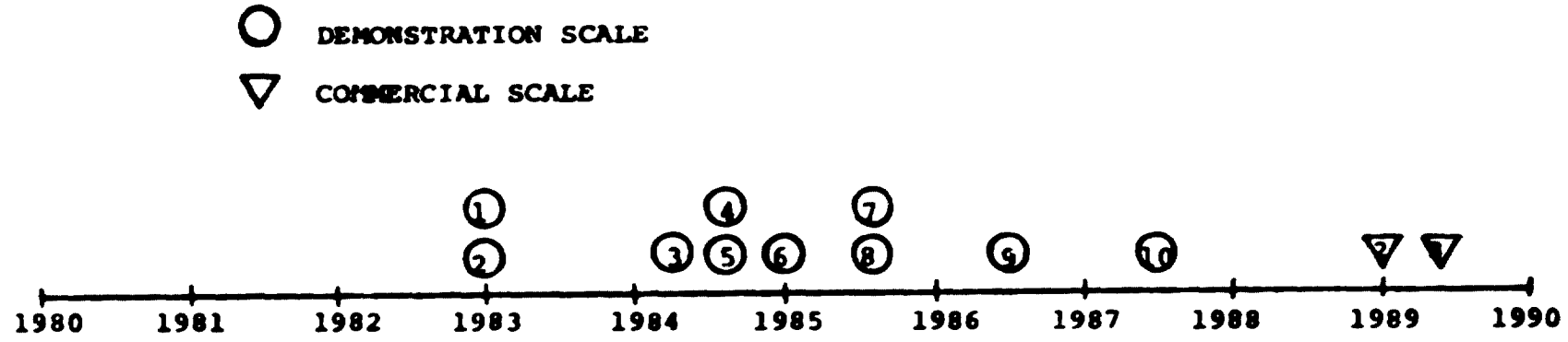
** DEVELOPMENT PHASE. O- OPERATIONAL, C- CONSTRUCTION, D- DESIGN, P- PROPOSED

STATUS OF COAL GASIFICATION PROCESSES

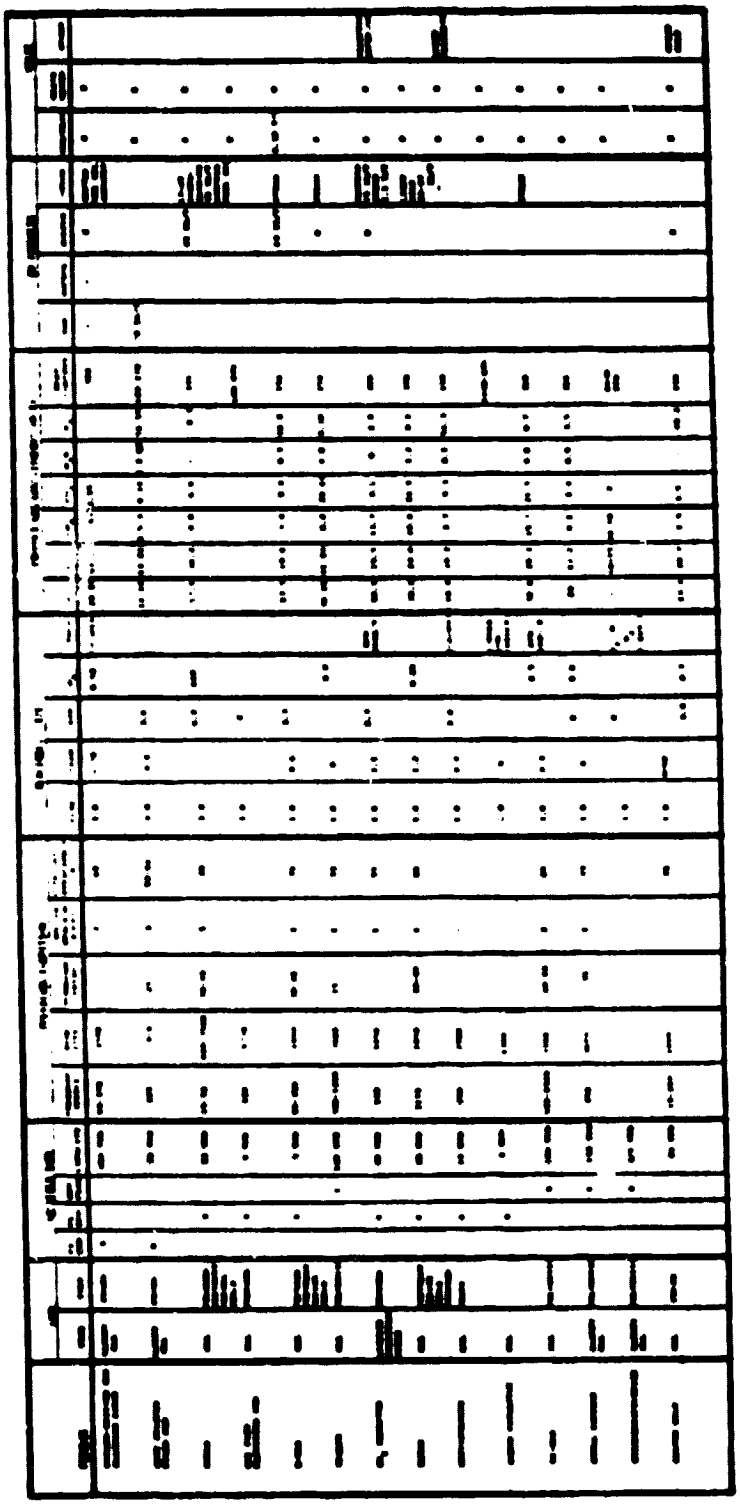
COMMERCIAL PROCESSES	STATUS	COAL CONSUMPTION
Great Plains/SNG/LURGI	P	28,400 TPD (Full Scale)
TVA/Texaco ?	D	20,000 TPD
DEMONSTRATION PROCESSES		
COGAS (ICGG)	D	2,300 TPD
British Gas/Slagging Lurgi (CONOCO)	D	3,800 TPD
Texaco (W.R. Grace)	D	1,700 TPD
HYGAS	P	7,340 TPD
U-GAS (Memphis)	D	2,800 TPD
LARGE SCALE PILOT PLANTS		
BIGAS	O	120 TPD
COGAS	O	50 TPD
HYGAS	O	80 TPD
Shell-Koppers	O	160 TPD
Rockwell Molten Salt	P	100 TPD
British Gas/Slagging Lurgi	P	110 TPD
Texaco (TVA)	C	170 TPD
SMALL SCALE PILOT PLANTS		
Texaco	O	15 TPD
METC Stirred Fixed Bed	O	20 TPD
HRI Fast Fluid Bed	O	9 TPD
Rockwell Molten Salt	O	24 TPD
CO_2 Acceptor	O	30 TPD
Shell Koppers	O	6 TPD
Westinghouse	O	15 TPD
Exxon Catalytic Gasification	C	1 TPD
Hydrogasification	O	0.75 TPD
Grand Forks Slagging Fixed Bed	C	24 TPD
U-GAS	O	6 TPD

*O-Operational, C-Construction, D-Design, P-Proposed

PROCESS DEVELOPMENT SCHEDULE FOR TEST PROGRAM



1 - COGAS
2 - Slagging Lurgi
3 - Texaco Partial Oxidation
4 - U-Gas
5 - HYGAS
6 - Shell-Koppers
7 - Molten Salt
8 - Westinghouse
9 - Exxon Catalytic Gasification
10 - Hydrogasification
11 - METC Stirred Fixed Bed
12 - BIGAS
13 - CO_2 Acceptor
14 - HRI Fast Fluidized Bed



PROGRAMMATIC STATUS

	FUNDING: $K	
	FY80	FY 81
COGAS DEMONSTRATION PLANT (ILLINOIS COAL GASIFICATION GROUP - PERRY CO., ILLINOIS)		
BRITISH GAS SLAGGING LURGI (CONOCO - NOBIL CO., OHIO)	51,000	56,000

- PROJECT OBJECTIVE IS TO CONFIRM DESIGN CRITERIA AND DEMONSTRATE NEAR-TERM HIGHER EFFICIENCY PROCESS FOR PRODUCTION OF HIGH BTU PIPELINE GAS FROM EASTERN CAKING COAL:
  - PARALLEL CONCEPTUAL DESIGN STUDIES INITIATED IN MID-1977
  - COMPETING PROJECTS WITH SELECTION TO PROCEED TO DEMONSTRATION SCHEDULED BY MAR/APR 1980
- COGAS PROCESS DEVELOPED BY COGAS DEVELOPMENT CO. (FMC CORP., CONSOLIDATED GAS SUPPLY CO., PANHANDLE EASTERN PIPELINE CO., TENN GAS PIPELINE CO.):
  - CONSISTS OF MULTI STAGE FLUID BED PYROLYZERS, FLUID BED GASIFIER, SLAGGING CHAR FINES COMBUSTOR
  - PILOT PLANT LOCATED AT LEATHERHEAD, ENGLAND (INCLUDES COED 50 TPD COAL PYROLYSIS PROCESS DEVELOPED IN PILOT PLANT IN PRINCETON, N.J. DURING EARLY 1970's)
- BRITISH GAS SLAGGING LURGI PROCESS DEVELOPED BY BRITISH GAS CORP. AT WESTFIELD, SCOTLAND:
  - LURGI (DRY ASH) PROCESS MODIFIED TO ACCEPT CAKING COALS AND OPERATE AT HIGHER TEMP OVER SLAGGING ASH BOTTOMS
  - 300 TPD DEVELOPMENT UNIT IN OPERATION

PROGRAMMATIC STATUS

COGAS (CONTINUED)

- DEMONSTRATION PLANT CAPACITIES:
  - COGAS 2200 TPD/OPERATION 1983
  - SLAGGING LURGI 3700 TPD/OPERATION LATE 1982
- FY81 FUNDING WILL PROVIDE FOR ENGINEERING DESIGN COMPLETION, LONG LEAD PROCUREMENT, SITE ACQUISITION, CONSTRUCTION START

PROGRAMMATIC STATUS

METC STIRRED FIXED BED

FUNDING: $K	
FY80	FY81
6,000	7,000*

- CURRENT PROJECT OBJECTIVES INCLUDE:
  - CONTINUE IMPROVEMENTS TO GASIFIER AND ITS SUPPORT SYSTEMS
  - SUPPORT DEVELOPMENT PROGRAM FOR GAS CLEAN UP SYSTEMS((TESTING OF STRETFORD UNIT TO BEGIN IN 1980) AND WASTE TREATMENT
  - PROCESS CHEMISTRY INVESTIGATIONS VIA ADVANCED INSTRUMENTATION
  - PROVIDE SOURCE OF LOW BTU GAS FOR COMBUSION STUDIES AND VALVE TESTING
- 42-INCH DIA. GASIFIER HAS BEEN UNDER DEVELOPMENT/OPERATION SINCE 1968
- FY81 FUNDING WILL PERMIT:
  - CONTINUED DATA ACQUISITION FOR EQUIPMENT EVALUATION AND SCALE-UP OF FIXED BED GASIFIERS
  - INTEGRATION/TEST OF TAR COMBUSTOR AND DIRTY WATER EVAPORATE INTO PILOT PLANT

PROGRAMMATIC STATUS

HRI FAST FLUIDIZED BED

- PROGRAM OBJECTIVES INCLUDE:
  - DEVELOPMENT OF LOW/MED BTU GASIFIER TO ACHIEVE SIGNIFICANT INCREASE IN THROUGHPUT AND IMPROVED TURNDOWN CAPABILITY
  - CAPABILITY FOR PROCESSING CAKING COALS WITHOUT PRETREATMENT
- CURRENT PDU PROGRAM INITIATED IN 1976 WITH HYDROCARBON RESEARCH, INC. IN TRENTON, N. J.
  - PDU OPERATED DURING 1978 ON EASTERN BITUMINOUS COAL
  - DESIGN MODIFICATION STUDIES COMPLETED FOR HIGHER TEMP OPERATION AND RECYCLING BOTTOMS AND FINES
  - TESTING TO BE PERFORMED DURING FY80
- FY81 FUNDING - ?

PROGRAMMATIC STATUS

U-GAS (IGT)

- PRECURSOR STUDIES BEGAN BY IGT IN 1945:
  - 6 INC. DIA. FLUIDIZED BED REACTOR USED FOR INVESTIGATIONS
  - CYCLONE REACTOR ALSO EMPLOYED
- 18 TPD PLANT CONSTRUCTED IN CHICAGO IN 1950:
  - FEATURED FLASH PULVERIZER AND SLAGGING GASIFIER
  - STUDIES CONTINUED UNTIL 1953
  - CONTINUED R&D WITH PDU DURING 1964-1973 PERIOD FOR DEVELOPMENT OF BOTH U-GSA AND HYGAS (HIGH-BTU)
- .6TPD PILOT PLANT OPERATION STARTED IN CHICAGO IN 1974:
  - OPERATED UNTIL 1977 WITH OCR AND DOI FUNDS
  - CONTINUED (1978-PRESENT) UNDER DOE AND MEMPHIS LIGHT, GAS & WATER INDUSTRIAL FUEL GAS DEMO PLANT PROGRAM
- MEMPHIS LIGHT, GAS & WATER AWARDED CONTRACT BY DOE FOR CONCEPTUAL DESIGN OR A 2800 TPD MBG DEMO PLANT IN 1978
  (EARLY 1989 "SELECTED OVER W. R. GRACE IN COMPETITION")

PROGRAMMATIC STATUS

TEXACO

- PRECURSOR PROCESS DEVELOPMENT TRACEABLE TO 1945:
  - "TEXACO SYNTHESIS GAS GENERATION" PROCESS
  - 75 PLANTS WITH 160 GASIFIERS LICENSED SINCE 1950
- TEXACO COAL GASIFICATION PROCESS DEVELOPMENT INITITATED IN 1948
- COMMERCIAL DESIGN BY W. R. GRACE & CO. (DOE FUNDING) OF 1700 TPD DEMO PLANT FOR PRODUCTION OF 1200 TPD AMMONIA AT BASKETT, KY 1977-1980 ("LOST COMPETITION" TO MEMPHIS LIGHT IN EARLY 1980)
- DESIGN AND CONSTRUCTION FOR TVA BY BROWN & ROOT OF 170 TPD PLANT TO PRODUCE 135 TPD AMMONIA AT MUSCLE SHOALS, AL. 1978-1980
- TVA BEGAN SITING AND CONCEPTUAL DESIGN STUDIES FOR 20,000 TPD MBG COMMERCIAL SCALE DEMO PLANT FOR NORTH ALABAMA (TEXACO GASIFIER UNDER CONSIDERATION) IN 1979
- CURRENTLY, TEXACO OPERATES 15 TPD HIGH PRESS PLANT AT MONTEBELLO, CA. AND RECENTLY COMPLETED 160 TPD PLANT IN ESSEN, WEST GERMANY

PROGRAMMATIC STATUS

CO_2 ACCEPTOR

- CONSOLIDATED COAL CO. PERFORMED EXTENSIVE BENCH TESTS IN 1964 AND PRIOR YEARS
- OCR/ERDA/DOE SUPPORT INITITATED IN 1964 RESULTED IN 30 TPD PILOT PLANT AT RAPID CITY, S. D.:
  - OPERATION STARTED IN MID-1972
  - PILOT PLANT OPERATED FROM 1972-1977 WITH LONGEST CONTINUOUS RUN OF 12 DAYS
- CURRENT STATUS: PILOT PLANT WORK COMPLETED

PROGRAMMATIC STATUS

HYGAS

- PILOT PLANT HAS BEEN OPERATING AT IGT, CHAICAGO SINCE 1972:
  - 80 TPD CAPACITY CONVERSION TO PIPELINE GAS PLANT OPERATING UNDER OCR/DOI/AGR SPONSORSHIP
  - OPERATIONS PERFORMED WITH HYDROGEN SOURCE FROM STEAM REFORMING OF NATURAL GAS DURING 1971-1972
- MAJOR EMPHASIS (BY DOE) PLACED ON PROVIDING DESIGN CONCEPTS FOR COMMERCIAL DEMONSTRATION IN 1977 (DOE CONTRACT TO PROCON
- COMMERCIAL DESIGN COMPLETED IN 1979

PROGRAMMATIC STATUS

WESTINGHOUSE TWO-STAGE FLUIDIZED BED

FUNDING: $K	
FY80	FY81
8,000	9,000*

- PROGRAM OBJECTIVES INCLUDE:
  - DEVELOPMENT OF LOW/MED BTU GASIFIER TO ACHIEVE SIGNIFICANT INCREASE IN THROUGHPUT AND IMPROVED TURNDOWN CAPABILITY
  - CAPABILITY FOR PROCESSING CAKING COALS WITHOUT PRETREATMENT
- PROCESS UNDER DEVELOPMENT SINCE 1972:
  - 15 TPD PDU COMPLETED IN 1974 AT MONROEVILLE, PA
  - OPERATION OF COMPLETE INTEGRATED SYSTEM PERFORMED DURING 1978/79
  - PROCESS PERFORMANCE AND PRODUCT GAS CHARACTERIZATION DATA FOR VARIOUS COALS OBTAINED DURING FY80
- FY81 FUNDING WILL BE USED TO CONTINUE THIS PROJECT TO OBTAIN DATA ON:
  - DESIGN AND SCALE-UP DATA ON GASIFIER SYSTEM AND COMPONENTS
  - TRANSIENT/FAILURE MODE BEHAVIOR
  - CONTROL SYSTEM CHARACTERISTICS
  - PROCESS ECONOMICS

PROGRAMMATIC STATUS

CATALYTIC GASIFICATION

FUNDING: $K	
FY80	FY81
9,000	13,200

- PROMISING 3RD GENERATION PROCESS
  - USES COAL IMPREGNATED WITH ALKALI METAL CATALYST TO CONVERT COAL DIRECTLY INTO SNG WITHIN GASIFIER IN SINGLE STEP
  - HIGHER EFFICIENCY THAN THERMAL PROCESSES
  - REDUCED REACTOR HEAT INPUT AND GAS STREAM HEATING AND COOLING
- PDU INITIATED AT EXXON IN FY79 (BAYTOWN, TEXAS)
  - STUDIES BY A&E FIRM INDICATE SAVINGS TO BE GAINED BY MODIFYING AN EXISTING PILOT PLANT FOR SCALE-UP OF CATALYTIC PROCESS WOULD NOT OFFSET THE ADDED OPERATING COST OF THE OLDER, USED EQUIPMENT AND THE EXTRA DOWN TIME REQUIRED AND MAINTENANCE
  - PDU OPERATION WILL CONTINUE THROUGH FY80
- FY81 ACTIVITIES:
  - DESIGN OF GRASS ROOTS PILOT PLANT FOR PROCESS DEVELOPMENT TESTING AS PRECURSOR TO SCALE-UP
  - EFFORT TO INCLUDE DETAILED DESIGN, INITIATION OF LONG LEAD TIME PROCUREMENT
  - PDU TESTING WILL BE CONTINUED TO SUPPORT DESIGN EFFORT

PROGRAMMATIC STATUS

BI-GAS PILOT PLANT

FUNDING: $K	
FY80	FY81
13,500	10,000

- 5 TON/HR GRASS ROOTS HIGH BTU SYSTEM AT HOMER CITY, PA OPERATED BY STEARNS-ROGER:
  - PROCESS DEVELOPED BY BITUMINOUS COAL RESEARCH, INC.
  - CONSTRUCTION OF INTEGRATED FACILITY COMPLETED IN FY76
- START-UP PERIOD EXTENDED DUE TO:
  - DESIGN COMPLEXITY
  - UNANTICIPATED PROBLEMS WITH VARIOUS COMPONENTS
- FIRES OCCURRED DURING 1978 AND 1979
  - PLANT SHUT DOWN FOUR MONTHS
  - DETAILED SAFETY ANALYSIS PERFORMED AND EQUIPMENT AND OPERATIONAL CHANGES MADE
- ADDITIONAL DEVELOPMENT WORK WILL CONTINUE FOR 2-3 YEARS TO OBTAIN ADEQUATE DESIGN DATA BASE
- FY 81 FUNDING WILL PERMIT APPROX 10 MONTHS OPERATION OF INTEGRATED SYSTEM:
  - TWO-STAGE PRESSURIZED ENTRAINED-BED OXYGEN BLOWN GASIFIER
  - DOWN STREAM PROCESSES - CO SHIFT, ACID GAS REMOVAL, METHANATION, SULFUR RECOVERY
  - WILL PROVIDE DETAILED INFORMATION FOR SCALE-UP TO NEAR-COMMERCIAL OR COMMERCIAL
  - DATA FROM DOWNSTREAM COMPONENTS APPLICABLE TO OTHER GASIFICATION PROJECTS

PROGRAMMATIC STATUS

SHELL KOPPERS (SHELL INTERNATIONAL PETROLEUM CO. AND KRUPP-KOPPERS GmbH)

- SHELL UNDERTAKING JOINT DEVELOPMENT WITH KRUPP-KOPPERS OF A PRESSURIZED ENTRAINED COAL GASIFICATION PROCESS
- 6 TPD PILOT PLANT HAS BEEN IN "CONTINUOUS" OPERATION AT SHELL'S AMSTERDAM LABORATORY SINCE DEC 1976
  - OPERATED FOR OVER 3000 HOURS
  - NUMBER OF DIFFERENT COALS AND PETROLEUM COKES HAVE BEEN SUCCESSFULLY GASIFIED AT 450 PSI
- 150 TPD PROTOTYPE PLANT CONSTRUCTED AT GERMAN SHELL HAMBURG/HARBURG REFINERY WITH SUCCESSFUL START-UP IN NOV. 1978 (ESTIMATED COST $25M)

PROGRAMMATIC STATUS

HYDROGASIFICATION

FUNDING: $K	
FY80	FY81
7,000	11,800

- PROMISING 3RD GENERATION PROCESS:
  - NEAR ALL METHANE PRODUCED IS GENERATED IN GASIFIER BY DIRECT HYDROGENERATION OF RAW COAL
  - HIGH THERMAL EFFICIENCY
- DURING FY79 STUDIES TO EXPAND DATA BASE WERE PERFORMED AT:
  - ROCKWELL INTERNATIONAL (RI)
  - PETC/METC
  - CARNEGIE-MELLON INSTITUTE OF RESEARCH
- DURING FY80 DEVELOPMENT AT RI EXPANDED:
  - SHORT RESIDENCE TIME HYDROGASIFIER TESTED AT 3/4 TPH LEVEL
  - DESIGN/CONSTRUCTION OF MINIMAL INTEGRATED PDU
  - CONTINUED SUPPORT WORK IN RELATED HYDROGASIFICATION AREAS
- FY81 ACTIVITIES TO INCLUDE:
  - COMPREHENSIVE TESTING OF RI 3/4 TPH PDU
  - PRELIMINARY DESIGN OF COMMERCIAL PROCESS
  - HYDROGASIFICATION SUPPORT EFFORTS

PROGRAMMATIC STATUS

PROCESS RESEARCH/TECHNOLOGY DEVELOPMENT	FUNDING: $K	
	FY80	FY81
	4,131	5,000

- 3RD GENERATION PROCESSES FOR ADVANCING STATE-OF-THE-ART:
  - HI-MASS FLUX (HMF) GASIFIER TO PRODUCE MBG
  - MOLTEN SALT TO PRODUCE LBG (MBG BY USING OXYGEN VS. AIR)
- HMF (BELL AEROSPACE TEXTRON) AWARDED CONTRACT BY ERDA IN 1976 TO ASSESS FEASIBILITY OF ENTRAINED FLOW GASIFIER WITH RESIDENCE TIME OF 100 MILLISECONDS
  - .5 TPH AIR BLOWN REACTOR (15 ATM, 2400°F) USED FOR PROCESS EVALUATION TO BE COMPLETED IN FY80
  - FY81 ACTIVITY TO INCLUDE UPGRADING UNIT FOR HIGHER PRESSURE, LONGER DURATION, AND COMMERCIAL PLANT STUDIES
- MOLTEN SALT (RI)
  - PDU PROGRAM FOR PRODUCING LBG WILL BE COMPLETED DURING FY80 INCLUDING TEST OF CONSTRUCTION MATERIALS AND COLLECTION OF OPERATING DATA
  - DESIGN AND PROCUREMENT WILL BE INITIATED FOR PDU FOR OPERATION WITH OXYGEN

PROGRAMMATIC STATUS

LOW BTU -ENTRAINED-BED GASIFICATION (ATMOSPHERIC)

FUNDING: $K	
FY80	FY81
3,000	3,000

- PROJECT WITH COMBUSTION ENGINEERING BEGUN IN 1974 TO CONVERT HIGH SULFUR EASTERN COALS
  - PILOT PLANT AT WINDSOR, CONN COMPLETED IN 1979
  - UNDERGONE STARTUP AND INITIAL TESTING OF PITTSBURGH SEAM COAL
- NO FUNDS REQUESTED IN FY80 BECAUSE PROJECT WAS EXPECTED TO BE COMPLETED:
  - HOWEVER, ADVANTAGE OF AN EXISTING FACILITY IN CONJUNCTION WITH AN EXPERIENCED DEVELOPMENT TEAM TO BE COMPLETE TESTING WITH THE DESIGN COAL WAS RECOGNIZED AND LED TO DECISION TO CONTINUE PROJECT IN FY80
  - CONGRESS ADDED $3M TO FY80 APPROPRIATIONS TO CONTINUE TESTING PROGRAM
- FY81 ACTIVITIES PLANNED TO:
  - TEST COALS FROM ILLINOIS, MONTANA, ARIZONA, AND LIGNITE
  - WILL USE AIR-BLOWN AND OXYGEN ENRICHED AIR-BLOWN GASIFICATION

IV. SELECTED COAL GASIFICATION PILOT PLANT PERFORMANCE HISTORIES

SRS

COAL GASIFICATION PLANT FAILURES

- Study of 550 reported failures in coal gasification plants showed the following causes:

Erosion	19%	(Piping, valves, pumps, cyclones)
Corrosion	30%	
Stress Corrosion	8%	
Manufacturing Defect	20%	
Stress Temperature	5%	
Unknown	10%	

- At one pilot plant, only one out of six failure incidents were said to be reported to DOE *

* Mr. Larry Zeis, Pullman Kellogg - Conference on Corrosion/Erosion of Coal Conversion System Materials, January 24-26, 1979. Sponsored jointly by National Association of Corrosion Engineers, DOE, Lawrence Berkley Laboratory

- The National Bureau of Standards Failure Informational Center has summarized the failure modes of 463 reports from various pilot and demonstration plants from 1976 to Aptil, 1979

PARTIAL REFERENCE LIST

- "TECHNICAL EVALUATION FOR JOINT DOE-GRI COAL GASIFICATION"
  C. F. BRAUN & CO. (BY ROGER DETMAN)
  EFFORT BEGAN IN 1972 AND CONTINUED UNTIL 1978

- "ENGINEERING SUPPORT SERVICES FOR THE DOE-GRI COAL GASIFICATION RESEARCH PROGRAM" PULLMAN KELLOGG
  EFFORT BEGAN IN 1978 AND IS CURRENTLY ONGOING

- "LOW BTU COAL GASIFICATION PROCESSES VOL. 1 SUMMARY, SCREENING AND COMPARISONS" ORNL

- "ASSESSMENT OF LONG-TERM RESEARCH NEEDS FOR COAL-GASIFICATION TECHNOLOGIES"
  FOSSIL ENERGY RESEARCH WORKING GROUP-DOE

- PROCEEDINGS OF "INTERNATIONAL MEETING ON MATERIALS FOR THE CONVERSION AND UTILIZATION OF COAL", OCT. 11-13, 1977 WASHINGTON, D. C.

COAL GASIFICATION
PILOT PLANT RUN HISTORIES

- BIGAS
- HYGAS
- WESTINGHOUSE
- CO_2 ACCEPTOR
- SYNTHANE

BIGAS PILOT PLANT

LOCATION	-	HOMER CITY, PA.
SPONSORS	-	DOE/GRI
DEVELOPER	-	BITUMINOUS COAL RESEARCH (BCR)
PRIME CONTRACTOR	-	BITUMINOUS COAL RESEARCH
TECHNICAL CONSULTANT	-	BITUMINOUS COAL RESEARCH
MANAGEMENT CONTRACTOR	-	PHILLIPS COAL RESEARCH
OPERATIONS & MAINTENANCE CONTRACTOR	-	STEARNS-ROGER INC.
PLANT DESCRIPTION	-	120 TPD CAPACITY, ENTRAINED FLOW, SLAGGING 2 STAGE GASIFIER THAT OPERATES UP TO TEMPERATURES OF ABOUT 3000°F AND PRESSURES OF 1500 PSIG. PLANT UNITS INCLUDE COAL PREP, GASIFIER, CHAR RECOVERY, GAS CLEAN UP, ACID GAS REMOVAL & METHANATOR
INITIAL OPERATION DATE	-	1976

BIGAS

PILOT PLANT OPERATION

MAJOR TIME LOSSES	CAUSE
AUG. - DEC. 76	FAILURE OF GASIFIER OVERHEAD QUENCH SYSTEM W/RESULTANT DOWNSTREAM DAMAGE
DEC. 76 - MAR. 77	HIGH STORAGE POND LEVEL AND HIGH CONCENTRATION OF H_2S IN PURGE GAS
DEC. 77 - JAN. 78	CHAR BURNER PROBLEMS: COOLING WATER LEAKS & EXPANSION BELLOWS LINER MELTING
FEB. 78 - JULY 78	RUPTURED CHAR BURNER PIPE RESULTING FIRE DESTROYED ELECTRICAL EQUIPMENT NEAR GASIFIER
FEB. 79 - AUG. 79	RUPTURED CHAR BURNER: RESULTING FIRE DAMAGE TO BUILDING

BIGAS PILOT PLANT
MOST NOTABLE PROBLEMS

- SLAG TAP HOLE PLUGGING AND LACK OF CONFIRMATION OF SLAG TAPPING
- MEASUREMENT PROBLEMS WITH
  - COAL & CHAR FEED TO GASIFIER
  - COAL & CHAR CYCLONE LOSSES IN GAS WASHER EFFLUENT
  - AMOUNT OF SLAG FORMED
  - BED LEVEL IN GASIFIER
  - TEMPERATURE IN GASIFIER (THERMOCOUPLES)
- MATERIALS PROBLEMS
  - HIGH TEMPERATURE & PRESSURES AREAS
  - HIGH VELOCITY AREAS
- CHAR & COAL FEED SYSTEM PLUGGING
- INABILITY TO SUSTAIN A REASONABLE PERIOD OF STEADY STATE FLOW

TEST RUN SUMMARY
BCR BI-GAS PILOT PLANT
HOMER CITY, PENNYSYLVANIA

BI-GAS TEST RUN NUMBER	DATE	RUN DURATION	REASON FOR TERMINATION	RESULTING TURNAROUND WORK
G-6E	Dec. 1, 1978	9 Hr.	- Failure of both Stage I thermocouple sheaths. - Leaking high pressure boiler relief valves	
G-6F	Dec. 13,14, 1978	27 Hr.	- Loss of visual confirmation of slag tapping - Unreliable thermoncouple readings - Unable to relight the slag tap burner - Problems with slag removal - Sampling problems & various vessel level control problems	- Raised slag tap hole - Reduced size of slag tap hole from 6" to 2" - Installed an agitator in the bottom of the slag quench section
G-7	Feb. 4. 1979	8 Hr.	- Gasifier cooling water leak into Stage I at char burner	
G-7A	Feb. 24,25, 1979	8 Hr.	- Rupture of char burner resulting in fire in the gasifier building	- Replace all char burner & coal feed leg 321-SS bellows with incology 825 & relocate bellows from the back of the burner to near the face

TEST RUN SUMMARY
BCR BI-GAS PILOT PLANT
HOMER CITY, PENNSYLVANIA

BI-GAS TEST RUN NUMBER	DATE	RUN DURATION	REASON FOR TERMINATION	RESULTING TURNAROUND WORK
G-8	Aug. 4,5, 1979	4.5 Hrs.	- Loss of 2 Stage I thermocouples - Poor TV picture - Problems lighting slag tap burners - Coal slurry pumping problems - Coal & char leg plugging - Level detection problems	
G-8A	Aug. 14,15, 1979	21.3 Hrs.	- Erratic coal & char feed - Char line plugging	
G-8B	Sept. 5,7, 1979	33.5 Hrs.	- Char & coal feed legs plugged - Poor detection of char line plugs	- Modification of char burners - Addition of a natural gas heater prior to injection into char burner
G-9	Oct. 2,3, 1979	23 Hrs.	- 2 char lines plugged problems in coal grinding area - Recycle gas compressor malfunction resulting in plant wide power failure	- Modifications to char burner "A" - More instrumentation added to char feed system

TEST RUN SUMMARY
BCR BI-GAS PILOT PLANT
HOMER CITY, PENNSYLVANIA

BI-GAS TEST RUN NUMBER	DATE	RUN DURATION	REASON FOR TERMINATION	RESULTING TURNAROUND WORK
G-10	Oct. 23-25, 1979	35 Hrs.	- Leaking valve at "A" coal leg	- Modification of char feed "C"
G-10A	Dec. 10-12, 1979	55.5 Hrs.	- Coal feed problems to the gasifier	

HYGAS PILOT PLANT

LOCATION	-	CHICAGO, ILL.
SPONSORS	-	DOE/GRI
DEVELOPER	-	IGT
CONTRACTOR	-	IGT
PLANT DESCRIPTION	-	80 TPD CAPACITY, FLUIDIZED BED, 2 STAGE HYDROGASIFICATION GASIFIER THAT OPERATES AT TEMPERATURES UP TO ABOUT 1850°F AND PRESSURES OF 1175 PSIG. PLANT UNITS INCLUDE COAL PREP, GASIFIER, GAS PURIFICATION, SULFUR RECOVERY & METHANATION
INITIAL OPERATION DATE	-	1971

HYGAS PILOT PLANT
SHUT-DOWN CAUSES AND MAJOR PROBLEMS

	1972		1973		1974		1975		1976		1977		1978		TOTAL	TOTAL
	Shut-Down Cause	Major Problems	Shut-Down Cause	Major Problems	Shut-Down Cause	Major Problems	Shut-Down Cause	Major Problems	Shut-Down Cause	Major Problems	Shut-Down Cause	Major Problems	Shut-Down Cause	Major problem	Shut-Down Cause	Major Problems
Number Tests in Year	11	-	14	-	7	-	11	-	15	-	10	-	9	-	77	-
Coal Supply System																
Coal Preparation	0	0	0	0	1	0	0	1	0	1	0	1	0	5	1	8
Pretreatment System	0	0	0	0	0	0	3	3	2	1	0	5	2	4	7	13
Slurry Feed System	1	0	0	0	0	0	1	1	0	0	0	1	0	6	2	8
Total Coal Supply System	1	0	0	0	1	0	4	5	2	2	0	7	2	15	10	29
Reaction System																
Temp. Control (Clinkers)	0	2	0	1	1	0	1	2	0	3	1	3	1	2	4	13
Solids Flow Stoppages	1	3	7	1	1	1	2	9	6	3	3	2	0	3	20	22
Leaks	1	2	0	0	0	2	2	0	3	0	3	2	2	1	11	7
Burners, erosion holes	2	1	2	0	2	1	0	3	0	2	0	1	1	1	7	7
Valves	1	0	1	0	0	3	2	5	0	2	0	2	0	1	4	13
Refractory	1	0	1	0	0	0	0	0	0	1	0	1	0	0	2	2
Total Reaction System	6	8	11	2	4	7	7	19	9	9	7	11	4	8	48	65
Quench System	1	0	2	0	0	2	2	0	1	0	1	1	1	3	8	6
Auxiliary Systems (Total)	3	5	2	3	2	6	3	10	3	5	2	1	2	4	17	34
Boilers	2	2	1	0	1	0	2	2	0	1			0	1	6	6
Compressors, Pumps	1	2		-	0	1	1	1	1	0					3	4
Coal Supply							0	1	1	-					1	1
Nitrogen Supply					1	0			1	0			2	-	4	-
Water Supply							0	1			1	-	0	1	1	2
Electric Power Supply							0	1			1	-			1	1
Natural Gas Supply					0	1									0	1
Line Freeze-Ups			1	0			0	1			0	1			1	2
Instrument Freeze-Ups									0	3					0	3
Flows Accumulation			0	2											0	2
Coal Fines			0	1	0	1									0	2
Hydrogen (start-up only)	0	1			0	1	0	1					0	1	0	6
Oxygen System							0	2	0	1			0	1	0	1
Fires														(Methanator)		

HYGAS PILOT PLANT
MOST NOTABLE PROBLEMS

- EROSION IN SLURRY FEED SYSTEM PARTLY DUE TO LACK OF CONTROL OF DENSITY & VELOCITY OF SLURRY
- PLUGGING OF H.P. PUMPS AND LINES IN SLURRY SYSTEM
- EROSION IN THE REACTION SYSTEM ESPECIALLY IN THE SOLIDS FLOW SYSTEM
- FORMATION OF CLINKERS DUE TO TEMPERATURE CONTROL PROBLEMS
- VALVE PROBLEMS (EROSION AND MECHANICAL FAILURE)

TEST RUN SUMMARY
IGT HYGAS PILOT PLANT
CHICAGO, ILLINOIS

IGT TEST NUMBER	DATE	RUN DURATION	REASON FOR TERMINATION	RESULTING TURNAROUND WORK
75	Oct. 3-6, 1978		- Trouble with high pressure slurry pumps - Coal mill problems - Valve problems	
76	Nov. 2-17, 1978			
77	Dec. 16, 1978 - Jan. 14, 1979	20-24 Hrs.	- Char feed problems - Coal pretreater problems weather	
78	Feb. 10, 1979 - Mar. 11, 1979	98 Hrs.	- Solids flow obstruction in the slurry dryer - Valve erosion at bottom of slurry mix tank - Slurry feed problems (equipment & plugging) - Weather	- Modify coal mill operation - Installation of 400 ton pretreated char storage system

TEST RUN SUMMARY
IGT STEAM-OXYGEN HYGAS PILOT PLANT
CHICAGO, ILLINOIS

IGT TEST NUMBER	DATE	OPERATION	REASON FOR TERMINATION	RESULTING TURNAROUND WORK
79	April 27-May 9, 1979	178 Hrs.	- Voluntary shut down - Problems: (1) Leaking H.P. Slurry Pump. (2) Seal blown in transfer line (3) Coal prep & coal feed	None
80	June 18-July 3, 1979	16.5 Hrs. S.S.	- Coal feed problems - Lift line restrictions causing pressure rupture in pipes - Slurry line leaks - Leaking packing in H.P. steam valves - Malfunction of level & density valves	- Revised control system
81	Aug. 7-Aug. 9, 1979	19 Hrs.	- Mechanical linkage to valve failed in slurry dryer to gasifier line - Instrumentation failure - Coal prep problems	- Stainless steel tubing on instrumentation replaced by incoloy

TEST RUN SUMMARY
IGT-STEAM-OXYGEN HYGAS PILOT PLANT
CHICAGO, ILLINOIS

IGT TEST NUMBER	DATE	RUN DURATION	REASON FOR TERMINATION	RESULTING TURNAROUND WORK
82	Sept. 6-11, 1979		- Thermocouple problems - Clinker problems - Solids flow problems	- Replacement of worn parts
83	Oct. 17-27, 1979		- Holes in lines causing solids flow problems in the slurry dryer & high temperature reactor - Thermocouples dislodged	- Pretest of solids flow lines
84	Dec. 5-14, 1979	2-40 Hrs.	- Slurry dryer and/or lines plugged - Solids flow problems	

WESTINGHOUSE PDU

LOCATION	-	WALTZ MILL, PA.
SPONSORS	-	DOE/GRI
DEVELOPER	-	WESTINGHOUSE
CONTRACTOR	-	WESTINGHOUSE
PLANT DESCRIPTION	-	15 TPD, FLUIDIZED BED, 2 STAGE PRESSURIZED GASIFICATION SYSTEM OPERATING AT PRESSURES TO 250 PSIG AND TEMPERATURES TO 2000°F. PLANT INCLUDES COAL PREP, DEVOLATILIZER, CYCLONES, GASIFIER COMBUSTOR, AND SCRUBBER SYSTEM.
INITIAL OPERATION DATA	-	1974

WESTINGHOUSE PDU
MOST NOTABLE PROBLEMS

- ASH REMOVAL PROBLEMS
- SLAG AND/OR CLINKER BUILDUP
- SOLIDS BUILDUP IN GASIFIER
- CYCLONE PROBLEMS (SOLIDS BUILDUP AND IMPROPER OPERATION)
- MATERIAL PROBLEMS (BROKEN, CRACKED, OR ERODED PIPE, ETC.)
- MECHANICAL PROBLEMS (COAL FEED EQUIPMENT, ETC.)

CO_2 ACCEPTOR PILOT PLANT

LOCATION	-	RAPID CITY, SD
SPONSORS	-	DOE/GRI
DEVELOPER	-	CONSOLIDATED COAL CO.
CONTRACTOR	-	CONOCO COAL DEVELOPMENT CO.
PLANT DESCRIPTION	-	40 TPD CAPACITY, 2 BED FLUIDIZED BED GASIFIER AND A SINGLE BED REGENERATOR, OPERATING TEMPERATURE 1850°F, OPERATING PRESSURE 150 PSIG, PLANT CONSISTS OF COAL PREP & PRE-HEAT, REGENERATOR, GASIFIER, QUENCH TOWERS, ACID GAS REMOVAL, SCRUBBER & FOUL WATER STRIPPER
INITIAL OPERATION DATE	-	1972

CO_2 ACCEPTOR PILOT PLANT

MOST NOTABLE PROBLEMS

- INSTRUMENTATION & CONTROLS (MEASUREMENT, CONTROL VALVES, ETC.)
- MATERIAL FAILURES (RUPTURED LINES, EROSION, CORROSION, ETC.)
- PLUGGED LINES (LIFT LINES, CHAR TRANSFER LINES, ETC.)
- SOLIDS BUILD UP IN GASIFIER
- REFRACTORY PROBLEMS
- POWER FAILURE

SYNTHANE PILOT PLANT

LOCATION	-	BRUCETON, PA.
SPONSORS	-	DOE/GRI
DEVELOPER	-	DOE-PERC
CONTRACTOR	-	LUMMUS
PLANT DESCRIPTION	-	75 TPD CAPACITY, FLUIDIZED BED GASIFIER OPERATING TEMPERATURE 1800°F OPERATING PRESSURE 1000 PSIG PLANT INCLUDES COAL PREP & PRETREATMENT, GASIFIER, SCRUBBER, WASTE TREATMENT, ACID GAS REMOVAL, METHANATOR
INITIAL OPERATION DATE	-	1971

SYNTHANE PILOT PLANT
MOST NOTABLE PROBLEMS

- PUMP FAILURE & PROBLEMS
- PLUGGED STAND PIPE TO CHAR COOLER
- ELECTRICAL CONTROLS & INSTRUMENTATION
- GASIFIER OPERATIONAL PROBLEMS (PRESSURE & TEMPERATURE CONTROL)
- CLINKER FORMATION
- FEED & TRANSFER LINE PLUGGING
- MATERIALS PROBLEMS (VALVE FAILURE, PIPELINE SYSTEM LEAKS, EROSION)

	FREQUENCY OF OCCURRENCE OF MAJOR PROBLEMS AT PILOT PLANTS																					
	HYGAS									BIGAS					SYNTHANE					WESTINGHOUSE					COMBINED TOTALS
YEAR	72	73	74	75	76	77	78	79	TOTAL	76	77	78	79	TOTAL	76	77	78	79	TOTAL	76	77	78	79	TOTAL	TOTAL
Number of Runs	11	14	7	11	15	10	12	7	87	2	27	8	8	45	21	53	30	0	104	1	15	9	5	30	266
PROBLEM AREAS																									
Coal Supply				1					1																1
Coal Prep.			1	1	1	1	6	2	12							1			1						13
Pretreating System				3	1	5	5		14								2		2						16
Feed System				1		1	6	5	13		2	1	4	7	2	3	5		10			2		2	32
TOTAL COAL SUPPLY SYSTEM			1	6	2	7	17	7	40		2	1	4	7	2	4	7		13			2		2	62 62
Burner Problems											6	3	2	11											11
Temp. Control, Clinkers	2	1		2	3	3	2	1	14						2	6			8		5			5	27
Solids Flow Stoppage	3	1	1	9	3	2	3	2	24		4	1		5	7	5	5		17		5		4	9	55
Leaks	2		2			2	1	2	9						1	2	2		5			1		1	15
Ruptures, Erosion, Damage	1		1	3		1	1	3	10		6	2		8	1	2	1		4		2			2	24
Valves			1	5	2	2	2	2	16			1	1	2		2			2						20
Refractory					1	1			2																2
TOTAL REACTION SYSTEM	8	2	7	19	9	11	9	10	75		16	7	3	26	11	17	8		36		12	1	4	17	154 154
QUENCH SYSTEM				2			1	1	6	1	1			2											8 8
Boilers	2	1		2	1		1		7		2			2	1	1			2				1	1	12
Fgp't, Pumps, Compress.	2		1	1				1	5		2			2	1	6	1		8		5	2		7	22
Water & Waste Treat'mt				1			1		2	1	5	1	1	8							1			1	11
Electric Power Supply				1					1				1	1		1			1						3
Natural Gas Supply			1						1																1
Line Freeze-Ups		1	1	1		1		1	4		2	1	4	7		2			2		3	1	4	17
Instrument Problems					3			4	7		8	7	4	19	2	3	2		7		1		1	34
Fines Accumulation															2	4			6						6
Hydrogen Feed	1		1	1			1		6																6
Fires											1	1		2							1				3
TOTAL AUXILARY SYSTEM	5	2	3	7	4	1	3	6	33	1	20	10	10	41	6	17	3		26		7	6	2	15	115 115
									151					76					75					34	339

MATERIALS APPLICATIONS FOR ENTRAINED FLOW COAL GASIFICATION PLANT

PROCESS STEP	EQUIPMENT	MATERIALS
COAL PREPARATION	SLURRY TRANSFER & SLURRY CIRCULATING PUMPS	NICKEL-CHROME WHITE CAST IRON CASE AND IMPELLER, SHAFT SLEEVE 8620 STEEL CARBURIZED TO 550 BHN
SLURRY DRYING SYSTEM	SPRAY DRYER	1-1/4% CR-1/2% MO STEEL SHELL
	HEATER	TUBES A-106, GR. B,A335 GRADES P-1, P-11, P-22, 304 S.S.
	HOT NITROGEN TRANSFER LINE	316 STAINLESS STEEL PIPE
	WASHER RECYCLE PUMPS	CARBON STEEL CASE & IMPELLER WITH 12% CR TRIM
	COAL CYCLONE VESSEL	A516-70
GASIFIER SYSTEM	REACTANT INJECTION	CARBON STEEL CASE WITH NO. 3 STELLITE NOZZLES & INTERNALS (NOT REPLACEABLE) (2 SPARES)
	PIPING	304 STAINLESS STEEL
	PIPING	MONEL-RESISTANT TO COMBUSTION IN OXYGEN
	GASIFIER-REACTOR	2-1/4% CR-1% MO. REACTOR SHELL & PIPING REFRACTORY LINED.

MATERIALS APPLICATIONS FOR ENTRAINED FLOW COAL GASIFICATION PLANT

	GASIFIER QUENCH SECTION PIPING	WATER COOLED AND REFRACTORY LINED, 2-1/4% CR-1% MO; QUENCH ZONE IS WATER JACKETED, 309 STAINLESS STEEL
	CHARFEED VESSEL	1-1/4% CR-1/2% MO STEEL CLAD WITH 1/8-in. 316 STAINLESS STEEL
	RAW GAS TRANSFER PIPE	304 STAINLESS STEEL
	SLAG OUTLET LOCK-HOPPER	SA-516-70 STEEL SHELL
RAW GAS CLEANUP	GAS WASHER	1-1/4% CR-1/2% MO, STEEL CLAD INTERNALLY WITH 1/8-in. MONEL
	GAS WASHER RECYCLE COOLER	304 S.S. HEADER & TUBES
	GAS WASHER CIRCULATING PUMPS	316 STAINLESS STEEL CASE & IMPELLER, 17-4 PH SHAFT
CO SHIFT	CO SHIFT HEATER	316 STAINLESS STEEL
	CO SHIFT REACTOR	1-1/4% CR-1/2% MO STEEL SHELL. CLADDING IS 1/8-in. 316 STAINLESS STEEL
PRIMARY METHANATION	METHANATOR FEED HEATER	2-1/4% CR-1% MO

MATERIALS APPLICATIONS FOR ENTRAINED FLOW COAL GASIFICATION PLANT

	PIPE FROM METHANATOR FEED HEATER TO ZINC OXIDE GUARD CHAMBER & FLUID BED METHANATOR	1-1/4% CR-1/2% MO STEEL 2-1/4% CR-1% MO STEEL
SECONDARY METHANATOR	NOS. 1 & 2 SECONDARY METHANATOR REACTORS	1-1/4% CR-1/2% MO STEEL

SPECIFIC PROBLEMS
ENTRAINED FLOW GASIFICATION

(PROBLEMS FOR ENTRAINED FLOW ARE FAIRLY TYPICAL OF THE COAL GASIFICATION INDUSTRY)

PROBLEMS	MATERIAL
INJECTOR/BURNER EROSION, STRESS CORROSION CRACKING, SULFUR ATTACK ETC.	INCONEL ALLOY 600 321 SS INCOLOY 825
CENTRIFUGAL SLURRY CIRCULATIING PUMPS ABRASIVE WEAR	NICKEL CHROME WHITE CAST IRON
THERMOCOUPLE FAILURE DUE TO EROSION OF SHEATH (TYPICAL PROBLEM FOR ALL TEMPERATURE MEASUREMENT INSTRUMENTATION)	MOLYBDENUM WITH 0.03" THICK $CR_2 O_3$ COATING
LEVEL DETECTION INSTRUMENTATION FAILURE DUE TO TAP PLUGGING	
FLOW METER INSTRUMENTATION FAILURE	

SPECIFIC PROBLEMS
ENTRAINED FLOW GASIFICATION (CON'T)

PROBLEMS	MATERIAL
PUMP SEALS EROSION FAILURE	TUNGSTEN CARBIDE ON BRONZE (LAYERED 1 HARD, 1 SOFT)
VERTICAL CENTRIFUGAL PUMPS CORROSION/EROSION FAILURE	316 SS
PIPING EROSION FAILURES	304 SS MONEL

PILOT PLANT OPERATIONS

- THE MAJOR PROBLEMS ARE SIMILAR AT MOST PILOT PLANTS RFGARDLESS OF PROCESS
- MAJOR PROBLEMS ARE RELATED TO HIGH-TEMPERATURE/PRESSURE COAL SLURRY & DIRTY GAS
- PILOT PLANTS ARE IN BUSINESS TO MAKE PROCESS WORK; NOT TO DEVELOP PUMPS, VALVES ETC.
- A FAILURE OF A PUMP OR VALVE MAY NOT BE CONSIDERED A FAILURE UNLESS A PLANT SHUT DOWN RESULTS, eg. A VALVE FAILS BUT CAN BE BY-PASSED
- MOST PIPING, PUMPS & VALVES FAILURES ARE CONSIDERED MAINTENANCE PROBLEMS & NOT REPORTABLE FAILURES
- THESE " MAINTENANCE PROBLEMS " ARE CONTINUOUS

VI. SELECTED COMMERCIAL COAL GASIFICATION PLANT OPERATIONAL HISTORIES

SRS

COMMENTS ON K-T PROCESS

- KOPPERS TOTZEK PRODUCES A GAS SIMILAR TO THE TEXACO PROCESS PRODUCT GAS
  - ASH REMOVAL TECHNIQUE ABOUT THE SAME AS TEXACO
  - KT CAN BE THROTTLED TO ABOUT 25% OF RATED CAPACITY

- 50 PLANTS HAVE BEEN BUILT AROUND THE WORLD USING KT PROCESS (ABOUT 20 ARE IN OPERATION)
  - MODDERFONTEIN, SOUTH AFRICA PLANT CONTAINS SIX TWO-HEADED GASIFIERS (1000 TONS/DAY AMMONIA PLUS SOME METHANOL)
  - TALCHER, INDIA PLANT CONTAINS THREE FOUR-HEADED GASIFIERS (1000 TONS/DAY AMMONIA)
  - CONTRACT SIGNED (MARCH,1979) TO PROVIDE PLANT FOR PETROBRAS OF BRAZIL

- THERE ARE NO KT PLANTS OF ANY SCALE IN U. S. BUT THERE IS AT LEAST ONE PROJECT THAT IS CONSIDERING KT FOR A 10,000 TPD PLANT

- THE THEORETICAL ADVANTAGES OF SOME OF THE 2ND AND 3RD GENERATION PROCESSES ARE ATTRACTIVE, HOWEVER, THE CONFIDENCE WHICH CAN BE PLACED IN THESE PROCESSES FOR TIMELY CONTINUOUS PRODUCT GAS IS STILL IN QUESTION
  - KT IS A PROVEN PROCESS AND POSSIBLE DEVELOPMENTS IN THE PROCESS (E.G. PRESSURIZED VERSION) SHOULD BE CONSIDERED
  - KT GASIFIER COULD BE USED AS A RELIABLE SOURCE OF MED-BTU GAS FOR TESTING COMPONENTS AND PARTS FOR SEVERAL PROCESSES BECAUSE OF THE SIMILAR PRODUCTS

- KT HAS DEMONSTRATED CAPABILITY TO PROCESS ALL TYPES OF COAL INCLUDING LIGNITE

KOPPERS

Gasification plants using the K-T process

	Fuel	Number of Gasifier Units	Capacity: CO + H_2 in 24 hours	Use of Synthesis Gas	Year of Order
Charbonnages de France, Paris, Mazingarbe Works (P.d.C.) France	Coal Dust, Coke-Oven-Gas, Tail Gas	1	75 000– 150 000 Nm^3 2 790 000– 5 580 000 SCF	Methanol- and Ammonia Synthesis	1949
Typpi Oy, Oulu Finland	Coal Dust, Oil, Peat	3	140 000 Nm^3 5 210 000 SCF	Ammonia Synthesis	1950
Nihon Suiso Kogyo Kaisha, Ltd., Tokyo Japan	Coal Dust	3	210 000 Nm^3 7 820 000 SCF	Ammonia Synthesis	1954
Empresa Nacional "Calvo Sotelo" de Combustibles Liquidos y Lubricantes, S.A., Madrid, Nitrogen Works in Puentes de García Rodríguez, Coruña Spain	Lignite Dust	3	242 000 Nm^3 9 000 000 SCF	Ammonia Synthesis	1954
Typpi Oy, Oulu Finland *	Coal Dust, Oil, Peat	2	140 000 Nm^3 5 210 000 SCF	Ammonia Synthesis	1955
S.A. Union Chimique Belge, Brussels, Zandvoorde Works Belgium	Bunker-C-Oil, Plant convertible for Coal Dust Gasification	2	176 000 Nm^3 6 550 000 SCF	Ammonia Synthesis	1955
Amoniaco Português S.A.R.L., Lisbon, Estarreja Plant Portugal	Heavy Gasoline, Plant extendable to Lignite- and Anthracite Dust Gasification	2	169 000 Nm^3 6 300 000 SCF	Ammonia Synthesis	1956
The Government of the Kingdom of Greece, The Ministry of Coordination, Athens, Nitrogenous Fertilizer Plant, Ptolemais, Greece	Lignite Dust, Bunker-C-Oil	4	629 000 Nm^3 23 450 000 SCF	Ammonia Synthesis	1959
Empresa Nacional "Calvo Sotelo" de Combustibles Liquidos y Lubricantes, S.A., Madrid, Nitrogen Works in Puentes de García Rodríguez, Coruña, Spain	Lignite Dust or Naphtha	1	175 000 Nm^3 6 500 000 SCF	Ammonia Synthesis	1961
The General Organization for Executing the Five Year Industrial Plan. Cairo, Nitrogen Works of Société el Nasr d'Engrais et d'Industries Chimiques, Attaka, Suez United Arabian Republique	Refinery Off-Gas, L.P.G. and Light Naphtha	3	778 000 Nm^3 28 950 000 SCF	Ammonia Synthesis	1963
Chemical Fertilizer Company Ltd, Thailand, Synthetic Fertilizer Plant at Mae Moh, Lampang Thailand	Lignite Dust	1	217 000 Nm^3 8 070 000 SCF	Ammonia Synthesis	1963

* Repeat Order

	Fuel	Number of Gasifier Units	Capacity: $CO + H_2$ in 24 hours	Use of Synthesis Gas	Year of Order
Azot Sanayii T.A S., Ankara, Kutahya Works, Turkey	Lignite Dust	4	775 000 Nm^3 26 850 000 SCF	Ammonia Synthesis	1966
Chemieanlagen Export-Import G.m.b.H., Berlin fur VEB Germania, Chemieanlagen und Apparatebau, Karl-Marx-Stadt VEB Zeitz Works	Vacuum residue and/or fuel oil	2	380 000 Nm^3 13 400 000 SCF	Raw gas to produce hydrogen for hydro-genation	1966
Kobe Steel Ltd., Kobe Japan for Industrial Development Corp., Zambia, at Kafue near Lusaka Zambia, Africa	Coal Dust	1	214 320 Nm^3 7 980 000 SCF	Ammonia Synthesis	1967
Nitrogenous Fertilizers Industry S.A., Athens, Nitrogenous Fertilizers Plant Ptolemais, Greece *	Lignite Dust	1	165 000 Nm^3 6 150 000 SCF	Ammonia Synthesis	1969
The Fertilizer Corporation of India Ltd., New Delhi, Ramagundam Plant, India	Coal Dust	4 (1 of them as stand-by)	2 000 000 Nm^3 74 450 000 SCF	Ammonia Synthesis	1969
The Fertilizer Corporation of India Ltd., New Delhi, Talcher Plant, India *	Coal Dust	4 (1 of them as stand-by)	2 000 000 Nm^3 74 450 000 SCF	Ammonia Synthesis	1970
Nitrogenous Fertilizers Industry S A., Athens, Nitrogenous Fertilizers Plant Ptolemais, Greece *	Lignite Dust	1	242 000 Nm^3 9 009 000 SCF	Ammonia Synthesis	1970
The Fertilizer Corporation of India Ltd., New Delhi, Korba Plant, India *	Coal Dust	4 (1 of them as stand by)	2000000 Nm^3 74450000 SCF	Ammonia Synthesis	1972
AE & CI Ltd., Johannesburg, Modderfontein Plant, South Africa	Coal Dust	6	2150000 Nm^3 80025000 SCF	Ammonia Synthesis	1972
Indeco Chemicals Ltd., Lusaka, Kafue Works, Zambia*	Coal Dust	1	220 800 Nm^3 8220000 SCF	Ammonia Synthesis	1974
Indeco Chemicals Ltd., Lusaka, Kafue Works, Zambia*	Coal Dust	2	441 600 Nm^3 16 440 000 SCF	Ammonia Synthesis	1975

Koppers Company, Inc.
Pittsburgh, Pa. 15219
KOPPERS
Engineering and Construction

* Repeat Order

KOPPERS TOTZEK COMMERCIAL PLANT
OPERATIONAL HISTORIES

MODDERFONTEIN PLANT - AE&CI LTD, JOHANNESBURG, SOUTH AFRICA

- PLANT ORDERED IN 1972, INITIAL STARTUP IN LATE 1974
  - SIX TWO-HEADED GASIFIERS
  - DESIGN CAPACITY: 1100 TONS/DAY AMMONIA (~ 210 TON/DAY/GASIFIER)
  - OXYGEN BLOWN, OPERATING TEMP ~ 2900°F
  - COAL FEED: SUBBITUMINOUS, 14% ASH, 1% SULFUR, 36% VOLATILES

- DESIGN PHILOSOPHY
  - TWO-HEADED GASIFIERS SELECTED BECAUSE OF LACK OF OPERATING EXPERIENCE WITH FOUR-HEADERS AT THAT TIME
  - PLANT MADE UP OF SINGLE, DOUBLE, AND MULTISTREAM UNITS FOR RELIABILITY, HOWEVER - NO SPARE GASIFIER (IN RESTROSPECT IT WAS RECOGNIZED ADVANTAGEOUS TO HAVE SPARE GASIFIER TO ALLOW SCHEDULED GASIFIER MAINTENANCE WITHOUT REDUCING OVERALL PLANT RATE)
  - INCREASED CAPITAL COST WAS CONSIDERED NECESSARY BECAUSE OF EXPECTED LOW RELIABILITY OF CERTAIN UNITS DUE TO COAL RELATED PROBLEMS OR USE OF FEWER STREAMS WOULD HAVE RESULTED IN SIZE SCALE-UP WELL BEYOND THE RANGE OR TRIED AND PROVEN EQUIPMENT EXISTING AT THAT TIME
  - PLANT DESIGNED FOR STABLE OPERATION DOWN TO 50% OF DESIGN RATE TO PERMIT CONTINUOUS OPERATION WITH EQUIPMENT DOWN
  - PROVISION FOR TWO UNITS OF BOILERS, ELECTROSTATIC PRECIPITATORS, AND GAS COMPRESSORS CONSIDERED ECONOMICALLY JUSTIFIED (SOLIDS FOULING EXPECTED)

KOPPERS-TOTZEK COMMERCIAL PLANT
OPERATIONAL HISTORIES

MODDERFONTEIN PLANT - AE&CI LTD, JOHANNESBURG, SOUTH AFRICA

- OPERATING EXPERIENCE
  - START-UP TESTING OF ENTIRE FACILITY INITIATED IN LATE 1974
  - NUMBER OF BOTH MECHANICAL AND PROCESS PROBLEMS OCCURRED DURING FIRST FEW YEARS OF OPERATION (THRU 1979)
  - PLANT DID OPERATE IN 1978 WITH ON-STREAM TIME OF 81% AND HAS ACHIEVED DESIGN OUTPUT FOR FIVE GASIFIERS FOR LIMITED PERIODS
  - PROBLEMS WERE STILL OCCURRING IN 1979

- MAJOR PROBLEM AREAS
  - MANY SPURIOUS SHUTDOWNS DUE TO FAILURE OF DUST BUNKER LEVEL DETECTORS
  - DUST BUNKER EXPLODED ON ONE OCCASION DUE TO OXYGEN BACK FLOW
  - EXPLOSION OCCURRED IN WASH TOWER AND IN A GAS SHUT-OFF VALVE DOWNSTREAM OF WASH TOWER CAUSED BY FAILURE OF OXYGEN TRIP VALVES TO STOP FLOW AFTER A GASIFIER SHUTDOWN
  - ASH IMPINGEMENT ON BOILER TUBES CAUSED EROSION AND FAILURE (AS A TRAIL FIX, TUBE SURFACES COATED WITH ABRASION RESISTANT ALUMINA MATERIALS)
  - NUMEROUS SHUTDOWNS DURING EARLY OPERATION RESULTED IN THERMAL CYCLING WHICH CAUSED MANY LEAKS IN PIPES AND VESSEL JOINTS (ON-SITE TEAM OF LEAK REPAIR EXPERTS ESTABLISHED)
  - WHILE K-T PLANTS HAD OPERATED IN GREECE AND TURKEY FOR YEARS WITH SAME REFRACTORY LININGS, MODDERFONTEIN SYSTEMS HAD TO BE REDESIGNED AND ALL GASIFIERS WERE RELINED IN 1977 (PROBLEMS RELATED TO COAL FEEDSTOCK)

KOPPERS-TOTZEK COMMERCIAL PLANT
OPERATIONAL HISTORIES

MODDERFONTEIN PLANT - AE&CI LTD, JOHANNESBURG, SOUTH AFRICA

- MAJOR PROBLEM AREAS (CONTINUED)
  - MINOR LEAKS OF PRODUCT GAS THROUGHOUT PLANT HAVE LED TO PERSONNEL BEING EFFECTED BY TOXICITY OF CO
  - GAS COMPRESSORS HAVE BEEN PRONE TO LEAKAGE FROM CASING JOINTS AND SEALS (MODIFICATION WERE MADE AND A CO INFRARED ANALYZER WAS TO BE INSTALLED TO MONITOR 12 LOCATIONS)
  - LABORATORY ASSISTANT WAS KILLED BY CO INHALATION WHILE TAKING GAS SAMPLE FROM ELECTROSTATIC PRECIPITATORS WHICH ARE USED TO REMOVE ASH FROM RAW GAS
  - RELEASE VALVE FAILURE ON GAS COMPRESSOR OIL CONSOLE CAUSED OIL FIRE
  - NUMEROUS SHUTDOWNS CAUSED BY INSTRUMENTATION FAILURE/INACCURACY IN MONITORING/CONTROLLING OPERATION OF BLOWPIPE PRESSURES, SCREW FEEDER-SPEED, OXYGEN FLOW RATES, AND DUST BUNKER LEVELS
  - COAL DUST PRECIPITATORS ON COAL MILLING PLANT REQUIRED MODIFICATION TO MEET COAL DUST EMISSION LIMIT OF 150 mg./cu.m.

KOPPERS-TOTZEK COMMERCIAL PLANT

OPERATIONAL HISTORIES

MODDERFONTEIN PLANT - AE&CI LTD, JOHANNESBURG, SOUTH AFRICA

CONCLUSIONS

- BASIC PROCESS UNITS HAD BEEN PROVEN ELSEWHERE BEFORE BEING SELECTED FOR MODDERFONTEIN PLANT
  - BUT AT LOWER CAPACITIES AND IN DIFFERENT PROCESS ROUTES
  - PLANT WAS TO SOME EXTENT A PROTOTYPE

- MANY PROBLEMS ATTRIBUTED TO NATURE OF SOUTH AFRICAN COAL
  - INITIAL COAL USED HAD ASH FLOW TEMP OF 1375° - 1390°C
  - GASIFIER OUTLET TEMP OF 1550° - 1600°C RESULTED IN MOLTEN SLAG CONTACTING REFRACTORY LINING MATERIAL (CASTABLE CHROME)
  - COOLING SYSTEM NOT DESIGNED FOR THIS CONDITION AND FROZEN SLAG LAYER NOT ESTABLISHED WHICH PERMITTED LOSS OR REFRACTORY
  - INITIAL COAL PRODUCED 80% ASH ENTRAINMENT VERSUS 55% EXPECTED

- TRAIL GASIFICATION OF ORIGINAL COAL FEEDSTOCK IN A FULL-SCALE GASIFICATION PLANT WOULD HAVE IDENTIFIED MANY PROBLEMS AT THE DESIGN STAGE

- EVEN WITH PROBLEMS ENCOUNTERED, PROCESS IS BASICALLY SOUND

KOPPERS TOTZEK COMMERCIAL PLANT
OPERATIONAL HISTORIES

RAMAGUNDAM AND TALCHER, INDIA PLANTS - FERTILIZER CORP. OF INDIA

- RAMAGUNDAM PLANT ORDERED IN 1969, INITIAL STARTUP 1978/79
- TALCHER PLANT ORDERED IN 1970, INITIAL STARTUP 1978/79
- BOTH PLANTS ARE SIMILAR AND HAVE ADOPTED IDENTICAL PROCESS ROUTES
  - THREE FOUR-HEADED GASIFIERS (FIRST KRUPP-KOPPERS FOUR-HEADERS)
  - DESIGN CAPACITY: 900 TON/DAY AMMONIA (~ 390 TON/DAY/GASIFER)
  - OXYGEN BLOWN, OPERATING TEMP ~ 2900°F
  - COAL FEED: BITUMINOUS, 18% ASH, 30% VOLATILE MATTER
- DESIGN PHILOSOPHY
  - WEIGH AVAILABLE TECHNOLOGY (K-T, PRESSURIZED LURGI, WINKLER, OTTO RUMMEL) AND REVIEW PILOT PLANT DATA
  - KEY SELECTION CRITERIA WITH DIFFERING ASH CHARACTERISTICS, SWELLING AND CAKING INDEXES DESPITE HIGHER OXYGEN CONSUMPTION (CONCERN WITH LURGI ROTARY GRATE)
  - ADDITIONAL CRITERIA WAS "IMPORT FACTOR" (LURGI PLANT WOULD REQUIRE HIGHER PROPORTIONS OF IMPORTS FOR PLANT EQUIPMENT)

KOPPERS TOTZEK COMMERCIAL PLANT
OPERATIONAL HISTORIES

RAMAGUNDAM AND TALCHER, INDIA PLANTS - FERTILIZER CORP. OF INDIA

- OPERATING EXPERIENCE
  - ALL THREE GASIFIERS AT TALCHER PLANT HAVE BEEN COMMISSIONED (GASIFIER NO. 1 410 HRS, NO. 2 244 HRS, NO. 3 112 HRS: CONTINUOUS RUN 76 HRS)
  - TWO GASIFIERS COMMISSIONED AT RAMAGUNDAM (GASIFIER NO. 1 278 HRS, NO. 2 154 HRS, CONTINUOUS RUN 67 HRS.)
  - REMAINING FACILITY SYSTEMS ARE BEING COMMISSIONED IN 1979

- MAJOR PROBLEM AREAS
  - DURING COMMISSIONING OF TALCHER NO. 1 GASIFIER 50 RUNS WERE MADE WITH VARIOUS PROBLEMS OCCURING
  - DUST BUNKER LEVEL DETECTORS
  - ADDITION OF LIMESTONE FLUX IN EARLY RUNS TO CREATE REFRACTORY SLAG LAYER FREQUENT CHOKING OF GASIFIER NECK OCCURRED
  - HIGHER THAN NORMAL MOISTURE CONTENT IN COAL FEED (2-3% vs. 1%) CAUSED PROBLEMS IN TRANSFERRING COAL DUST, FROM SERVICE BUNKER AND JAMMING OF SCREW FEEDERS
  - BACK FIRING OF BLOW PIPES DUE TO HIGHER FINES CONTENT (SCREW FEED RATE INCONSISTENT WITH PREADJUSTED OXYGEN - COAL DUST BURNER DIAMETER REDUCED)

KOPPERS TOTZEK COMMERCIAL PLANT
OPERATIONAL HISTORIES

RAMAGUNDAM AND TALCHER, INDIA PLANTS - FERTILIZER CORP. OF INDIA

- MAJOR PROBLEM AREAS (CONTINUED)
  - ASH IMPINGEMENT ON BOILER TUBES
  - SIMILAR PROBLEMS ENCOUNTERED DURING COMMISSIONING OF RAMAGUNDAM PLANT

- CONCLUSIONS
  - FULL FACILITIES COMMISSIONING STILL UNDERWAY IN 1979
  - MANY PROBLEMS ENCOUNTERED WHILE COMMISSIONING FIRST GASIFIER
  - FEWER PROBLEMS ENCOUNTERED WITH SECOND GASIFIER
  - MAJOR PROBLEMS RELATED TO INSTRUMENTATION/CONTROLS AND CAUSES EXTERNAL TO GASIFIER, e.g. NONAVAILABILITY OF NITROGEN, OXYGEN, POWER FAILURE, BOILERFEED WATER FAILURE
  - NO BASIC DESIGN PROBLEMS

VII. CRITICAL TECHNOLOGY AREAS

SRS

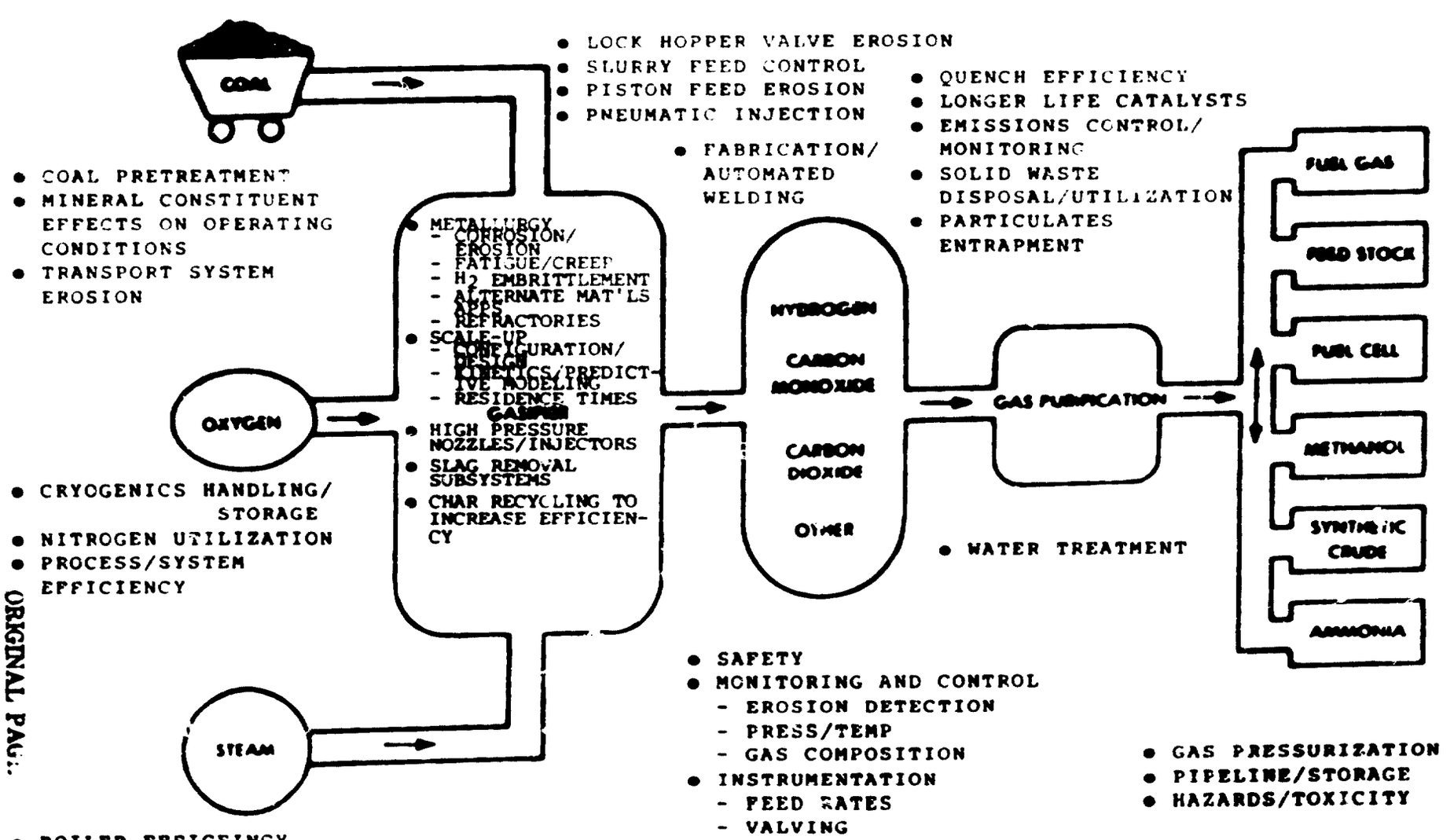
CRITICAL TECHNOLOGY AREAS

CRITICAL TECHNOLOGY DEVELOPMENT REQUIREMENTS CAN BE CATAGORIZED BY MAJOR SYSTEM ELEMENTS OR GENERIC DISCIPLINE AREAS

- MAJOR SYSTEM ELEMENTS:
  - COAL PREPARATION AND INJECTION
  - AIR SEPARATION
  - AUXILLIARY EQUIPMENT
  - GASIFIER
  - GAS CLEANUP
  - WASTE DISPOSAL
  - GAS DISTRIBUTION

- GENERIC DISCIPLINE AREAS:
  - CONVERSION PROCESSES
  - MATERIALS AND COMPONENTS
  - INSTRUMENTATION AND CONTROLS

CRITICAL TECHNOLOGY AREAS



- LOCK HOPPER VALVE EROSION
- SLURRY FEED CONTROL
- PISTON FEED EROSION
- PNEUMATIC INJECTION
- FABRICATION/ AUTOMATED WELDING
- QUENCH EFFICIENCY
- LONGER LIFE CATALYSTS
- EMISSIONS CONTROL/ MONITORING
- SOLID WASTE DISPOSAL/UTILIZATION
- PARTICULATES ENTRAPMENT
- COAL PRETREATMENT
- MINERAL CONSTITUENT EFFECTS ON OPERATING CONDITIONS
- TRANSPORT SYSTEM EROSION
- CRYOGENICS HANDLING/ STORAGE
- NITROGEN UTILIZATION
- PROCESS/SYSTEM EFFICIENCY
- WATER TREATMENT
- BOILER EFFICEINCY
- HEAT EXCHANGER EFFICIENCY
- SAFETY
- MONITORING AND CONTROL
  - EROSION DETECTION
  - PRESS/TEMP
  - GAS COMPOSITION
- INSTRUMENTATION
  - FEED RATES
  - VALVING
  - STEAM/OXYGEN INJECTION
  - ASH/SLAG REMOVAL RATES
- GAS PRESSURIZATION
- PIPELINE/STORAGE
- HAZARDS/TOXICITY

COAL GASIFICATION

CRITICAL AREAS FOR SUPPORTING TECHNOLOGY DEVELOPMENT

COAL INJECTION

- LOCK HOPPER VALVE EROSION
- SLURRY FEED FLUID SEPARATION/CONTROL
- PISTON FEED EROSION
- PNUEMATIC INJECTION FEASIBILITY

AIR SEPARATION

- CRYOGENIC FLUIDS HANDLING/STORAGE
- NITROGEN UTILIZATION
- SEPARATION PROCESS/SYSTEM EFFICIENCY

AUXILIARY EQUIPMENT

- GAS PRESSURIZATION
  - APPLICATION OF GAS-TURBINE POWERED CENTRIFUGAL COMPRESSIONS
  - TURBINE BLADE CORROSION, EFFICIENCIES, CONTROL
- WATER PURIFICATION
  - APPLICATION OF FORCED CONVECTION AIR COOLERS OR DRY COOLING TOWERS TO REDUCE BLOWDOWN EFFLUENT
  - ALTERNATE WATER QUENCHING AND WASHING TECHNIQUES

COAL GASIFICATION

CRITICAL AREAS FOR SUPPORTING TECHNOLOGY DEVELOPMENT

GASIFIER

- METALLURGICAL DEVELOPMENT
  - H_2S COROSION AND HYDROGEN EMBRITTLEMENT OF STEEL AT HIGH TEMPERATURE
  - ADVANCED/ALTERNATE MATERIALS APPLICATIONS
  - CO AND H_2 ATTACK AT INTERMEDIATE TEMPERATURES
  - ABRASIVE WEAR OF METALS
  - EROSIVE WEAR OF REFRACTORIES
  - STRESS CORROSION CRACKING
  - TEMPER EMBRITTLEMENT OF STEEL AT HIGH TEMPERATURES
  - METAL FATIGUE AND CREEP AT HIGH TEMPERATURES
- SCALE-UP UNCERTAINTIES
  - COAL PRETREATMENT AND FEED MECHANISMS
  - GASIFIER CONFIGURATION/DESIGN
  - COMBUSTION KINETICS/REACTIONS/RESIDENCE TIMES
  - PREDICTIVE MODELING
  - COAL MINERAL CONSTITUENTS EFFECTS ON REACTOR OPERATING CONDITIONS
- MONITORING AND CONTROL
  - EROSION DETECTION AND MONITORING E.G. ULTRASONIC TRANSDUCERS FOR COAL, ASH, AND CHAR TRANSPORT SYSTEMS
  - PRESSURE, TEMPERATURE, GAS COMPOSITION, ETC. IN AND AROUND CRITICAL COMPONENTS
  - CONTROL INSTRUMENTATION FOR COAL FEED RATES AND ASSOCIATED VALVING, STEAM AND OXYGEN INJECTION, ASH AND SLAG REMOVAL RATES
- SLAG TAR AND CHAR REMOVAL
  - SLAG TAP HOLE REDESIGN/MODIFICATION TO PREVENT PLUGGING AND FREEZING
  - COAL TAR REMOVAL/ACCUMULATION PREVENTION
  - DEVICES/MECHANISMS FOR CHAR RECYCLING TO INCREASE EFFICIENCY

COAL GASIFICATION

CRITICAL AREAS SUPPORTING TECHNOLOGY DEVELOPMENT

WASTE DISPOSAL

- PROCESS-SPECIFIC DATA TO CHARACTERIZE TOTAL SPECTRUM OF POLLUTANTS
- SO_2, CO_2,NOX HAZARDOUS TRACE MATERIALS EMISSIONS CONTROL/MONITORING
- SOLID WASTE DISPOSAL/UTILIZATION OF BY-PRODUCTS
- AIRBORNE PARTICULATES ENTRAPMENT

GAS DISTRIBUTION

- PIPELINE/STORAGE FACILITY MATERIALS/DESIGN FOR GAS COMPOSED OF HIGH CONCENTRATIONS OF H_2 AND CO
- HAZARDS/TOXICITY

AEROSPACE TECHNOLOGY TRANSFER

- ROCKETDYNE DIVISION/ROCKWELL INTERNATIONAL IS CONDUCTING RESEARCH PROGRAM FOR DOE TO DEVELOP TECHNOLOGY TO LIQUEFY COAL VIA DIRECT HYDROGENATION:
  - RAPID MIXING, REACTION, AND QUENCHING OF PULVERIZED COAL/HYDROGEN MIXTURE TO FORM HYDROCARBON LIQUIDS
  - COAL FED TO REACTOR FROM A BATCH FEEDER BY PRESSURIZING HOLDING TANK WITHOUT FLUIDIZING THE COAL
  - MIXED WITH 1500°F HYDROGEN IN ENTRAINED FLOW REACTOR
  - COAL AND HYDROGEN REACT FOR 10-100 MILLISECONDS
  - EFFLUENT IS QUENCHED BY WATER SPRAY NOZZLES TO PREVENT FURTHER HYDROGENATION TO GAS
- J-2 STAND AT SANTA SUSANA FIELD UTILIZED FOR ONE-TON-PER-HOUR TEST FACILITY
- REACTOR UTILIZES A ROCKET ENGINE INJECTOR ELEMENT

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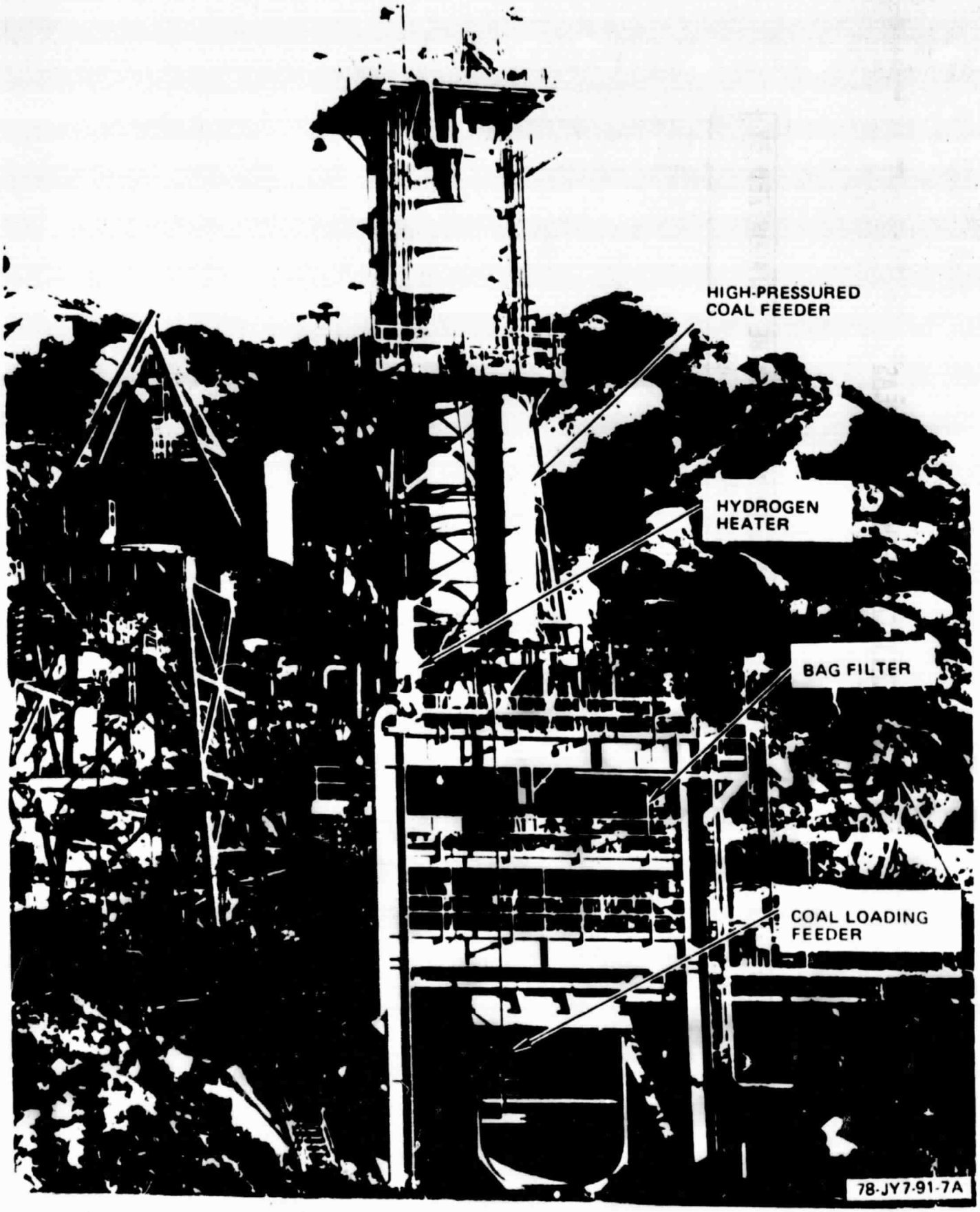
OF POOR QUALITY


HIGH-PRESSURED
COAL FEEDER
HYDROGEN
HEATER
BAG FILTER
COAL LOADING
FEEDER
78-JY7-91-7A

CRITICAL TECHNOLOGY AREAS

CRITICAL TECHNOLOGY DEVELOPMENT REQUIREMENTS CAN BE CATAGORIZED BY MAJOR SYSTEM ELEMENTS OR GENERIC DISCIPLINE AREAS

- MAJOR SYSTEM ELEMENTS:
  - COAL PREPARATION AND INJECTION
  - AIR SEPARATION
  - AUXILLIARY EQUIPMENT
  - GASIFIER
  - GAS CLEANUP
  - WASTE DISPOSAL
  - GAS DISTRIBUTION

→ • GENERIC DISCIPLINE AREAS:
  - CONVERSION PROCESSES
  - MATERIALS AND COMPONENTS
  - INSTRUMENTATION AND CONTROLS

GENERIC DISCIPLINE AREAS

CONVERSION PROCESSES

REQUIREMENT FOR PROCESS IMPROVEMENTS TO LOWER COST:

- SIMPLIFY/REDUCE NUMBER OF STEPS
- INCREASE PRODUCTION RATES PER UNIT VOLUME OF REACTOR
- INCREASE THERMAL EFFICIENCIES

- DEVELOP BASIC CHEMICAL AND ENGINEERING KNOWLEDGE TO FACILITATE INCEPTION/ DEVELOPMENT OF NEW/MODIFIED PROCESSES

- DETERMINE TECHNICAL FEASIBILITY OF NEW PROCESS CONCEPTS UNDER STEADY STATE CONDITIONS

- CONDUCT SUPPORTING R&D TO COMPLEMENT/IMPROVE KNOWN PROCESSES UNDER DEVELOPMENT

EXAMPLE TECHNOLOGY DEVELOPMENT AREAS

CONVERSION PROCESSES

- ASSESS EFFECTIVENESS OF LIME TREATMENT OF CAKING COALS TO:
  - INCREASE REACTION RATES/METHANE YIELDS
  - ELIMINATE CAKING TENDENCIES FOR VARIETY OF COALS
- EVALUATE TECHNICAL FEASIBILITY/ECONOMIC POTENTIAL OF ADVANCED GAS CLEANUP PROCESSES TO REMOVE CO_2, COS, H_2S
- ESTABLISH ENGINEERING DATA BASE ON REACTION KINETICS/CHEMISTRY/THERMODYNAMICS OF GASIFICATION PROCESSES
- ANALYTICAL MODELING OF GASIFICATION PROCESSES
- NEW METHANATION CATALYSTS AND ADVANCED METHANATION REACTOR CONFIGURATIONS
- INFLUENCE OF MIXING ON KINETIC PROCESSES IN ENTRAINED FLOW GASIFIERS
- COAL AND CHAR REACTIVITIES IN GASIFICATION ENVIRONMENTS
- MECHANISM OF THE H_2S - DOLOMITE REACTION
- HIGH PRESSURE VENTURI SCRUBBERS

MATERIALS AND COMPONENTS

REQUIREMENT FOR IMPROVED MATERIALS/COMPONENTS:

- CONVERSION EFFICIENCY ENHANCED AT HIGHER TEMP/PRESS
- CORROSION/EROSION/ABRASION/FATIGUE/OTHER DETERIORATION INCREASED
- HISTORICALLY EVERY DEVELOPING TECHNOLOGY KEYED TO PRIOR DEVELOPMENT OF CRITICAL MATERIALS

- DEVELOP ENGINEERING KNOWLEDGE OF MECHANISMS OF EROSION/CORROSION/ABRASION/FATIGUE/OTHER DETERIORATION ENCOUNTERED IN COAL CONVERSION SYSTEM OPERATING ENVIRONMENTS
- DEVELOP COMPATIBLE MATERIALS FOR ECONOMY OF COST AND ENDURANCE AGAINST WEAR AND DETERIORATION
- INVESTIGATE EXTRA-STRONG AND WELDABLE STEELS FOR THICK-WALLED PRESSURE VESSELS
- OBTAIN REALISTIC MATERIAL-TEST DATA

EXAMPLE TECHNOLOGY DEVELOPMENT AREAS

MATERIALS AND COMPONENTS

- DEVELOP/SELECT COMPATIBLE COATINGS FOR INTERNAL SURFACES OF GASIFIERS
- DEVELOP SULFIDATION RESISTANT ALLOYS AND METALS FOR USE IN HIGH TEMP GASIFIERS
- TECHNIQUES FOR WELDING AND CLADDING LOW ALLOY AND CR-MO PRESSURE VESSEL STEELS
- INVESTIGATE MICROSTRUCTURAL EFFECTS IN ABRASIVE WEAR
- STABILITY OF SILICON CARBIDE REFRACTORIES IN COAL GASIFIER ENVIRONMENTS
- WEAR RESISTANT ALLOYS FOR COAL HANDLING EQUIPMENT
- DESIGN/ENGINEERING OF REFRACTORY LINERS FOR SLAGGING GASIFIERS
- FRACTURE MECHANICS AND SURFACE CHEMISTRY STUDIES OF STEELS
- DEVELOP AUTOMATED WELDING PROCESSES FOR FIELD FABRICATION OF THICK-WALLED PRESSURE VESSELS
- DEVELOP TECHNIQUES FOR CONTINUOUS FEEDING OF COAL TO PRESSURIZED REACTORS
- DEVELOP/TEST LOCK HOPPER VALVES TO PERFORM UNDER HARSH ENVIRONMENTS
- CENTRIFUGAL SLURRY FEED PUMPS/O_2 COMPRESSORS

INSTRUMENTATION AND CONTROLS

REQUIREMENT FOR RELIABLE, ACCURATE MEASUREMENT AND CONTROL OF KEY PERFORMANCE/RELIABILITY PARAMETERS IN GASIFICATION PROCESSES

- DEVELOP ENGINEERING KNOWLEDGE OF GASIFIER SYSTEM INSTRUMENTATION AND CONTROL REQUIREMENTS/PERFORMANCE CRITERIA
- IDENTIFY ADVANCED SENSORS/SENSING TECHNIQUES, INSTRUMENTATION AND CONTROL DEVICES AND CONCEPTS
- DEVELOP AND TEST UNDER ACTUAL/SIMULATED OPERATING ENVIRONMENTS

EXAMPLE TECHNOLOGY DEVELOPMENT AREAS

INSTRUMENTATION AND CONTROLS

- ADVANCED TRANSDUCERS AND THERMOCOUPLES FOR MONITORING OF REACTOR VESSEL OPERATING CONDITIONS
- EROSION DETECTION AND MONITORING FOR COAL/ASH/SLAG/CHAR TRANSPORT SUBSYSTEMS
  - ULTRASONIC TRANSDUCERS
  - ACOUSTIC COUPLING MATERIALS
- GAMMA RADIOGRAPHY/THERMOGRAPHY FOR INSPECTION OF REFRACTORY LINED TRANSFER SUBSYSTEMS
- OPTICAL AND MICROWAVE TECHNIQUES FOR AUTOMATED GAS SPECIES DETERMINATION
- APPLICATION OF MICROPROCESSORS FOR SIGNAL CONDITIONING
- MEASUREMENT OF FLOW RATES FOR COAL, RECYCLE SOLIDS, ETC.
- CONTROL OF SLAG BATH LEVEL
- INTEGRATED, COMPUTERIZED MASTER CONTROL SYSTEM AND VISUAL DISPLAYS
- AUTOMATED PROCESS CONTROLS

VIII. COAL GASIFICATION TECHNOLOGY DEVELOPMENT REQUIREMENTS

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COAL GASIFICATION TECHNOLOGY DEVELOPMENT REQUIREMENTS

- SYSTEMS DEVELOPMENT
- MATERIALS
- INSTRUMENTATION

SUPPORTING TECHNOLOGY DEVELOPMENT RATIONALE

- COAL GASIFICATION FACILITIES ARE HIGHLY CAPITAL INTENSIVE AND END PRODUCT COSTS ARE VERY SENSITIVE TO:
  - CONVERSION EFFICIENCY
  - OPERATING CONDITIONS

- IMPROVEMENTS IN CONVERSION PROCESS ECONOMICS AND EFFICIENCY WILL RESULT FROM:
  - PLANT SCALEUP
  - HIGHER PRESSURES/TEMPERATURES
  - FASTER REACTION TIMES
  - BETTER CONTACT BETWEEN REACTANTS

- MANY CURRENT OPERATING PROBLEMS AND SHUTDOWNS IN PILOT PLANTS ARE DIRECTLY ATTRIBUTABLE TO USE OF COMMERCIAL SUBSYSTEMS/COMPONENTS
  - NOT DESIGNED FOR HIGH TEMP'S/HARSH ENVIRONMENT OF GASIFIER
  - DESIGN MUST BE FOR SPECIFIC APPLICATION

- TECHNICAL AND ECONOMIC VIABILITY ARE DIRECTLY DEPENDENT ON:
  - PROCESS CONTROL VIA INSTRUMENTATION
  - EFFICIENCY/RELIABILITY/DURABILITY/MAINTAINABILITY OF SUBSYSTEMS, COMPONENTS, AND MATERIALS

FOSSIL ENERGY RESEARCH WORKING GROUP REPORT

(APRIL 1979)

- In spite of past commercial developments and use, major components and major steps in coal gasification technology remain characterized by a deficiency of basic knowledge
- There is inherent difficulty in transferring technology from overseas:
  - Need for building equipment in U.S., even equipment that simply duplicates something already working abroad
  - If built here can easily be seen by other interested parties
- Coal gasification should be approached from the systems viewpoint:
  - Greater emphasis should be placed on larger multidisciplinary problems that interrelate equipment, processes, amd materials
  - Real operational difficulties are usually not well documented in the literature
- Hydrodynamics of gasifiers are poorly understood:
  - Channeling in gasifiers beds
  - Formation of vostex flows
  - Development of excessively heated regions in fixed bed reactors
  - Turbulent flows/two phase flows
- Diagnostic tools now used are too crude to provide quantitative information of the type needed for modeling:
  - Direct probing of reactor beds is usually inadequate for determining concentrations and local temperatures
  - Locating hotspots by inserting steel rods that melt is too crude a technique to define temperature levels acceptably
- Diagnostic techniques and methods in existing gasification units tend to be simple and are in general, inadequate
  - Mostly apply commcercial instrumentation used in the petrochemical and and oil refinery industries
  - E.G., synthane unit at PETC, no in-situ measurements of temp densities, or chemical species were being made in the preheater, main unit, or clean up operations following thermal gasifier

FOSSIL ENERGY RESEARCH WORKING GROUP

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Vincente Bendenillo	Manager, Fossil Energy Projects Gas Research Institute
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Arthur M Squires	Department of Chemical Engineering Virginia Polytechnic Institute and State University
John Thomas[2]	President Chevron Research Company

(1) Alternate members (from Exxon)
(2) Alternate members (from Chevron)

FOSSIL ENERGY RESEARCH WORKING GROUP

RECOMMENDATIONS OBTAINED
FROM DIRECTORS OF MAJOR GASIFICATION PROJECTS

ORGANIZATION	INDIVIDUAL
C-E Lummus	A. J. Weiss, Manager Coal Gasification
Bituminous Coal Research, Inc.	Erle K. Diehl, Manager Utilization Research
C. F. Braun & Co.	Roger Detman, Project Manager
Conoco Coal Development Co,	John D. Sudbury, Vice President
Grand Forks Energy Technology Center, DOE	Robert C. Ellman, Research Supervisor Gasification
Morgantown Energy Technology Center, DOE	John S. Wilson, Assistant Director Energy Conversion and Utilization Division
Synthane Pilot Plant, DOE	Robert Lewie, Manager Synthane Program
Rockwell International, Atomic International Div.	A. L. Kehl, Program Manager Molten Salt Gasification Program
Institute of Gas Technology (I.G.T.)	P. B. Tarman Assistant Vice President Process Research

SYSTEMS DEVELOPMENT REQUIREMENTS

COAL FEED

- DRY SOLIDS FEEDERS
- SEAL VALVES AND ROTARY VALVES
- INTERNAL SOLIDS CONTROL VALVES

GASIFIER

- SHELL DESIGNS AND CONSTRUCTION
- REFRACTORY MATERIALS

PUMPS

- CENTRIFUGAL PUMPS
- RECIPROCATING PUMPS

SOLIDS REMOVAL IN GASEOUS STREAMS

- DUST COLLECTORS
- ELECTROSTATIC PRECIPITATORS

POWER RECOVERY GAS EXPANDER TURBINES

COAL FEED

DRY SOLIDS FEEDERS

- METHODS INCLUDE EXTRUDERS, SCREW PUMPS & PISTON FEEDERS
- A REASONABLE AMOUNT OF DEVELOPMENT WORK IS BEING DONE IN THIS AREA; IN ORDER TO PROVIDE SUITABLE FEEDER SYSTEMS FOR COAL GASIFICATION COMMERCIALIZATION THIS DEVELOPMENT SHOULD CONTINUE

SEAL VALVES AND ROTARY VALVES

- PRIMARY USE IN LOCK HOPPER APPLICATIONS WHERE SEAL VALVES AND ROTARY VALVES ARE CRITICAL COMPONENTS
- PRESENT TECHNOLOGY IS NOT AVALIABLE FOR SATISFACTORY OPERATION IN COAL GASIFICATION
- PROBLEMS INCLUDE EROSION OF SEALING SURFACES, MIGRATION OF COAL DUST INTO STUFFING BOX, LARGE SHAFT MECHANICAL DESIGN
- THE STATUS OF DEVELOPMENT FOR SEAL VALVES AND ROTARY VALVES IS NOT SUFFICIENT FOR COMMERCIAL SCALE PLANTS BUT IF CURRENT DEVELOPMENT CONTINUES MOST OF THE MAJOR PROBLEMS SHOULD BE SOLVED.

INTERNAL SOLIDS CONTROL VALVES

- EXISTING HARDWARE AND TECHNOLOGY CANNOT MEET ALL THE CRITICAL REQUIREMENTS OF SOLIDS FLOW SUCH AS, LARGE VOLUME FLOW, EROSIVE CONDITIONS, HIGH TEMPERATURES, HIGH PRESSURE AND CORROSIVE ATMOSPHERE
- A DEVELOPMENT PROGRAM AND A FACILITY CAPABLE OF TESTING PROTOTYPE VALVES ARE NEEDED

GASIFIER

SHELL DESIGN AND CONSTRUCTION

- INDUSTRY IS PRESENTLY CAPABLE OF DESIGNING AND FABRICATING VESSELS TO THE REQUIREMENTS OF MOST PROCESSES
- DEVELOPMENT WORK SHOULD BE DONE IN THE AREAS OF ADVANCEMENT OF THE STATE-OF-THE-ART AND OPTIMIZATION OF MATERIALS, PROCEDURES AND TOOLS;
- MINIMUM REQUIREMENTS FOR DESIGN, FABRICATION, ERECTION, AND INSPECTION NEED TO BE ESTABLISHED

REFRACTORY MATERIALS

- MATERIALS ARE CURRENTLY AVAIABLE FOR FIRST COMMERCIAL PLANTS
- THE EFFECTS OF START-UP, SHUT-DOWN AND LOAD-FOLLOWING CYCLES ARE NOT WELL KNOWN
- SUITABLE REFRACTORIES ARE NEEDED FOR DIRECT CONTACT WITH MOLTEN SLAG OR A MOLTEN BATH IN ORDER TO REDUCE DOWN TIME

PUMPS

CENTRIFUGAL PUMPS:

- COAL SLURRY AT MODERATE TEMPERATURE AND PRESSURE (100°F, 350 PSIG) AND CHAR SLURRY AT MODERATE TEMPERATURE AND HIGH PRESSURE (600°F, 1500 PSIG) WITH UP TO 50% SOLIDS MUST BE PUMPED)
- DEVELOPMENT WORK IS NEEDED ON CENTRIFUGAL PUMPS ESPECIALLY IN THE CONTROL OF ABRASIVE WEAR AND EROSION ON WETTED PARTS (IMPELLER, SUCTION & DISCHARGE TUBES, ETC.)
- THIS DEVELOPMENT WOULD SUPPORT OPTIMIZATION OF FLUID FLOW CHARACTERISITCS AND PUMP MATERIALS.

RECIPROCATING PUMPS

- MAY BE USED IN SOME APPLICATIONS FOR COAL-WATER OR COAL-OIL FEED
- RECIPROCATING PUMPS ARE AVAILABLE FOR COAL FEED APPLICATIONS ON COMMERCIAL PLANT SCALE

SOLIDS REMOVAL FROM GASEOUS STREAMS

THE REMOVAL OF SOLIDS FROM HOT, HIGH TEMPERATURE GAS (2000°F, 1000 PSIG) IS BEYOND THE PRESENT STATE-OF-THE-ART.

DUST COLLECTORS (CYCLONES & GRANULAR BED FILTERS)

- CAPACITIES, TEMPERATURES, PRESSURES AND EROSIVE CONDITIONS UNIQUE TO COAL GASIFICATION ARE NOT DIRECTLY COMPARABLE TO PRESENT COMMERCIAL PRACTICES
- PROBLEMS NOT WELL DEFINED: MATERIALS NEED TO BE FOUND FOR SERVICE IN THE HIGH TEMPERATURE ENTRAINED SOLIDS GAS
- PREDICTED SCALE-UP INFORMATION NEEDED ON PERFORMANCE OF CYCLONES RELATIVE TO EFFICIENCY AND PARTICLE SIZE
- POSSIBLE USE OF GRANULAR BED FILTERS NEEDS TO BE VERIFIED WITH ADDITIONAL DESIGN AND DEVELOPMENT TO MEET THE REQUIREMENTS OF COAL GASIFICATION

ELECTROSTATIC PRECIPITATORS

- OPERATING LIMITS OF ELECTROSTATIC PRECIPITATORS SHOULD BE EXTENDED TO ACCOMODATE THE HIGHER RANGES OF TEMPERATURES AND PRESSURES ENCOUNTERED IN COMMERCIAL SIZE PLANTS
- DEVELOPMENT WORK IS NEEDED TO ACHIEVE A RELIABLE ELECTRICAL AND MECHANICAL SYSTEM

POWER RECOVERY GAS EXPANDER TURBINES

- POWER RECOVERY GAS EXPANDER EXPERIENCE HAS BEEN PRIMARILY IN FLUID CATALYTIC CRACKER REGENERATOR OFF GAS AND NITRIC ACID PLANT TAIL GAS POWER RECOVERY APPLICATION

- DEVELOPMENT IN SOLIDS REMOVAL FROM GASEOUS STREAMS WILL HELP DETERMINE REQUIREMENTS FOR GAS RECOVERY COMPONENTS

- PROBLEM AREAS:
  - CORROSION FROM GAS CONSTITUENTS
  - EROSION OF GAS PATH CONPONENTS
  - EXCESSIVELY HIGH VLADE AND DISC TEMPERATURES
  - INTERSTAGE DEPOSITION OF PARTICULATES

MATERIALS REQUIREMENTS

- INTERRELATED TO SYSTEMS DEVELOPMENT AND INSTRUMENTATION AND CONTROLS REQUIREMENTS
- ESTABLISHING NEEDS IS A MAJOR PROBLEM: KNOWING WHICH PROCESSES OR PROCESS CONDITIONS TO DESIGN FOR APPEARS TO BE A MOVING TARGET
- UNIQUE MATERIALS WILL BE REQUIRED FOR THE HARSH ENVIRONMENT OF COAL GASIFICATION
- PILOT AND DEMONSTRATION PLANTS ARE NEEDED WITH THE NECESSARY DIAGNOSTICS ABILITY TO PROVIDE DEFINITION AND CONTROL OF AN ENVIRONMENT TO SIMULATE COMMERCIAL SCALE CONDITIONS
- MAJOR PROBLEMS AREAS INCLUDE:
  - HIGH TEMPERATURE SCALING AND EROSION UNDER GASIFICATION CONDITIONS
  - AQUEOUS CORROSION BY CONDENSATES AND IN QUENCH SYSTEMS
  - EROSION BY DRY AND WET SOLIDS
  - LACK OF ENGINEERING DESIGN DATA FOR CRITICAL HIGH TEMPERATURE COMPONENTS

MATERIALS FAILURE MODES IN COAL CONVERSION PLANTS

FAILURE MODE	PRESSURE VESSELS	PUMPS	PIPING	VALVES	BELLOWS	AUXILIARY PROCESS EQUIP.	THERMOWELLS	THERMOCOUPLES	TOTALS
CORROSION:									
CARBURIZATION	2	0	8	0	0	2	0	0	12
METAL DUSTING	0	0	5	0	0	0	0	0	5
OXIDATION	0	0	4	0	1	1	1	2	9
PITTING	5	1	11	3	3	3	1	0	27
SULFIDATION	1	0	16	0	1	2	3	5	28
CREEP	1	0	2	0	0	1	0	0	4
DESIGN	11	13	13	8	2	23	2	0	72
EQUIPMENT MALFUNCTION:									
OVERHEATING	4	3	8	1	3	11	4	1	35
OVERSTRESSING	1	1	1	3	0	2	0	0	8
EROSION	2	23	31	25	1	14	1	0	97
FABRICATION	0	1	6	1	0	0	0	2	10
FATIGUE	2	2	5	3	0	2	0	0	14
QUALITY CONTROL	1	0	5	8	1	6	0	2	23
STRESS CORROSION CRACKING:									
GENERAL	4	0	17	0	0	0	1	0	22
CHLORIDE	2	0	18	0	3	0	0	0	23
THERMAL CYCLING	1	0	2	0	0	2	0	0	5
THERMAL SHOCK	0	0	1	0	0	0	1	0	2
THERMAL STRESS	5	1	0	0	0	3	0	0	9
UNKNOWN	3	3	25	10	3	9	2	3	58
TOTALS	45	48	178	62	18	81	16	15	463

MATERIALS REQUIREMENTS

PROBLEM AREAS AND DEVELOPMENT REQUIREMENTS

- AT GASIFIER CONDITIONS, METALS MAY BE SUSCEPTIBLE TO OXIDATION, SULFIDATION, CARBURIZATION, HYDROGEN ATTACK, ETC. CORROSION MAY OCCUR BELOW THE SURFACE AND CORROSION PRODUCTS MAY DISSOLVE OR DISINTEGRATE THE METAL.

- ALLOYS MAY BE SUSCEPTIBLE TO CHEMICAL DEGRADATION AND PHASE CHANGES.

- MECHANICAL PROPERTIES OF CONSTRUCTION MATERIALS UNDER THE AMBIENT ATMOSPHERES, STRESS LEVELS, CYCLIC STRESS, AND TEMPERATURES EXPECTED IN COMMERCIAL COAL-GASIFICATION PLANTS NEED TO BE INVESTIGATED

- REFRACTORIES NEED TO BE FOUND THAT HAVE MECHANICAL AND INSULATING PROPERTIES AT GASIFIER CONDITIONS AND REMAIN RELATIVELY CRACK-FREE THROUGHOUT THE APPLICATION AND OPERATING SEQUENCES.

- METALS SHOULD BE DEVELOPED THAT WILL PROVIDE ADEQUATE LONG-TERM EROSION RESISTANCE AT GASIFIER CONDITIONS.

- METALS, HARDFACINGS, AND REFRACTORIES ARE NEEDED TO PROVIDE ADEQUATE EROSION RESISTANCE FOR COAL-HANDLING EQUIPMENT.

MATERIALS REQUIREMENTS

PROBLEM AREAS AND DEVELOPMENT REQUIREMENTS (CON'T)

- VERIFICATION THAT MATERIALS BEHAVE AS PREDICTED AND ARE ADEQUATE FOR THE OPERATING CONDITIONS ACTUALLY ENCOUNTERED.

- IDENTIFY AND CONTROL UNFORESEEN MATERIALS DESIGN LIMITATIONS THAT MAY ARISE IN SPECIFIC EQUIPMENT ITEMS OR DOWNSTREAM FACILITIES

- STRESS-CORROSION, ASH-CORROSION, CORROSION-FATIGUE, PITTING-CORROSION AND THERMAL CYCLE FATIGUE FOR EXPECTED ENVIRONMENTAL CONDITIONS MUST BE STUDIED.

- DEVELOP NONDESTRUCTIVE TESTING TECHNIQUES FOR MATERIAL INSPECTION DURING PLANT OPERATION

INSTRUMENTATION AND CONTROLS REQUIREMENTS

- MUCH OF THE AVAILABLE INSTRUMENTATION IS INADEQUATE FOR THE REQUIREMENTS OF ADVANCED PROCESSES

- LITTLE INCENTIVE FOR ADVANCEMENT OF INSTRUMENT TECHNOLOGY BY THE USUAL COMMERCIAL EQUIPMENT SUPPLIERS DUE TO:
  - LACK OF SIGNIFICANT MARKET
  - UNDERFINED SPECIFICATIONS
  - EFFECTS OF THE DYNAMIC NATURE OF SYNTHETIC FUEL TECHNOLOGY ON EQUIPMENT REQUIREMENTS

- TECHNOLOGY REQUIRED TO IDENTIFY THE APPROPRIATE MEASUREMENTS AND CONTROLS IS LACKING: THE LIMITED AMOUNT OF DIAGNOSTIC AND PERFORMANCE INSTRUMENTATION INSTALLED AT PILOT PLANTS HAS FURTHER COMPOUNDED THIS PROBLEM

- HIGH PRIORITY PROBLEM AREAS IN MEASUREMENT, TESTING ETC.:
  - TEMPERATURE
  - MULTI-MASS FLOW
  - LETDOWN
  - PHASE DETECTION
  - ON LINE ANALYSIS
  - LEVEL DETECTION
  - VISCOMETRY

INSTRUMENTATION AND CONTROLS REQUIREMENTS
GENERAL PROBLEM AREAS

- TECHNOLOGY READINESS FOR DEMONSTRATION AND EARLY COMMERCIAL PLANT APPLICATION
- MEASUREMENTS
- TESTING

TECHNOLOGY READINESS FOR DEMONSTRATION AND EARLY COMMERCIAL PLANT APPLICATION

- CURRENT PRACTICE IS TO DESIGN ON A PROJECT-BY-PROJECT BASIS USING:
  - COMPONENTS THAT ARE COMMERCIALLY AVAILABLE
  - MANUFACTURERS' RECOMMENDATIONS
  - INADEQUATE METHODS OF COMPARING & EVALUATING CAPABILITIES AND LIMITATIONS
  - PROPRIETARY INFORMATION WHICH IMPEDES EVALUATION

- INADEQUATE APPLICATION OF AVAILABLE TECHNOLOGY
  - DUPLICATION OF EFFORT
  - POOR INFORMATION EXCHANGE
  - PROPRIETARY INFORMATION

- TECHNOLOGY DEVELOPMENT SCHEDULES DO NOT COINCIDE WITH DEMONSTRATION PLANT SCHEDULES

- COAL/SOLIDS PROPERTIES AS THEY AFFECT INSTRUMENTATION AND CONTROLS ARE NOT WELL KNOWN

- IMPROVED MATERIALS FOR INSTRUMENTATION ARE NEEDED AS WELL AS BETTER SELECTION OF AVAILABLE MATERIALS

MEASUREMENTS

- ATMOSPHERES OF MIXED PHASE MASS FLOW ARE CORROSIVE AND ABRASIVE, OFTEN AT HIGH TEMPERATURE AND PRESSURE

- VELOCITY PROFILES ARE COMPLEX, LIQUID, SOLID & GAS FRACTIONS FLOW AT DIFFERENT AVERAGE SPEEDS. PARTICLE SPEED DEPENDS ON PARTICLE SIZE IN THE SOLID FRACTION

- TEMPERATURE MEASUREMENT INSIDE REACTORS IS CHARACTERIZED BY HIGH TEMPERATURES PRESSURES, AND SEVERE EROSIVE/CORROSIVE CONDITIONS
  - HIGHER TEMPERATURE PROBES HAVE SHORT LIFETIME (OFTEN LESS THAN 50 HOURS) AND INSUFFICIENT LONG-TERM CALIBRATION STABILITY

- NO EQUIPMENT EXIST FOR MAKING DIRECT BED LEVEL MEASUREMENT

- FLUID BED LEVEL & DENSITY MEASUREMENTS ARE COMPLICATED BY PLUGGING IN PRESSURE TAPS, VOIDS IN BEDS, NON-UNIFORMITY OF DENSITIES AND LEVELS IN THE REACTOR

- COMMERCIALLY AVALIABLE EQUIPMENT DOES NOT MEET REQUIREMENTS FOR ON LINE COMPOSITION MONITORING, ESPECIALLY STREAMS BETWEEN COMBUSTION OR CONVERSION VESSELS

TESTING

- PILOT PLANTS HAVE A PROCESS DEVELOPMENT MISSION TO PERFORM
  - TESTING MUST BE DONE ON A NONE INTERFERENCE BASIS

- PILOT PLANT SCHEDULES ARE NOT RELIABLE TO THE EXTENT REQUIRED TO PLAN FIRM TEST SCHEDULES
  - PROBLEMS WITH EXPERIMENTAL EQUIPMENT CAN CAUSE DELAYS IN PLANT SCHEDULES

- CALIBRATION OF NEW INSTRUMENTATION CANNOT BE ACCOMPLISHED AT PILOT PLANTS

IX. DOE FOSSIL ENERGY COAL GASIFICATION ADVANCED RESEARCH AND SUPPORTING TECHNOLOGY DEVELOPMENT

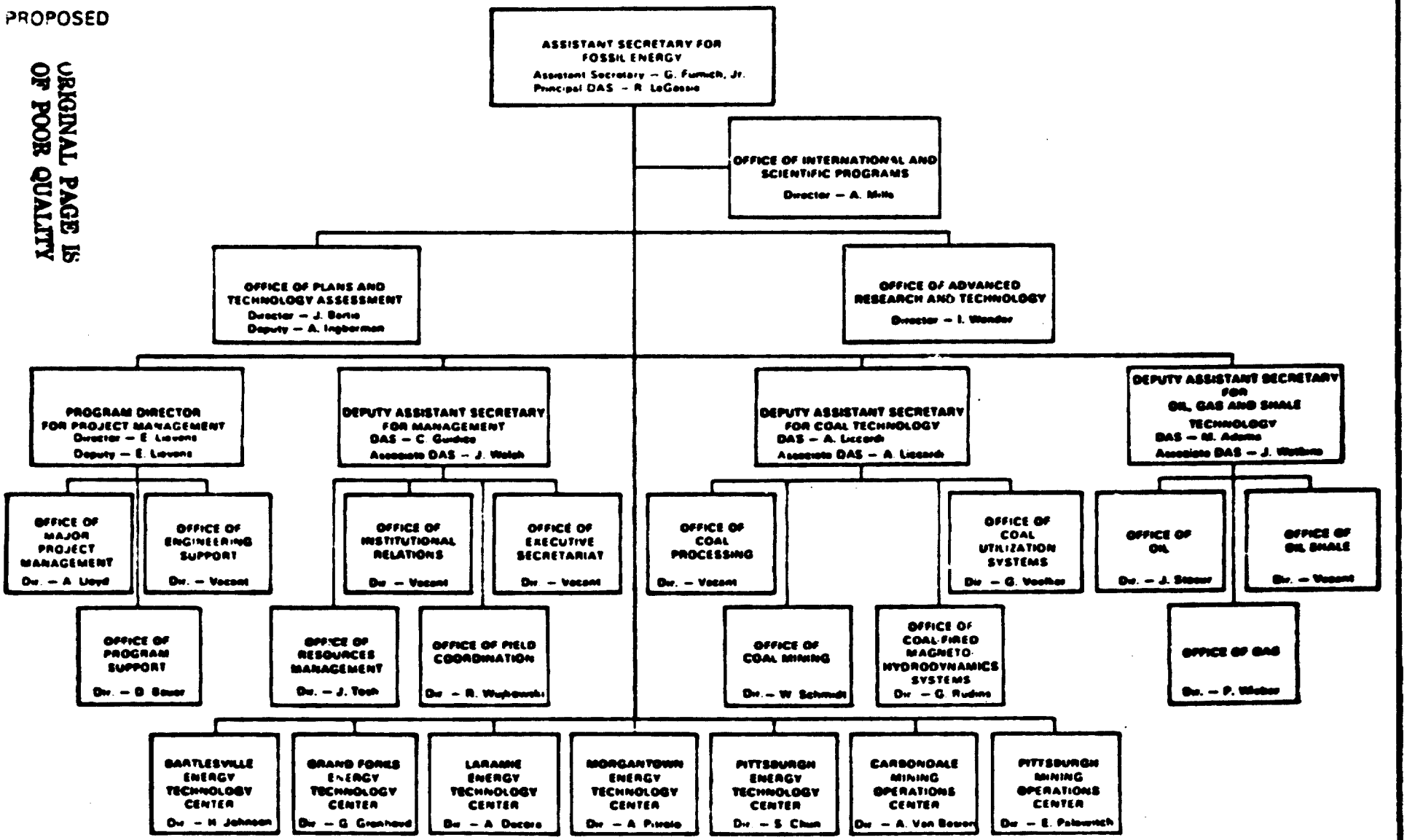
SRS

U.S. DEPARTMENT OF ENERGY

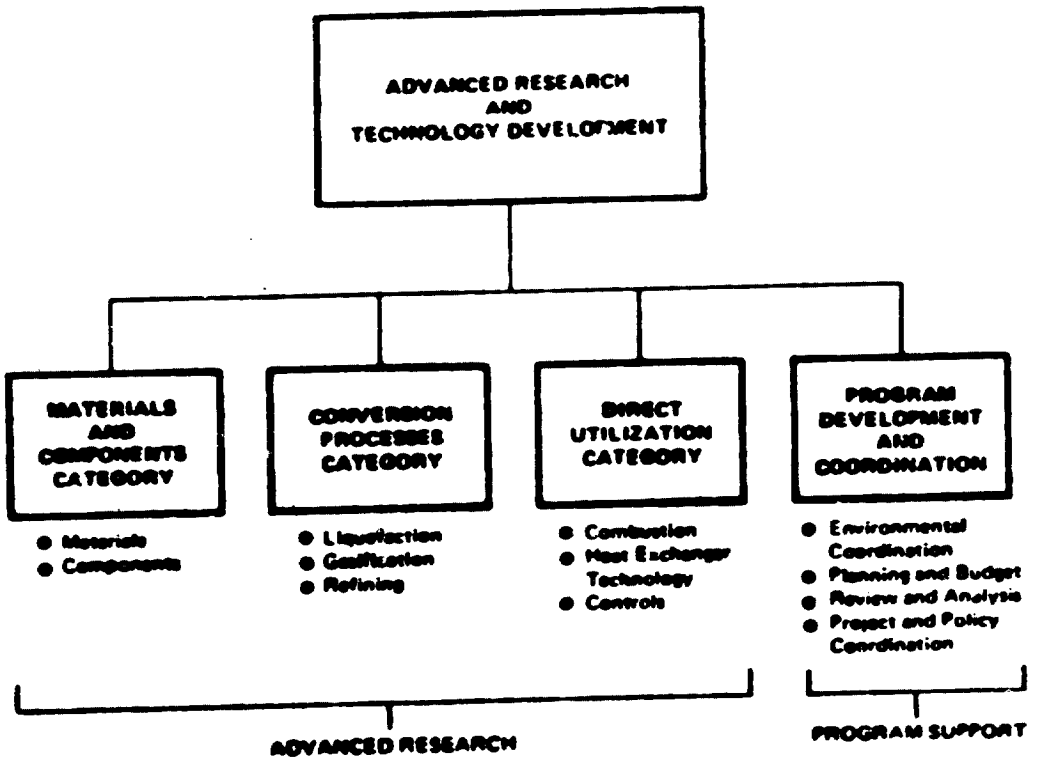
OFFICE OF ASSISTANT SECRETARY FOR FOSSIL ENERGY

Note: All individuals are acting in the positions shown except the Assistant Secretary

PROPOSED



DEPARTMENT OF ENERGY
FOSSIL ENERGY



DEPARTMENT OF ENERGY

FOSSIL ENERGY

ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

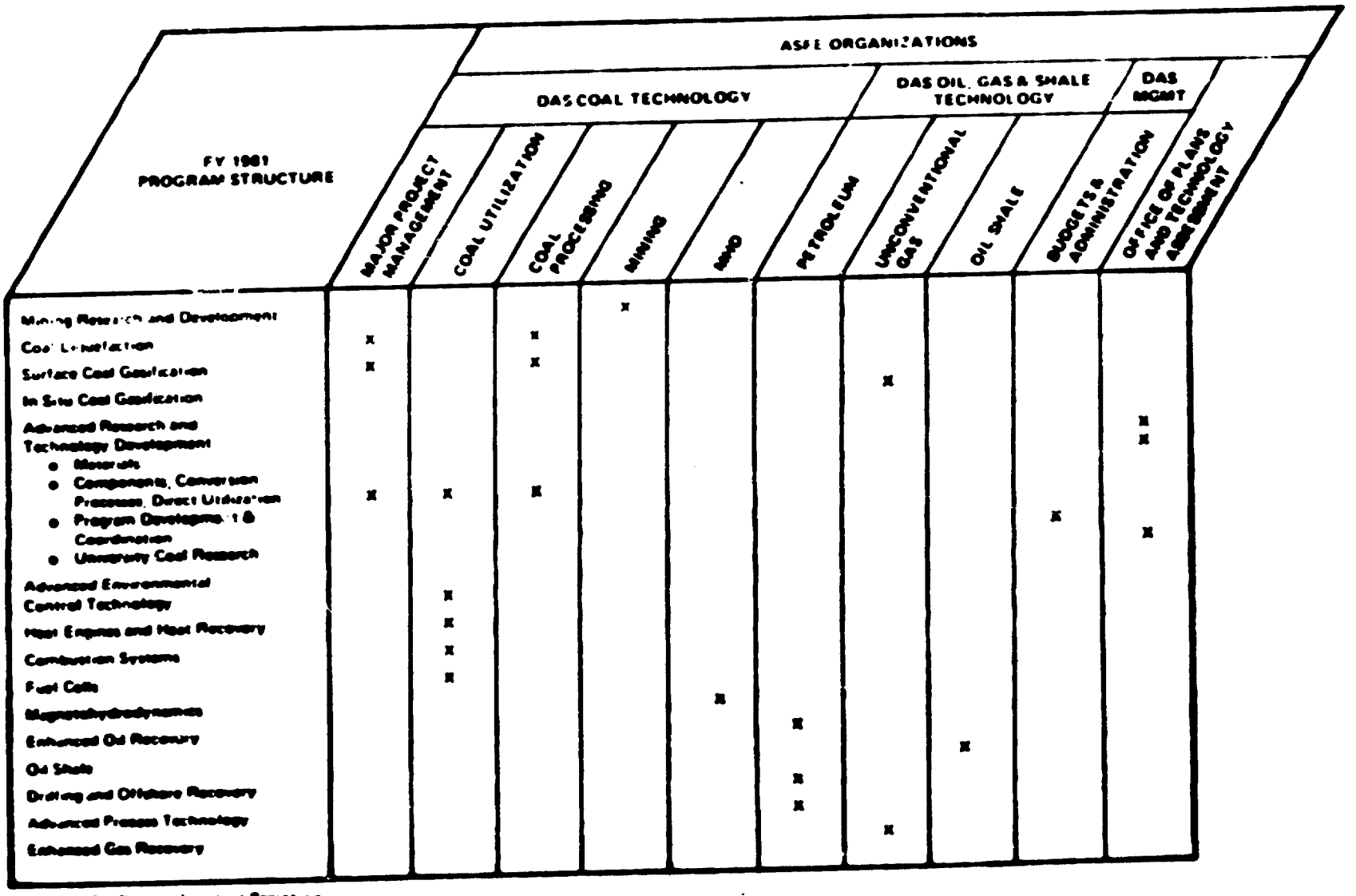
OBJECTIVES

- PROVIDE FOR A CENTRAL RESEARCH FOCUS AND PROGRAM COORDINATION FOR ALL PROGRAM AREAS OF FOSSIL ENERGY.
- PROVIDE A FOUNDATION FOR INNOVATIVE TECHNOLOGY LEADING TO ADVANCED PROCESSES THROUGH PROGRAMS IN THE DOE ENERGY TECHNOLOGY CENTERS (ETCs), NATIONAL LABORATORIES (NLs), OTHER GOVERNMENT AGENCIES, PRIVATE INDUSTRY, AND UNIVERSITIES.
- FACILITATE RELIABLE AND EFFICIENT OPERATION OF SYNTHETIC FUEL PLANTS THROUGH MATERIALS AND COMPONENTS RESEARCH.
- ACCELERATE DIRECT UTILIZATION OF COAL OR COAL-DERIVED SYNFUELS THROUGH TECHNOLOGY DEVELOPMENT FOR COMBUSTION SYSTEMS, HEAT EXCHANGERS AND CONTROL SYSTEMS, INCLUDING APPLICATIONS TO HEAT ENGINES AND FUEL CELLS.
- ENSURE AN ADEQUATE SUPPLY OF TRAINED TECHNICAL PERSONNEL FROM THE NATION'S UNIVERSITY SYSTEM.
- ASSESS THE VIABILITY OF FOSSIL ENERGY PROCESSES UNDER DEVELOPMENT IN TERMS OF NATIONAL NEEDS, ECONOMIC, SOCIAL AND ENVIRONMENTAL CONSTRAINTS AND BENEFITS.
- PROVIDE TECHNICAL ASSESSMENT, ENVIRONMENTAL AND SYSTEMS ASSURANCE SUPPORT FOR FOSSIL ENERGY PROGRAMS.

DEPARTMENT OF ENERGY
FOSSIL ENERGY

ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)		
SUBACTIVITIES	ACTUAL FY 1979	APPROPRIATION FY 1980	ESTIMATE FY 1981
Processes	7,880	14,800	20,400
Direct Utilization	8,450	7,100	11,000
Materials and Components	9,280	12,900	9,000
Program Development and Coordination	13,158	7,700	7,851
University Cost Research	0	5,000	5,000
Capital Equipment	375	400	500
Construction	6,300	8,250	10,700
TOTAL	48,673	88,198	84,451

Program Responsibilities by Fossil Energy Offic



Note: DAS = Deputy Assistant Secretary

Major Field Project Responsibilities and Activities

FY 1981 PROGRAM STRUCTURE	FIELD AGENCIES					
	BETC	GFETC	LETC	METC	PETC	OTHERS
Mining Research & Development					X	X[1]
Coal Liquefaction						X[2]
SRC I & II				X		
Surface Coal Gasification						
Low-Rank Coals (Applic. Center)		X				X[3]
Fuel Gas Demonstration				X		
Coal Feeding Systems						
In Situ Coal Gasification			X			
Advanced Research and Technology Development	X	X	X	X	X	X[5]
Advanced Environmental Control Technology				X		
Gas Stream Cleanup						X[6]
Heat Engines & Heat Recovery	X			X		
Combustion Systems					X	
Direct Coal Combustion					X	
Coal Mixtures				X		
Fluidized Bed Combustion						X[6]
Internal Combustion Systems	X					
Fuel Cells						
Magnetohydrodynamics						X[4]
MHD/CDIF					X	
MHD Combustion						
Enhanced Oil Recovery	X					
Oil Shale			X			
Drilling & Offshore Recovery	X					
Advanced Process Technology	X					
Enhanced Gas Recovery				X		
Western Tight Gas Sands	X			X		
Eastern Gas Shales				X		
Coalbed Methane						

1 Carbondale MTC/Pittsburgh MTC
2 Oak Ridge Operations
3 Chicago Operations
4 Idaho Operations
5 AL, ANL, BNL, INEL, LASL, LBL, LLL, ORNL, PNL, SL
6 NASA

DOE FOSSIL ENERGY

ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

CONVERSION PROCESSES

MAJOR THRUSTS IN FY 80

- DEVELOPMENT/EVALUATION OF INNOVATIVE GASIFICATION PROCESSES
- FUNDAMENTAL STUDIES ON COAL CHEMISTRY
- DEVELOPMENT OF IMPROVED CATALYSTS
- COAL MINERAL CONTENT EFFECTS
- DATA ON SHORT RESIDENCE TIMES REACTIONS OF COAL WITH HYDROGEN
- DEMONSTRATE BENEFIT OF LIME PRETREATMENT OF COAL
  - INCREASED REACTION RATES/METHANE YIELDS
  - ELIMINATION OF CAKING TENDENCIES FOR A VARIETY OF COALS

FY 81 ACTIVITIES

- NOVEL CONCEPTS FOR PRODUCTION OF LOW COST SYNTHESIS GAS
- FUNDAMENTAL STUDIES ON:
  - COAL CHEMISTRY/STRUCTURE
  - CONVERSION PROCESSES
  - CONTROLLING PARAMETERS IN PROCESSES
- EXPANDED EFFORT ON INCREASING THERMAL EFFICIENCY

DOE FOSSIL ENERGY

ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

MATERIALS AND COMPONENTS

MAJOR THRUSTS IN FY 80

- ENGINEERING DESIGN DATA FOR PRESSURE VESSELS
- CONSTRUCTION OF PILOT FACILITY FOR TESTING SLAGGING GASIFIERS
- OPERATION OF TUBULAR CERAMIC HEAT EXCHANGER
- TESTING OF LOCK HOPPER VALVES
- HIGH PRESS/VOL SLURRY PUMP DEVELOPMENT MODULE FAB/ASSEMBLY
- TESTING OF HIGH CAPACITY OXYGEN COMPRESSOR
- SELECTION/DEVELOPMENT OF COMPATIBLE COATINGS FOR INTERNAL SURFACES OF GASIFIERS
- FEASIBILITY STUDY TO GUIDE DEVELOPMENT OF SULFADATION-RESISTANT ALLOYS AND METALS FOR USE IN HIGH TEMP GASIFIERS

FY 81 ACTIVITIES

- MATERIALS EFFORT WILL SHIFT EMPHASIS:
  - FROM TEST/EVAL OF ALLOYS FOR SPECIFIC GASIFIER INTERNALS
  - TO STUDIES TO DETERMINE MECHANISMS OF CORROSIVE ATTACK
- DETERMINATION OF DESIGN PARAMETERS FOR SLAGGING GASIFIER REFRACTORY LININGS AND PERFORM PILOT PLANT TESTS
- REFINE MATERIALS CRITERIA FOR CERAMIC HEAT EXCHANGERS
- CONTINUED DEVELOPMENT/TEST OF COAL FEED SYSTEMS THROUGH PILOT PLANT SCALE (BY FY82)

DOE FOSSIL ENERGY

ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

INSTRUMENTATION AND CONTROLS

MAJOR THRUSTS IN FY 80

- COMBUSTION CONTROL TECHNOLOGY DEVELOPMENT/SCALING
- ACCOUSTICAL MEASUREMENTS OF MASS FLOW FOR COAL AND GAS MIXTURES
- DEVELOPMENT OF INSTRUMENTATION FOR DETERMINING:
  - MIXED-PHASE MASS FLOW
  - ON-LINE COMPOSITION
  - LEVEL OF FLUIDIZED BEDS
  - TEMPERATURE IN VESSELS AND ON VESSEL WALLS
- STUDIES OF CONTROL SYSTEMS CONCEPTS BASED ON EMERGING TECHNOLOGIES SUCH AS LASER FIBER OPTICS

FY 81 ACTIVITIES

- CONTINUE DEVELOPMENT EFFORTS
- FORMULATE/INITIATE DEFINITIVE ANALYTICAL AND EXPERIMENTAL PROJECTS RELATED TO CONTROL SYSTEMS

DOE FOSSIL ENERGY

ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

UNIVERSITY COAL RESEARCH

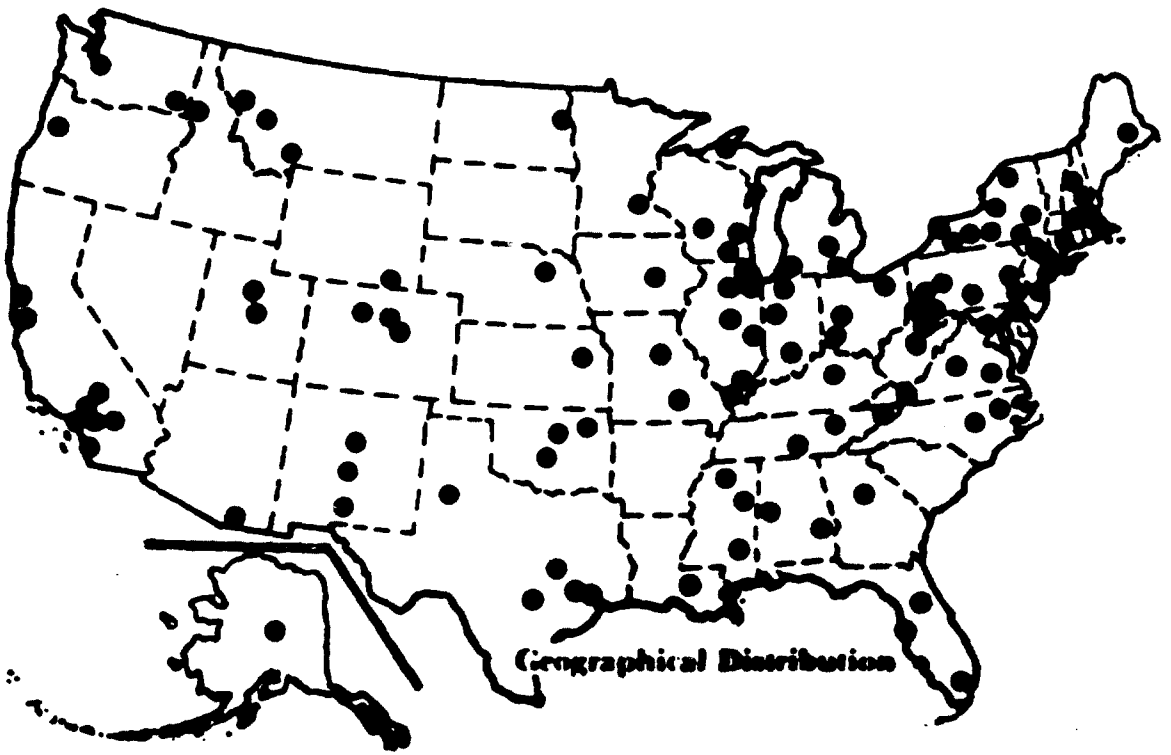
MAJOR THRUSTS IN FY 80

- COMBUSTION OF COAL AND SYNTHETIC FUELS
- COAL CHARACTERIZATION
- STRUCTURE AND REACTIONS OF COAL AND ANALYSIS OF ITS CONVERSION PRODUCTS
- MULTI-PHASE FLOW PHENOMENA
- FUNDAMENTAL PROBLEMS OF REACTOR ENGINEERING
- COAL CONVERSION ENVIRONMENTAL EMISSIONS
- WORKSHOPS WITH INDUSTRY RESEARCHERS FOR DATA EXCHANGE

FY 81 ACTIVITIES

- CONTINUE FY 80 EMPHASIS AREAS
- PROJECTS CHARACTERIZED AS "GOAL-ORIENTED BASIC RESEARCH AND HIGHER RISK, SPECULATIVE RESEARCH"
  (UNIVERSITY RESEARCH REPRESENTS APPROX. 25% OF AR&TD BUDGET)

Fossil Energy University Activities in FY 1990



TECHNOLOGY	ESTIMATED FUNDING (DOLLARS IN MILLIONS)
Advanced Environmental Control Technology	3.0
Coal Gasification and Liquefaction	6.3
Coal Combustion	1.6
Fuel Cells and Advanced Power Systems	1.2
Materials	1.8
MHD	17.4
Mining	1.3
Oil Shale, Tar Sands and Unconventional Gas	2.1
Enhanced Oil Recovery	5.8
Plans and Technology Assessment	2.1
TOTAL	842.4

DOE FOSSIL ENERGY
SURFACE COAL GASIFICATION

GASIFICATIONS SYSTEMS MULTI-TEST FACILITY

OBJECTIVE

- CENTRAL FACILITY WHERE COMPONENTS OF COAL GASIFICATION SYSTEMS CAN BE TESTED AND EVALUATED ON A COMMERCIAL SCALE
  - CONSTRUCTED IN STAGES TO MEET PRIORITIES OF GASIFICATION DEVELOPMENT PROGRAM
  - INITIAL PHASE TO INCLUDE 1ST GEN GASIFIER AND ONE OR TWO 2ND GENERATION GASIFIERS
  - 1ST GEN GASIFIER TO BE EVALUATED PLUS PROVIDE SYNTHESIS GAS OR FUEL GAS TO SUPPORT TESTS OF OTHER DOWNSTREAM EQUIPMENT OR PROCESSES
- TEST ADVANCED GASIFIERS (3RD GEN) AND CLEANUP SYSTEMS, METHANATOR MATERIALS, OTHER NEW EQUIPMENT

OPERATIONAL CONCEPT

- COORDINATION OF TEST PROGRAM TO BE RESPONSIBILITY OF A CONTRACTOR TO BE SELECTED
- FUNDED BY DOE (FY 79: $10M, FY80: $15M REQUEST TO COMPLETE DETAILED DESIGN AND ORDER LONG LEAD TIME EQUIPMENT)
- SITE TBD

DOE FOSSIL ENERGY
SURFACE COAL GASIFICATION

GASIFICATION SYSTEMS MULTI-TEST FACILITY

CURRENT STATUS

- DECISION MADE NOT TO PROCEED WITH FACILITY IN FY 81
- DETERMINED THAT TESTING COULD BE CONDUCTED AS PART OF SPECIFIC ONGOING PROJECTS
- PLANNING FOR PROPOSED FACILITY PLACED ON STANDBY UNTIL "SUCH TIME AS TESTING IS REQUIRED FOR ANY OF THE CANDIDATE PROJECTS"
- CONCEPTUAL DESIGN OF ONE GASIFIER CONCEPT CONSIDERED FOR DEVELOPMENT AS PART OF FACILITY TO BE COMPLETED WITH FY 80 FUNDS ($7M)

DOE FOSSIL ENERGY

ADVANCED RESEARCH AND SUPPORTING TECHNOLOGY DEVELOPMENT

PROGRAM ACTIVITIES SUMMARY

- CONVERSION PROCESSES -

DOE FOSSIL ENERGY
ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

PROJECT TITLE	DESCRIPTION	LOCATION, CITY, AND PRINCIPAL INVESTIGATOR (PI)	WORK LOCATION	DURATION	BUDGET (000's)	REFERENCE NO
Support Coal Gasification	Processes - Support DOE contracts on catalytic gasification	Pittsburgh Energy Technology Center Bruceton, PA PI - W.P. Haynes	Bruceton, PA	10/76 - continuing	$150	C-1
Improved Methanation System	Processes - Develop methanation boiler for coal gasification	Midland-Ross Technical Center Toledo, OH	Toledo, OH	4/76-3/78	$250	C-2
Methanation Catalyst Development	Processes - Develop catalysts for Synthane process	Pittsburgh Energy Technology Center Bruceton, PA PI - V.V.S. Rao M.R. Appell	Bruceton, PA	1971 - continuing	$100	C-3
Treatment of Coal Gasification Wastewater	Processes - Design integrated wastewater treatment system	Pittsburgh Energy Technology Center Bruceton, PA PI - W.P. Haynes	Bruceton, PA	8/77 - continuing	$70	C-4
Gas Purification in Coal Gasification Processes	Processes - Evaluate gas purification systems for sulfur removal	Pittsburgh Energy Technology Center Bruceton, PA PI - L. Lorenzi, Jr.	Bruceton, PA	1977 - continuing	$75	C-5
Advanced Gasification Concepts	Processes - Study and review coal gasification concepts	Morgantown Energy Technology Center Morgantown, WV PI - L.A. Bissett	Morgan-town, WV	10/76 - continuing	$125	C-6
Parametric Char Studies	Processes - Measure characteristics of chars from coal conversion	Morgantown Energy Technology Center Morgantown, WV	Morgan-town, WV	10/76 - continuing	$175	C-7

DOE FOSSIL ENERGY
ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

PROJECT TITLE	DESCRIPTION	CONTRACTOR, CITY, AND PRINCIPAL INVESTIGATOR (PI)	WORK LOCATION	DURATION	BUDGET ($000's)	REFERENCE NO.
Rapid Hydrogenation for Coal Conversion	Processes - Develop noncatalytic process for hydropyrolysis of coal to motor fuel	Institute of Gas Technology Chicago, IL	Chicago, IL	4/76-6/80	$1,500	C-8
Low-Btu Gases as Industrial Process Fuels	Processes - Evaluate feasibility of converting existing equipment to low- and medium-Btu gas fuels	Institute of Gas Technology Chicago, IL	Chicago, IL	10/76 - 11/78	$834	C-9
Medium- and High-Temperature Gas Cleanup	Processes - Apply electrofluidized bed to clean products of coal combustion	Massachusetts Institute of Technology Cambridge, MA	Cambridge, MA	9/77-9/79	$150	C-10
Hazardous Elements in Supplementary Coal Fuels	Processes - Obtain data on hazardous compounds in coal conversion process streams	Pittsburgh Energy Technology Center Bruceton, PA PI - A.G. Sharkey, Jr. C.E. Schmidt	Bruceton, PA	1975 - continuing	$150	C-11
Technical Support Services	Processes - Provide technical support to Division of Coal Conversion	Radian Corp. Austin, TX	Austin, TX	6/76-6/79	$967	C-12
Tables of Thermodynamic Data	Processes - Develop thermodynamic data for compounds associated with coal conversion/combustion	The Dow Chemical Co. Midland, MI	Midland, MI	9/76-8/79	$260	C-13
Chemical Structure of Coal and Coal-Derived Products	Processes - Characterize bituminous and lignite coal via new chemical and instrumental techniques	Argonne National Lab. Argonne, IL	Argonne, IL	10/76 - continuing	$55	C-14

DOE FOSSIL ENERGY
ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

PROJECT TITLE	DESCRIPTION	CONTRACTOR, CITY, AND PRINCIPAL INVESTIGATOR (PI)	MAP LOCATION	DURATION	BUDGET ($000's)	REFERENCE ID NO.
Automated Welding Processes	Processes - Develop and demonstrate an electron beam welding procedure for welding boiler and pressure vessel materials of up to 8 inches thick	Babcock and Wilcox Co. Alliance, OH	Alliance, OH	9/77-9/79	$223	C-15
Effect of Sulfation Accelerators and Corrosion Inhibitors on Material: in FBC Systems	Processes - Investigate the corrosion of structural materials used in atmospheric-pressure fluidized-bed coal combustors	Argonne National Lab. Argonne, IL	Argonne, IL	9/77 - continuing	$50	C-16
Coal Conversion Process Design Data	Processes - Obtain engineering process design data related to gaseous, liquid, and solid products of coal conversion processes	Bartlesville Energy Technology Center Bartlesville, OK PI - W.D. Good	Bartlesville, OK	1/75 - continuing	$250	C-17
Total Energy Technology Alternatives Study	Processes - Study the characteristics of advanced engines operating on coal or coal-derived fuels	Argonne National Lab. Argonne, IL PI - R.E. Holtz T.J. Marciniak	Argonne, IL	10/77 - continuing	$652	C-18
Alternative Fuels Technology	Processes - Provide technical support for substitution of alternative fuels for petroleum and natural gas	Argonne National Lab. Argonne, IL	Argonne, IL	10/77 - continuing	$77	C-19
Use of Multimetallic Bifunctional Catalysts to Convert Synthesis Gas to Methanol	Processes - Define more active catalysts to be used in the conversion of synthetic gas to methanol	Brookhaven National Lab. Upton, NY	Upton, NY	11/77 - 9/78	$46	C-20
Characterization of Coal Microstructure and Pyrite Distribution	Processes - Obtain microstructural-chemical information to clarify the nature of sulfur distribution in coal	Ames Lab. Mountain View, CA	Mountain View, CA	5/77 - continuing	$50	C-21

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ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

PROJECT TITLE	DESCRIPTION	CONTRACTOR, CITY, AND PRINCIPAL INVESTIGATOR (PI)	WORK LOCATION	DURATION	BUDGET (000's)	REFERENCE NO.
Investigation of Organosulfur Compounds in Coal and Coal-Derived Materials	Processes - Develop methods for reducing sulfur in coal to control the level of gas emissions generated during combustion	Ames Lab. Mountain View, CA	Mountain View, CA	6/78 - continuing	$55	C-24
Sodium Carbonate Process for Desulfurizing Coal	Processes - Develop a process to remove sulfur from coal using a sodium carbonate solution	Ames Lab. Mountain View, CA	Mountain View, CA	1976 - continuing	$125	C-25
Coal Desulfurization by Low-Temperature Chlorinolysis	Processes - Develop the low-temperature chlorinolysis process for removal of sulfur from coal	Jet Propulsion Lab. Pasadena, CA	Pasadena, CA	2/77-9/79	$499	C-26
Beneficiation of Dry Pulverized Coal by High-Intensity Magnetic Separation	Processes - Develop a process for removing pyritic sulfur and ash from dry pulverized coal	Oak Ridge National Lab. Oak Ridge, TN	Oak Ridge, TN	10/77 - continuing	$170	C-25
Oil Agglomeration and Recovery of Fine Coals	Processes - Develop the oil agglomeration method of cleaning and recovering fine-size coal	Ames Lab. Mountain View, CA	Mountain View, CA	1976 - continuing	$130	C-26
Investigation and Analysis of Frozen-Coal Handling Problems	Processes - Determine the handling and operating difficulties of using coal that has frozen	Energy Interface Associates, Inc.	---	8/78-1/79	$63	C-27
Reduction of Sodium in Lignite by Ion Exchange	Processes - Determine the most effective and economical method for removing sodium from lignite	U.S. Bureau of Mines Washington, DC	Washington, DC	3/77-3/78	$50	C-28
Demonstration of a Lignite Pelletizing and Pellet Drying Process	Processes - Demonstrate a process by which lignite pellets can be produced with low moisture content	Babcock Contractors, Inc. Bruceton, PA	Bruceton, PA	5/77 - 12/79	$263	C-29

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ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

PROJECT TITLE	DESCRIPTION	CONTRACTOR, CITY, AND PRINCIPAL INVESTIGATOR (PI)	WORK LOCATION	DURATION	BUDGET ($000's)	REFERENCE NO
Materials-Process-Product Methodology	Processes - Develop a model of the MPPM for materials processing technology	International Research and Technology Corp. McLean, VA	McLean, VA	2/78-8/79	$342	[illegible] 99
Investigation and Analysis of Frozen Coal Handling Problems	Processes - Determine the difficulties in handling frozen coal and measures to overcome the problems	Energy Interface Associates, Inc.	--	8/78-1/79	$56	C-31
Effects of Coal Cleaning on Fugitive Elements: Phase I	Processes - Assess the fate of fugitive elements in coal mining preparation, transportation, and utilization	Bituminous Coal Research Monroeville, PA	Monroeville, PA	3/77 - 12/77	$75	[illegible]
Fine Coal Desulfurization and Recovery	Direct Utilization - Develop methods for desulfurizing and recovering fine coal	Ames Lab. Mountain View, CA	Mountain View, CA	7/76 - continuing	$275	C-33
Chemical Removal of Sulfur from Coal	Direct Utilization - Develop process for wet desulfurization	Pittsburgh Energy Technology Center Bruceton, PA PI - S. Friedman J. Gunther	Bruceton, PA	1971 - continuing	$200	C-34
Coal Slag Based Glasses	Direct Utilization - Use coal slag based glasses for hot gas cleanup	General Electric Co. Schenectady, NY	Gale-Cynwyd, PA	6/77-6/78	$193	C-35
Regenerative Process for Desulfurization of Fuel Gases	Direct Utilization - Develop process for regenerating lime-based sorbents used in desulfurization of combustion and fuel gases	Brookhaven National Lab. Upton, NY PI - R.T. Yang M. Steinberg	Upton, NY	1976 - continuing	$357	C-36
Fireside Fouling and Corrosion	Direct Utilization - Develop improved characterization of coal/mineral interactions during combustion	Morgantown Energy Technology Center Morgantown, WV	Morgantown, WV	7/69-9/78	$251	C-37

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ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

PROJECT TITLE	DESCRIPTION	CONTRACTOR, CITY, AND PRINCIPAL INVESTIGATOR (PI)	WORK LOCATION	DURATION	PROJECT COST ($K)	REFERENCE NO.
Investigation of Fuels Containing Coal-Oil-Water Emulsions	Direct Utilization - Evaluate combustion of coal-oil-water slurries	Germantown Laboratories, Inc. Philadelphia, PA	Philadelphia, PA	8/77 - continuing	$494	C-[illegible]
Coal Fuels Combustion Mechanisms	Direct Utilization - Measure combustion properties of coal	Lawrence Berkeley Lab. Berkeley, CA PI - R.E. Sawyer	Berkeley, CA	1976 - continuing	$70	C-[illegible]
Combustion Chemistry of Low and Intermediate Btu Gases	Direct Utilization - Develop combustion parameters for flame stability	Battelle, Columbus Laboratories Columbus, OH	Columbus, OH	6/76-7/78	$341	C-[illegible]
Dry High-Gradient Magnetic Separation	Direct Utilization - Demonstrate removal of pyrites, etc. from dry pulverized coal by high-intensity magnets	Oak Ridge National Lab. Oak Ridge, TN	Oak Ridge, TN	2/77-9/78	$400	C-61
Formation of NO_x from Chemically Bound Nitrogen	Direct Utilization - Study formation of NO_x in stages of coal combustion	Exxon Research and Engineering Co. Linden, NJ	Linden, NJ	9/77 - 11/79	$533	C-62
Study of Chemically Reacting Turbulent Free Shear Layers	Direct Utilization - Measure concentration of chemically reacting species	Aerochem Research Laboratories, Inc. Princeton, NJ	Princeton NJ	9/76 - 11/78	$263	C-63
Rates and Mechanisms of Combustion	Direct Utilization - Characterize combustion properties of pulverized coals	Sandia Laboratories Albuquerque, NM	Albuquerque, NM	4/77 - continuing	$250	C-[illegible]

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ADVANCED RESEARCH AND SUPPORTING TECHNOLOGY

DEVELOPMENT

PROGRAM ACTIVITIES SUMMARY

- MATERIALS AND COMPONENTS -

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ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

PROJECT TITLE	DESCRIPTION	CONTRACTOR, CITY, AND PRINCIPAL INVESTIGATOR (PI)	WORK LOCATION	DURATION	BUDGET ($000's)	REFERENCE NO
Mechanical Reliability of Monolithic Refractory Linings	Materials and Components - Develop crack-free monolithic refractory lining configurations for coal gasification	Babcock and Wilcox Co. Lynchburg, VA	Alliance, OH	1/76 - 12/79	$1,481	C-[illegible]
Corrosion/Erosion Protection of Coal Gasification Vessels	Materials and Components - Develop coating system for large internal components	International Harvester San Diego, CA	San Diego, CA	9/77 - 10/78	$200	C-46
Weld Overlay in Coal Gasification Systems	Materials and Components - Develop weld-deposited overlays for corrosion resistance in coal gasification	International Nickel, Inc. Suffern, NY PI - E.P. Sadowski	Suffern, NY	8/77-8/79	$198	C-47
High-Temperature Behavior of Structural Alloys	Materials and Components - Evaluate corrosion behavior of iron- and nickel-base alloys	Battelle, Columbus Laboratories Columbus, OH PI - I.G. Wright	Columbus, OH	5/76 - 11/79	$227	C-48
Data Record on High-Temperature Oxidation	Materials and Components - Compile handbook on high-temperature corrosion of metals	Battelle, Columbus Laboratories Columbus, OH	Columbus, OH	2/76-3/78	$18	C-49
Inspection Techniques for Wear- and Process-Resistant Coatings	Materials and Components - Develop nondestructive techniques for inspecting protective coatings	Oak Ridge National Lab. Oak Ridge, TN PI - R.W. McClung G.W. Scott	Oak Ridge, TN	1/76 - continuing	$200	C-50
Fracture Toughness of Candidate Steels for Pressure Vessels	Materials and Components - Characterize tensile and fracture toughness of steels	Oak Ridge National Lab. Oak Ridge, TN PI - D.A. Canonico	Oak Ridge, TN	10/76 - continuing	$100	C-51

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ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

PROJECT TITLE	DESCRIPTION	CONTRACTOR, CITY, AND PRINCIPAL INVESTIGATOR (PI)	WORK LOCATION	DURATION	BUDGET ($000's)	REFERENCE NO
Techniques for Welding and Cladding	Materials and Components - Study cladding and field-welding technologies for coal gasifier steels	Oak Ridge National Lab. Oak Ridge, TN PI - D.P. Edmonds G.M. Goodwin	Oak Ridge, TN	7/76 - continuing	$100	C-52
Wear-Resistant Alloys for Coal Handling Equipment	Materials and Components - Develop wear-resistant alloys for coal transportation and fragmentation equipment	Lawrence Berkeley Lab. Berkeley, CA	Berkeley, CA	1/77 - continuing	$225	C-53
Low Alloy Steels	Materials and Components - Develop low-alloy steels for thick wall pressure vessels	Lawrence Berkeley Lab. Berkeley, CA	Berkeley, CA	10/76 - continuing	$160	C-54
Refractory Linings for Coal Gasification Equipment	Materials and Components - Determine effect of coal gasifier environments on commercially available refractory lining materials	U.S. Dept. of Interior, Bureau of Mines/Tuscaloosa Metallurgy Research Center Tuscaloosa, AL	Tuscaloosa, AL	1974 - continuing	$150	C-55
Coatings for Protecting Internal Components of Coal Gasification Vessels	Materials and Components - Design and improve high-temperature alloy resistant to attack in high sulfur gasification atmospheres	Lockheed Palo Alto Research Laboratories Palo Alto, CA	Palo Alto, CA	10/77 - 9/79	$303	C-56
Protective Layers on Alloys	Materials and Components - Modify best commercial alloy to achieve longer life with high-temperature, high-pressure, sulfur-rich gases in gasification	Sandia Laboratories Albuquerque, NM	Albuquerque, NM	2/76 - continuing	$160	C-57
Plant Materials for the Gasification of Coal	Materials and Components - Provide data on materials for use in coal gasification plants	Metal Properties Council, Inc. New York, NY	New York, NY	9/72 - 12/79	$4,915	C-58
Materials Research for Clean Utilization of Coal	Materials and Components - Develop equipment and test methods for coal gasification environments	National Bureau of Standards Gaithersburg, MD PI - [illegible]	Gaithersburg, MD	10/77 - continuing	$610	C-59

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PROJECT TITLE	DESCRIPTION	CONTRACTOR, CITY, AND PRINCIPAL INVESTIGATOR (PI)	WORK LOCATION	DURATION	BUDGET ($000's)	REFERENCE NO
Evaluation of Heat Exchanger Materials	Materials and Components - Obtain engineering data pertaining to materials used in fluidized-bed combustion	Battelle, Columbus Laboratories Columbus, OH	Columbus, OH	5/76 - continuing	$769	C-60
Materials Technology for Coal Conversion Processes	Materials and Components - Evaluate refractories for slagging gasifiers	Argonne National Lab. Argonne, IL	Argonne, IL	7/75 - continuing	$725	C-61
Heat Exchanger Material	Materials and Components - Evaluate the behavior of candidate heat-exchanger alloys in coal-fired atmospheric fluidized-bed combustors	Oak Ridge National Lab. Oak Ridge, TN PI - J.H. DeVan T.G. Godfrey	Oak Ridge, TN	6/76 - continuing	$105	C 62
Design and Evaluation of Components in Fossil Energy Systems	Materials and Components - Provide engineering support services including the design and operation of machinery in coal conversion plants for the DOE Components Branch	Mechanical Technology Inc. Latham, NY	Latham, NY	8/77-8/79	$389	C-63
Oxygen Centrifugal Compressors	Materials and Components - Assess the state-of-the-art of large centrifugal oxygen compressor construction	Southern Research Institute Birmingham, AL	Birmingham, AL	6/75-1/78	$426	C-64
Valve Testing and Development	Materials and Components - Produce long-life valves for handling solids feed and removal in coal conversion reactors	Morgantown Energy Technology Center Morgantown, WV	Morgantown, WV	7/74 - continuing	$2,834	C-65
Valve Development for Coal Gasification Plants	Materials and Components - Develop valves suitable for lock hoppers used in high-Btu gasification systems	Fairchild Stratos Division Manhattan Beach, CA	Manhattan Beach, CA	6/76-6/80	$2,238	C-66

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PROJECT TITLE	DESCRIPTION	CONTRACTOR, CITY, AND PRINCIPAL INVESTIGATOR (PI)	WORK LOCATION	DURATION	BUDGET (000's)	REFERENCE NO.
Wear Resistant Valve Materials	Materials and Components - Develop, test, and evaluate materials with abrasion, adhesion, and erosion resistance to operate in critical valves in gasification systems	Albany Metallurgy Research Center Albany, NY	Albany, NY	2/75 - continuing	$975	C-67
Turbine Materials Evaluation	Materials and Components - Provide engineering data on deterioration of gas turbine materials exposed to exhaust gas in pressurized fluidized-bed combustors	General Electric Co. Schenectady, NY	Washington, DC	7/76-6/78	$240	C-68
Particulate Control Cyclo-centrifuge	Materials and Components - Demonstrate the efficiency of a cyclocentrifuge for separation of particle matter from a hot, pressurized gas steam	Mechanical Technology Inc. Latham, NY PI - J.T. McCabe	Latham, NY	5/76-8/78	$485	C-69
Coal Slurry Feed System	Materials and Components - Develop and test a steam-dried slurry feed system for injecting dry crushed coal into a high pressure process	Morgantown Energy Technology Center Morgantown, WV	Morgantown, WV	6/76 - continuing	$520	C-70
Industrial Coal Conversion Equipment	Materials and Components - Identify the ability of industry to supply needed equipment for coal demonstration plants	Oak Ridge National Lab. Oak Ridge, TN	Oak Ridge, TN	10/76 - continuing	$300	C-71
Coal Equipment Test Program	Materials and Components - Examine specific equipment requirements for coal conversion demonstration plants	Oak Ridge National Lab. Oak Ridge, TN	Oak Ridge, TN	7/76 - continuing	$280	C-72
Lock Hopper Valve Development	Materials and Components - Design, manufacture, test, and evaluate valves for gasification plants	Consolidated Controls El Segundo, CA	El Segundo, CA	5/76-5/80	$2,575	C-73

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ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

PROJECT TITLE	DESCRIPTION	CONTRACTOR, CITY, AND PRINCIPAL INVESTIGATOR (PI)	WORK LOCATION	DURATION	BUDGET ($000's)	REFERENCE NO
Coatings for Protecting Internal Components of Coal Gasification Vessels	Materials and Components - Develop plasma spray-heat treatment processes for applying a corrosion-resistant nickel alloy to the surface of coal gasifier steel components	Solar Turbines International San Diego, CA	San Diego, CA	9/77-9/79	$201	C-74
Sulfidation-Resistant Alloy for Coal Gasification Service	Materials and Components - Design a high-temperature alloy that would have improved resistance to attack in high-sulfur coal gasification atmospheres	Lockheed Palo Alto Research Labs. Palo Alto, CA	Palo Alto, CA	7/77-10/78	$298	C-75
Heat Transfer through Refractory-Lined Gasifier Vessel Walls	Materials and Components - Provide a computer model to predict the impact of key parameters on heat flows in a coal gasification vessel	Battelle Columbus Labs. Columbus, OH	Columbus, OH	6/76-12/78	$535	C-76
Chromium-Molybdenum Steels for Fossil Utility Boiler Applications	Materials and Components - Develop a chromium-molybdenum steel with improved elevated-temperature strength and manufacturing properties	Oak Ridge National Lab. Oak Ridge, TN	Oak Ridge, TN	10/77-continuing	$128	C-77
Evaluation of Fracture Toughness of Pressure Vessel Steels	Materials and Components - Determine the effect of the operating environment of coal conversion systems on high- and low-temperature properties of pressure vessel steels	Oak Ridge National Lab. Oak Ridge, TN	Oak Ridge, TN	10/77-continuing	$150	C-78
Management and Coordination of Coal Science Tasks	Materials and Components - Assist the Division of Coal Conversion/Liquifaction and the Office of University Activities in coordinating coal science projects	Pittsburgh Energy Technology Center Bruceton, PA PI - A.G. Sharkey, Jr. M.L. Retcofsky	Bruceton, PA	1978-continuing	$100	C-79
Feasibility of Using a Rotating Fluidized Bed for Desulfurizing Hot Gases	Materials and Components - Assess the feasibility of a rotating fluidized-bed contacting device containing limestone which is used to desulphurize hot gases derived from coal combustion	Brookhaven National Lab. Upton, NY	Upton, NY	1978-continuing	$20	C-80

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ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

PROJECT TITLE	DESCRIPTION	CONTRACTOR, CITY, AND PRINCIPAL INVESTIGATOR (PI)	WORK LOCATION	DURATION	BUDGET ($000's)	REFERENCE NO
Plastic Heat Exchanger for Waste Heat Recovery	Materials and Components - Develop low-cost plastic heat exchangers to be used to conserve low-temperature waste heat	Argonne National Lab. Argonne, IL PI - R.E. Holtz R.N. Kreipmans	Argonne, IL	2/78-continuing	$50	C-81
Heat Exchanger Tube Vibrations	Materials and Components - Test segmentally baffled shell-and-tube heat exchangers, and quantify tube vibration data	Argonne National Lab. Argonne, IL	Argonne, IL	1977-continuing	$144	C-82
Optimizing Chromium Molybdenum Steels to Resist Hydrogen and Temper Embrittlements	Materials and Components - Evaluate and optimize the resistence to hydrogen, and temper embrittlement susceptibility of chromium-molybdenum steels for use as structural materials in coal conversion pressure vessels	Westinghouse Electric Corp. Pittsburgh, PA	Pittsburgh, PA	8/78-8/81	$207	C-83
Development of Wear-Resistant Valve Materials	Materials and Components - Develop and identify improved wear-resistant materials to be used for valve trim	Bureau of Mines, Albany Metallurgy, Research Center Albany, NY	Albany, NY	10/77-10/78	$150	C-84

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ADVANCED RESEARCH AND SUPPORTING TECHNOLOGY

DEVELOPMENT

PROGRAM ACTIVITIES SUMMARY

- INSTRUMENTATION AND CONTROLS -

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ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

PROJECT TITLE	DESCRIPTION	CONTRACTOR, CITY, AND PRINCIPAL INVESTIGATOR (PI)	WORK LOCATION	DURATION	BUDGET ($000's)	REFERENCE NO.
Direct Sampling and Characterization of Gaseous Species	Direct Utilization - Identify gaseous alkali metal species and develop sampling methods	Midwest Research Institute Kansas City, MO	Kansas City, MO	5/76 - 10/78	$197	C-85
Concentration Sensor for Coal/Water Mixtures	Materials and Components - Design, fabricate, and test two concentration sensors used for accurate measurement of coal/refuse/water concentrations in hydraulic transport pipelines	Science Applications, Inc. La Jolla, CA	La Jolla, CA	6/76-9/79	$533	C-86
Exchange of Ash and Sulfur Monitors	Direct Utilization - Exchange U.S. sulfur monitor for England's ash monitor	Morgantown Energy Technology Center Morgantown, WV PI - R. Stewart	Morgantown, WV	11/75 - 9/78	$1,000	C-87
Development of Nuclear Assay Instrument	Direct Utilization - Develop technique for direct determination of coal composition	Morgantown Energy Technology Center Morgantown, WV PI - R. Stewart	Morgantown, WV	9/76 - continuing	$190	C-88
Vibrational Spectroscopic Studies	Processes - Determine the nature of reactants and products during reaction on coal conversion catalysts	Pittsburgh Energy Technology Center Bruceton, PA PI - A.G. Sharkey, Jr. F.A. Braun L.E. Makovsky	Bruceton, PA	10/76 - continuing	$100	C-89
Instrumentation for Analysis of Low-Btu Gas	Processes - Design instrumentation for on-line analysis of low-Btu gas from coal	Ames Lab. Mountain View, CA	Mountain View, CA	3/77 - continuing	$75	C-93

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ADVANCED RESEARCH AND SUPPORTING TECHNOLOGY

DEVELOPMENT

PROGRAM ACTIVITIES NARRATIVE DESCRIPTION

- CONVERSION PROCESSES -

C-1 Pittsburgh Energy Technology Center, Bruceton, PA - Support for DOE contracts on catalytic gasification (conversion of coal into gaseous fuels) was provided in this project. Equipment was designed, assembled and operated. Chemicals that reduce the agglomerating (clustering) propensity of bituminous coals were determined. Tests were run to verify the catalytic process undergoing development at Battelle Memorial Institute.

C-2 Midland-Ross Technical Center, Toledo, OH - An improved boiler for producing methane was developed specifically for use in coal gasification plants (where coal is converted to gaseous products). A test facility began operating, and a computer simulation was used to compare the theoretical data and experimental results. The project aimed to 1) eliminate the need to recycle product gas for temperature control, 2) make approximately 90 percent of the reaction heat available for producing high-pressure steam, 3) reduce operating costs by eliminating recompression and providing high steam quality, and 4) reduce capital costs by combining the methanation part of the process with the already required heat exchangers (devices that enable heat transfer between two fluids).

C-3 Pittsburgh Energy Technology Center, Bruceton, PA - The purpose of this project was to develop improved catalysts for the Synthane process. The Synthane process is a coal gasification process (conversion of coal to gaseous products) in which coal is treated with a steam/oxygen mixture to give a synthesis gas with a high methane content suitable for upgrading to pipeline quality (high Btu) gas. Factors which affect stability, selectivity and activity of methanation catalysts were determined. An analysis was conducted of the deactivation to methane of the Raney nickel catalyst, an alloy of nickel and aluminum favored for converting synthesis gas and produced in the first stages of coal conversion processes.

C-4 Pittsburgh Energy Technology Center, Bruceton, PA - Methods for treating wastewater from coal conversion processes (converting coal to liquid or gaseous products) were developed. The design and construction of a wastewater treatment system integrated into the coal conversion process was completed. Design capacity is about one gallon per hour.

C-5 Pittsburgh Energy Technology Center, Bruceton, PA - The objective of this project was to evaluate gas purification systems which are potentially applicable to the coal gasification process (conversion of coal to gaseous products). A primary consideration was sulfur removal from the coal-derived gas. A review of the literature on gas treatment systems was completed. Gas purification process performance characteristics and economic estimates were obtained, and data were compared for several processes.

Morgantown Energy Research Center, Morgantown, WV - A study of coal gasification (conversion of coal to gaseous products) was made as an engineering assessment. The purpose of the study was to 1) determine the technical feasibility and economic impact of novel processes, 2) identify pertinent areas of research, and 3) increase the fundamental understanding of existing gasification processes with mathematical modeling. Major assessment work on the various gasification concepts was completed, and research proposals were prepared. C-6

Morgantown Energy Research Center, Morgantown, WV - The purpose of this project was to measure the physical and chemical characteristics and reactivities of chars produced from coal conversion processes (conversion of coal to liquid or gaseous products), and attempt to identify the best end uses for these products. Equipment for analyzing chars was installed and a series of experiments begun. Results were compared to published models of char reactivities. C-7

Institute of Gas Technology, Chicago, IL - This project was an attempt to develop a noncatalytic process for the hydropyrolysis of coal (decomposition of coal by heating and adding hydrogen) for the production of fuel gases and high-octane gasoline blending stock. A bench-scale unit was constructed and experimental work done. Studies were made of methods for separating and recovering methane, ethane, and carbon oxides. C-8

Institute of Gas Technology, Chicago, IL - It was the purpose of this project to assess industrial uses of low- and medium-Btu gases and the equipment adaptations that might be needed. Low- and medium-Btu gas is a product of coal gasification and has a low heating value. Eight types of burners were tested with low- and medium-Btu gases and their performances compared to their performance with natural gas. A manual was prepared to inform users of industrial burner equipment of the results of this study. C-9

Massachusetts Institute of Technology, Cambridge, MA - The objective of this study was to investigate the applicability of the electrofluidized bed (EFB) to the cleanup of particulates from the products of coal combustion. The EFB consists of a bed through which a fluid is passed at a speed high enough for solid particles to separate and become freely supported in the fluid. An electric current aids in the separation and removal of particles. A test rig is to become operational by fall 1979. C-10

Pittsburgh Energy Technology Center, Bruceton, PA - Research was undertaken to support coal conversion processes (producing liquid or gaseous fuels from coal) by obtaining data on possible hazardous elements and compounds. The feed coal, water, tar, char, and filter ash of coal conversion were screened for 60 to 70 trace and minor elements and for several hundred potentially hazardous compounds. Examinations are continuing. C-11

Radian Corporation, Austin, TX - Technical support is being provided to the Division of Coal Conversion regarding demonstration and pilot plant projects. Site suitability and water availability reports were provided for two coal conversion demonstration projects. An environmental review and a socioeconomic evaluation were prepared for other plants. Technical reviews were made of interim results of conceptual designs for steam-generating plants. C-12

The Dow Chemical Company, Midland, MI - A critical evaluation of pertinent literature was completed to develop tables of thermodynamic data for compounds associated with coal conversion and coal combustion processes. Data are included for boiler and gas turbine corrosion, sulfur control, and catalyst deactivation. Data will be published quarterly as part of the Joint Army-Navy-Air Force Thermochemical Tables. C-13

Argonne National Laboratory, Argonne, IL - Chemical and instrumental techniques were used to structurally characterize coal and solvent-refined coal (a product of the selective transfer of coal constituents from finely divided coal particles into a solvent). Elements were analyzed and constituents identified. The solvent extraction process and its products were compared for bituminous coals and lignite. A detailed report was prepared. C-14

Babcock & Wilcox Company, Alliance, OH - The objective of this project was to develop and demonstrate an electronbeam welding procedure (technique for joining materials in which parallel electron beams at low pressures are used to produce a highly concentrated heat source) for welding boiler and pressure vessel materials of up to 8 inches thick. Additional work was performed to acquire information, such as determination of desired vacuum level, joint fit requirements, demagnetization requirements, repair techniques, and mechanical properties, relative to the feasibility of electron beam welding for coal gasification units. C-15

Argonne National Laboratory, Argonne, IL - The aims of this project were to investigate the corrosion of structural materials used in atmospheric pressure fluidized bed coal combustors, to investigate the effect of pollution-reducing measures on the corrosion, and to find an optimal combination of corrosion-resistant equipment and minimally corroding pollution-reducing processes. A coal combustion test facility was completed and testing was initiated by means of special air-cooled corrosion probes. C-16

Bartlesville Energy Technology Center, Bartlesville, OK - The purpose of this project was to obtain engineering process design data related to gaseous, liquid, and solid products of coal conversion processes. Specific tasks performed included: correlating the combustability of coal-derived solids and liquids to the grade of the parent coal, measuring the solubility of hydrogen and synthetic gas in process solvents, and chemical characterization of key compounds important in the processing of liquids derived from coal. Heat generated by combustion and hydrogen solubility will be measured in samples generated by the Solvent Refined Coal-II Process. C-17

Argonne National Laboratory, Argonne, IL - The purpose of this project was to study the fuel flexibility potential, energy efficiency, and economic viability of advanced engines operating on coal or coal-derived fuels. Engines studied included Sterling cycle, external combustion Brayton cycle, small high-efficiency steam turbines, and coal-using diesel engines. The Sterling cycle engine using coal fuels could be competitive with gas turbines and diesel engines for community use; Brayton engines would be competitive in the large engine market. Coal-using diesel engines might be competitive operating on coal-derived fuels rather than coal itself. C-18

Argonne National Laboratory, Argonne, IL - Funding was provided for technical support services to help ensure the eventual substitution of alternate fuels for petroleum and natural gas. Tasks included evaluation of fuels for various applications, characterization of the combustion of alternate fuels, development of models and quantization of emissions, as well as technical monitoring of contracts and the evaluation of contract proposals. C-19

Brookhaven National Laboratory, Upton, NY - The goal of this contract was to find more active catalysts to be used in the conversion of synthetic gas to methanol. Methanol has the potential for use as a coal-derived synthetic fuel or feedstock. A new catalyst system was developed through a homogeneous analog and research on this plus a literature search explained a new mechanism for catalyzed synthetic gas reactions. C-20

Ames Laboratory, Mountain View, CA - The purpose of this project was to obtain microstructural-chemical information, using electron microscope techniques, to clarify the nature of sulfur distribution in coal. The forms of sulfur in a broad sampling of coal were analyzed and compared to facilitate their removal, using various purification procedures. The effects of sulfur removal on coal characteristics was assessed, and alternative processes were investigated. Further experimentation is being conducted to determine more efficient methods of sulfur characterization and removal. C-21

Ames Laboratory, Mountain View, CA - The objective of this project was to develop methods for reducing sulfur in coal to control the level of gas emissions generated during combustion in compliance with Federal environmental requirements. Coal and coal-derived materials were subjected to various desulfurization processes and the effectiveness of each procedure was evaluated. New methodologies for the identification, characterization and separation of sulfur are being developed. C-22

Ames Laboratory, Mountain View, CA - The purpose of this project was to develop a process using sodium carbonate solution to remove sulfur from coal. Numerous laboratory experiments were conducted to evaluate the important characteristics of the extraction process and the response of various types of coal to the treatment. Development of the procedure is being continued to determine optimum process conditions and to identify coals that respond favorably to desulfurization for production of clean coal for direct combustion. C-23

C-24

Jet Propulsion Laboratory, Pasadena, CA - The objective of this program was to develop the low-temperature chlorinolysis process for removal of sulfur from coal. The effects of various process conditions on the efficiency of this method were evaluated, and the effectiveness on various types of coal was assessed. Laboratory results were promising, and further testing and modification procedures were conducted to optimize the desulfurization process for pilot plant use.

C-25

Oak Ridge National Laboratory, Oak Ridge, TN - The objective of this project was to develop a process for removing pyritic sulfur and ash from dry pulverized coal using high-intensity magnetic fields. This method was developed to provide environmentally acceptable fuel coal for use in steam power plants or coal gasification and liquefaction plants. Tests were conducted to identify the controlling process conditions to maximize separation efficiency. Further tests are being conducted to optimize the procedure and to determine the magnetic separability of various coals.

C-26

Ames Laboratory, Mountain View, CA - The objective of this project was development of the oil agglomeration (process of collecting in a mass) method of cleaning and recovering fine-size coal to improve separation of coal and iron pyrites and increase capability for handling fine coal. Laboratory experiments determined that separation was improved significantly by chemically pretreating the particles, and suitable operating conditions for both pretreatment and agglomeration were identified. Development of both procedures is being continued to determine optimum process conditions and to identify coals that respond favorably to the method.

C-27

Energy Interface Associates, Inc. - The purpose of this project was to determine the handling and operating difficulties of using coal that has forzen into large chunks and slabs. A survey of mines, transfer points, and utilities was conducted to define the nature and extent of the problems and to identify and analyze potential solutions. Most utility plants are not equipped to handle or thaw frozen coal, and chemicals that prevent the condition may be applied to coal at the mines.

U.S. Bureau of Mines, Washington, DC - The purpose of this project was to determine the most effective and economical method for removing sodium from lignite (a type of coal) by ion exchange (a chemical reaction used to purify or separate substances). Sodium is the element chiefly responsible for the formation of ash deposits, which foul boiler tubes and decrease efficiency. An extractor was designed, assembled, and operated, using various testing and analysis procedures to investigate feasibility of the ion exchange process. Excellent results were achieved using this method. C-28

Babcock Contractors, Inc., Bruceton, PA - The objective of this project was to demonstrate a process by which lignite (a type of coal) pellets can be produced with low moisture content and a binder that will provide good mechanical strength and resistance to moisture pick-up, spontaneous ignition, and dusting during handling. The first phase of the study involved laboratory research to determine the variables and test and evaluate the procedures for producing the pellets. Results of these analyses were used in the second phase to produce large quantities of lignite pellets for pilot plant testing and cost study. C-29

International Research and Technology Corporation, McLean, VA - The objective of this project was to further develop a model based on the MPPM, for processing technology. The MPPM is an analytical tool in the form of an interactive, conversational computer program. For coal conversion processes, the program provides an analyst with rapid, systematic evaluations of technological developments, policy decisions and sensitivity to uncertainty. The model comprises a data base and a method of decision evaluations. C-30

Energy Interface Associates, Inc. - The study goal was to determine the difficulties in handling frozen coal and what expedient measures were adopted at various sites to overcome the problems. A report was prepared which included the conditions encountered and remedial action taken. The study is completed and will be used as a basis for writing a Request For Proposal for a research project aimed at developing cost-effective processes of overcoming problems associated with frozen coal. C-31

Bituminous Coal Research, Monroeville, PA - A principal objective of this project was to assess the fate of fugitive elements (i.e., non-coal) in coal mining, preparation, transportation, and utilization. Other tasks were to determine the effect of coal cleaning on fugitive elements and to describe analytical methods used to determine the concentration of selected trace elements in a variety of coals. Results of this study indicated that the cleaning of coal significantly reduced many of the constituents considered harmful, with respect to environmental or utilization viewpoints. C-32

Ames Laboratory, Mountain View, CA - It was the purpose of this project to develop ways of recovering and removing sulfur from finely crushed coal (fines). Froth flotation (separating the elements by bubbling one to the top) and selective oil agglomeration (clustering) were considered. In addition, preparations were made for pelletizing the fines. Construction has begun on a large bench scale system that will demonstrate all these methods. C-33

Pittsburgh Energy Technology Center, Bruceton, PA - Research results from this project provided the laboratory process R&D necessary to develop the oxydesulfurization process (chemical removal of sulfur from coal) to pilot plant operations. This process transforms many high-sulfur coals to boiler fuel that meets air quality standards for sulfur oxides. Two independent economic analyses of the process concluded that oxydesulfurization has excellent prospects for commercial development. C-34

General Electric Company, Fairfield, CT - In this study, emphasis was on providing gas (derived from coal) that is sufficiently free of particulates to permit turbine operation without undue corrosion or erosion. The clearing should take place at high temperature and pressure to improve overall system efficiency. In this approach, the usually glassy nature of the particles is capitalized upon by providing a glass coated sticky surface to trap particles. A preliminary conceptual design and an economic analysis were carried out. It was estimated that the "sticky wall" unit would be 25 percent less expensive than other existing systems. C-35

Brookhaven National Laboratory, Upton, NY - Basic process chemistry information was developed for the regeneration of limestone or lime-based sorbents (substances that take up and hold other substances) used in removing sulfur from combustion and fuel gases in power production cycles. It was found that calcium silicates possess the same sulfur removal capabilities as Green lime but their regeneration rates are five to ten times higher. Process design and analysis studies are continuing. C-36

Morgantown Energy Technology Center, Morgantown, WV - The objective of this project was to investigate fouling and corrosion problems in coal-fired boilers by characterizing coal-mineral interactions during the combustion and heat transfer processes. A plug-flow (vapor-liquid flow in which the gas flows as large plugs) combustor was redesigned and assembled. The role of corrodant compounds was documented. C-37

Germantown Laboratories, Inc., Philadelphia, PA - The combustion of coal-oil-water slurries (mixtures) prepared by five different emulsification (suspension of dispersion) systems were evaluated. The slurry systems, flame characteristics, and boiler efficiencies were all assessed. C-38

Lawrence Berkeley Laboratory, Berkeley, CA - The purpose of this project was to measure the combustion properties, such as burning rates and pollutant formation, of coal that will be important to the design of new combustion systems, the control of combustion processes, and the reduction of pollutant emissions. Burning rate and temperature profile measurements were obtained for pressed pulverized coal and graphite. The effect of water content in the fuel on burning rate and ash buildup was observed. Measurements for solvent refined coal (a coal extract derived from the selective transfer of desired coal constituents from finely divided coal particles to a solvent) were also made. C-39

Battelle, Columbus Laboratories, Columbus, OH - It was the objective of this study to define the chemistry of carbon monoxide and hydrogen interactions in combustion. For improved burning of these fuels, experimental data were obtained for predicting flame stabilities and flame lengths of coal-derived gases. Mathematical expressions were developed for predicting the burning rate of low- and intermediate-Btu gases. The next phase of work included methane in the fuel mixtures. C-40

Oak Ridge National Laboratory, Oak Ridge, TN - This study was an attempt to demonstrate the technical feasibility of removing heavy metals and other inorganic materials from dry pulverizd coal using high-intensity magnets. This process reduces the quantities of ash and sulfur dioxide produced during coal combustion. Separation efficiencies (percentage of impurities removed) were 80 to 85 percent for pyrites (a class of sulfides) and 55 percent for ash by means of a high-gradient magnetic separator. Several alternate approaches to continuous dry coal magnetic separation equipment designs were identified for further evaluation and development. C-41

Exxon Research and Engineering Company, Linden, NJ - This research involved completion of theoretical and experimental studies on the formation of nitrogen oxides in the stages of coal particle combustion-pyrolysis (decomposition of coal by heating in the absence of oxygen), gas combustion, and char (the solid residue from coal) burnout. Diagnostic equipment was put into operation and theoretical work was initiated. The work was to include a variety of coals broadly representative of available U.S. coal types. C-42

Aerochem Research Laboratories, Inc., Princeton, NJ - This contractor measured concentrations of chemically reacting species (atomic nuclei, atoms, molecules, or ions) in a turbulent reactor. In the reactor, a jet consisting of one compound spews into, mixes and reacts with a nearly stationary surrounding mixture. The concentration measurements were used as input to the modeling of realistic combustors. C-43

Sandia Laboratories, Albuquerque, NM - The combustion properties of pulverized coals were being characterized for evaluation of combustion modifications to minimize fouling and polluting substances. Coal combustion factors influencing the conversion of sulfur, nitrogen, and mineral matter to pollutants were determined in a laboratory- scale research program. High-speed cinematography was used to measure particle ignition, devolatilization (removal of volatile matter), and char (solid residue from coal) burn up intervals. Other measurements include particle-size distribution, porosity, density, and swelling. C-44

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PROGRAM ACTIVITIES NARRATIVE DESCRIPTION

- MATERIALS AND COMPONENTS -

C-45

Babcock and Wilcox Company, Alliance, OH - It was the objective of this project to determine whether a refractory (heat-resistant metal) lining could be developed for coal gasification (conversion of coal to gaseous fuels) process vessels. Cracking often occurs in this lining during the initial dry-out, heat-up, and cool-down phases. Because this type of lining is considered cheaper, easier to install, lighter in weight, and a better thermal insulator than brick, the focus of this project was on preventing the lining from cracking. A mathematical model relating time, temperature, and shrinkage upon cool-down was developed. The results of this study were used to develop refractory specifications, design and installation guidelines, and operating procedures.

C-46

International Harvester, San Diego, CA - The purpose of this project was to evaluate materials and powder compositions to develop a coating system suitable for protecting large internal components of coal gasifiers from corrosion. Data on coating composition, structure, and application techniques that could be transferred to the general materials industry were to be provided. Various coated metal alloys were partly immersed in coal char in an atmosphere of flowing steam/hydrogen/carbon dioxide and carbon monoxide with small amounts of hydrogen sulfide, methane, and ammonia at 980°C to test for corrosion.

C-47

International Nickel Co., Inc., Suffern, NY - This contractor developed and evaluated weld-deposited overlays to provide resistance to corrosion and erosion in coal gasification (conversion of coal to gaseous fuels) environments. Weld overlaying deposits a corrosion-resistant layer on a substrate or base. This circumvents the difficulty of fabricating highly corrosion-resistant alloys, specifically high-chromium alloys. Three welding processes were used. Upon completion of the welding, the layered materials were to be exposed to coal gasification conditions.

C-48

Battelle, Columbus Laboratories, Columbus, OH - The corrosion behavior of iron- and nickel-base alloys in coal gasification (conversion of coal to gaseous fuels) environments was evaluated. A statistical test design was developed on all combinations of alloys, temperatures, and oxygen levels. It was found that scales consisting of iron, nickel, and chromium sulfides were formed. Exposure time was approximately 1000 hours.

C-49

Battelle, Columbus Laboratories, Columbus, OH - Data were compiled on the high-temperature corrosion behavior of metals and alloys used in generating plants. A handbook was assembled to serve as a source of data for analysis and prevention of corrosion problems, as a guide for the selection of materials, and as a means of identifying data gaps. Sources used were reports of work on government contracts, technical and scientific literature, and private industry.

C-50

Oak Ridge National Laboratory, Oak Ridge, TN - The purpose of this project was to develop methods to inspect thin protective coatings on metals used in coal processing equipment. The purpose of such inspection is to detect existing failures and conditions that warn of incipient failure. Work on ceramic coatings was completed, and work was begun on metallic coatings. Inspection methods include ultrasonics (the use of sound waves above audibility of the human ear), electric current, and radiography (X-ray or gamma ray photography).

C-51

Oak Ridge National Laboratory, Oak Ridge, TN - This research was directed at characterizing the tensile and fracture toughness properties of steels that will be employed in the fabrication of large thick-walled pressure vessels. Heating and cooling rates at various thickness depths were measured. Additional studies will be made to determine the effect of aging in air and in hydrogen-rich environments.

C-52

Oak Ridge National Laboratory, Oak Ridge, TN - Cladding (bonded coating) and field-welding technologies were addressed by this program. Several major pressure vessel manufacturers were surveyed regarding their experience with clad overlaying. Weld deposits were evaluated for various welding processes. Work is now aimed at defining more clearly the range of welding conditions that minimizes defects.

C-53

Lawrence Berkeley Laboratory, Berkeley, CA - Wear-resistant alloys were developed for coal transportation and fragmentation equipment. The operating conditions of such equipment were identified. Laboratory abrasion tests were developed for ranking experimental alloys. Several steels were selected as suitable for use at various temperatures.

C-54

Lawrence Berkeley Laboratory, Berkeley, CA - Low alloy steels were adapted or developed that can be fabricated into large diameter, thick-well pressure vessels for coal gasification (conversion of coal to gaseous fuels) systems. Three tasks have been completed: 1) determining alloy design criteria, 2) developing methods of simulating thick plate material in the laboratory, and 3) characterizing commercial steels. Manganese-molybdenum nickel steels and chromium-molybdenum steels served as the basis for research. Future work includes modifying existing steels to achieve desired strength and toughness and developing new steels suited to thick wall application.

U.S. Department of the Interior, Bureau of Mines/Tuscaloosa Metallurgy Research Center, Tuscaloosa, AL - Results of this research determined the effect of coal gasifier environments on commercially available refractory (heat-resistant metal) liner materials. Refractory linings must be able to perform (i.e., to reduce heat losses and protect the metal shell from erosion by coal and ash particles) in a hostile environment rich in steam, hydrogen, carbon dioxide, and carbon monoxide, at high temperatures and pressures. Results indicated that an optimum lining would have high alumina content. Evaluation of commercially available liner materials is continuing. C-55

Lockheed Palo Alto Research Laboratories, Sunnyvale, CA - It was the objective of this project to design a high-temperature alloy that would have improved resistance to corrosion in high sulfur coal gasification environments. It was found that the alloy must contain aluminum and chromium in balanced proportions in order to form the scale of aluminum oxide that protects it from corrosion. Adding yttrium or hafnium gave the alumina scale resistance to degradation by cyclic heating and cooling. Long-term protective capability to 4000 hours was assessed, and recommendations made for future development and production. C-56

Sandia Laboratories, Albuquerque, NM - The specific objective of this project was to modify the best commercial iron-based and nickel-based alloy to achieve substantial improvement in the life of the alloy. Two test facilities were designed and fabricated for studying candidate alloys under a wide range of conditions. Design modifications were made to improve temperature uniformity and gas chemistry. Future focus will be on alloys modified with titanium. C-57

Metal Properties Council, Inc., New York, NY - The objective of this project was to provide data on metals and ceramics which is required for the design of coal gasification plants. Materials were screened and successful candidates were tested under conditions of gaseous environment, temperature, and pressure. Test autoclaves (vessels constructed of thick-walled steel for carrying out chemical reactions at high temperature and pressure) were constructed. Tests exposed sample materials to erosion by particulate matter and to corrosion by pressurized hot gases. C-58

National Bureau of Standards, Gaithersburg, MD - Equipment and test methods were developed to evaluate the durability of alloys and refractories (heat- resistant metals) in coal gasification (conversion of coal to gaseous fuels) environments. Various alloys were tested for susceptibility to stress corrosion and cracking under high temperature and pressure. Under a failure prevention information program, a data base of more than 500 reported operating incidents from coal conversion process plants has been developed. A summary of failure mode, material, and process plant was also prepared. C-59

Battelle, Columbus Laboratories, Columbus, OH - Engineering data on the resistance of heat-exchanger (a device which enables heat transfer between two fluids) materials to corrosion in a fluidized-bed coal combustor were obtained. A coal combustor is a device for burning coal that uses a gas or liquid stream whose velocity is high enough to float finely divided solids so that they behave as a fluid. The three parts of the program were completed: operation of the fluid-bed combustor facility, conduct of the corrosion/erosion research, and measurement of the velocity of the particulates in the bed. Performance of the materials was evaluated and a final report was issued. C-60

Argonne National Laboratory, Argonne, IL - Refractories (heat-resistant metals) for coal gasifiers (which convert coal to gaseous fuels) were evaluated and nondestructive evaluation methods were being developed for coal conversion systems. These methods will enable prediction of corrosion and erosion rates and determination of the cause of failure of pilot plant components. The feasibility of using acoustic emission (sound waves) to determine the optimum firing schedules (periods of high temperature) was established. More than a dozen component failures were analyzed and recommendations were issued. The nondestructive testing program emphasized continued development of ultrasonic and infrared wear measurement systems. C-61

Oak Ridge National Laborator, Oak Ridge, TN - The corrosion/erosion behavior of alloys used in heat exchangers (a device which allows heat transfer between two fluids) was evaluated. Tubing materials must be able to withstand oxidation and sulfidation (corrosion by sulfides). A 500-hour surveillance test was completed. Subsequently, an additional 1000-hour exposure test was conducted, with some of the tubes exposed for 1500 hours. The 1500-hour tubes were examined by a study of the structure of the metals, X-ray diffraction, and microprobe analysis (inducing radiation in a minute area of material so that the composition may be determined from the emission spectrum). C-62

Mechanical Technology Incorporated, Latham, NY - Engineering support services are being provided for the performance of selected tasks assigned by the DOE Components Branch. A review and evaluation was conducted of failure, maintenance, and operability data on components used in a pilot plant in South Dakota. Other tasks include correction of chronic maintenance problems in mechanical equipment, analytical design audits, and recommendations for improved specification writing. Machinery performance histories collected under this program will be useful for selecting and maintaining equipment for future plants. C-63

Southern Research Institute, Birmingham, AL - The objective of this project was to assess the state of the art of construction of large centrifugal oxygen compressors. Test procedures were designed to simulate oxygen conditions and principal events that can lead to fires. Twenty materials were tested at 1000 psi oxygen pressure. Aluminum was found to ignite at below 500°F, irons and carbon steels at 500°F to 600°F, and copper alloys between 1000°F and 1200°F. C-64

Morgantown Energy Research Center, Morgantown, WV - Long-life values for handling solids in coal conversion reactors (devices for producing liquid or gaseous fuels from coal) were developed. Commercially available valves have been surveyed and sixteen selected for testing. A statistical experiment design has been completed. Both static and dynamic test conditions were used. A workshop to bring together members of the valve manufacturing industry and Government and industry personnel working on development of components for coal conversion processes was planned. C-65

Fairchild Stratos Division, Manhattan Beach, CA - The purpose of this project was to develop a set of valves suitable for use in high-Btu coal gasification systems (systems for converting coal to high-quality gaseous fuels). The valves were to operate at 1600 psi and at temperatures up to 2000°F with media consisting of gaseous, coal, char, and slurry (a mixture of insoluble matter). Construction of a prototype valve was completed and feasibility of the design demonstrated. The 8-inch valves are being fabricated and tested under simulated coal gasification conditions. C-66

U.S. Department of the Interior, Bureau of Mines/Albany Metallurgy Research Center, Albany, OR - Tasks in this project involve developing, testing and evaluating materials that have abrasion, adhesion, and erosion resistance to be used in critical valves of coal gasification systems (systems which convert coal to gaseous fuels). An elevated temperature erosion testing machine was built in which sample materials are blasted with a gas propelled stream of alumina powder to create erosion conditions. Further emphasis was being placed on delineating the properties of promising materials. C-67

General Electric Company, Washington, DC - Research performed as part of this project resulted in engineering data on the corrosion/erosion deterioration of gas turbine materials exposed to the exhaust gas from a pressurized fluidized-bed combustor. Such a combustor is a device for burning coal which uses a gas or liquid stream whose velocity is high enough to float finely divided solids so that they behave as a fluid. Corrosion testing of selected alloys accumulated about 2000 hours under laboratory simulation of the Exxon Miniplant, where further materials testing was to continue. C-68

Mechanical Technology, Incorporated, Latham, NY - The efficiency of a mechanical aerodynamic device called a cyclocentrifuge was demonstrated for use in controlled separation of fine particulate matter from a hot, pressurized gas stream. High efficiency cleanup of hot, pressurized gas in a continuous and reliable manner is essential to fossil energy utilization such as the economic use of low-Btu gas. A laboratory-scale cyclocentrifuge was manufactured and a particulate measuring scheme devised to provide accurate test results in the particle size range of 1/2 to 10 microns. C-69

Morgantown Energy Technology Center (METC), Morgantown, WV - The purpose of this project was to develop and test a steam-dried coal slurry (suspension of pulverized solid in a liquid) feed system. This system is used to inject dry, crushed coal into a high pressure process. The system offers the potential for eliminating troublesome high pressure valve systems on coal feed lines. West Virginia University was contracted to design steam-slurry nozzles for the METC dryer, and a nozzle testing facility was assembled in the METC pilot plant. A lift dryer simulation study made by C.F. Braun and Co. was reviewed and the computer program was adapted for predicting operating parameters of the METC system. C-70

Oak Ridge National Laboratory, Oak Ridge, TN - Surveys were conducted to identify the present ability of industry to supply the equipment needed for coal conversion demonstration plants. The surveys included rotating components, valves, hot gas cleanup devices, and heat recovery equipment. The surveys were then expanded to include operating experience and reliability of equipment. Costs for available and currently unavailable equipment were determined. In addition, the contractor determined research and development needs for production of advanced design equipment for various unit operations of importance to the Department of Energy's coal conversion programs. C-71

Oak Ridge National Laboratory (ORNL), Oak Ridge, TN - It was the objective of this project to assess the equipment requirements for coal conversion demonstration plants designed under DOE-industry contracts. Critical components and means were developed for evaluation of the components prior to plant startup. The project provided a basis for the identification of troublesome components that would decrease start-up problems and prevent unscheduled shutdown of the plant. A study of the facility requirements for testing equipment was completed in cooperation with the Stearns-Rogers Engineering Company, Denver, Colorado. The study indicated that testing was feasible and useful but costly. ORNL, assisted by TRW Energy Systems, initiated work with four demonstration plant subcontractors. C-72

C-73 Consolidated Controls, El Segundo, CA - This contractor designed, manufactured, tested, and assessed 8- and 12-inch valves capable of withstanding the hostile operating conditions found in coal gasification plants. Reliable data were produced for the design and production of coal gas valves suitable for commercialization. An additional project objective was the transfer of technology to private industry. Preliminary design studies were conducted on a valve which was incorporated with high alumina ceramic and commercial refractory parts for longer life and high resistance to corrosion.

C-74 Solar Turbines International, San Diego, CA - The objective of this project was to develop plasma (hot, electrically-charged gas) spray-heat treatment processes for applying a corrosion-resistant nickel alloy to the surface of coal gasifier steel components. The alloy should possess resistance to corrosion from normal gasifier chemicals and temperatures such as those generated from hot solid char. Testing of the alloy under a variety of conditions was undertaken.

C-75 Lockheed Palo Alto Research Laboratories, Palo Alto, CA - The objective of this project was to design a high-temperature alloy that would have improved resistance to attack in high-sulfur coal gasification atmospheres, compared with commercially available stainless steel and super alloys. The alloy would improve process development, plant design factors, operational conditions and reliability of coal gasification plants. The commercial production of this alloy was studied.

C-76 Battelle, Columbus Laboratories, Columbus, OH - The objective of this project was to provide a computer model to predict the impact of key parameters on heat flows in a coal gasification vessel, in order to develop a cost-effective and reliable vessel design. Specifically, the model will incorporate material composition, geometric considerations, gas composition, pressure, temperature, flows and materials decomposition parameters into the design function.

C-77 Oak Ridge National Laboratory, Oak Ridge, TN - The objective of this project was to aid in the development of a chromium-molybdenum steel with improved manufacturing and elevated-temperature strength properties. The final product, from this and other projects, will be a commercially available steel used as tubing for installation in utility fossil boiler heaters. Tests were carried out and new testing equipment was developed.

C-78 Oak Ridge National Laboratory, Oak Ridge, TN - The objective of this project was to determine the effect of the operating environment of coal conversion systems on the high- and low-temperature properties of pressure vessel steels. In addition, a study of steel stress was implemented.

Pittsburgh Energy Technology Center, Bruceton, PA - The purpose of this project was to assist the Division of Coal Conversion/Liquefaction and the Office of University Activities in coordinating coal science projects. Responsibilities included assembling review boards, organizing review meetings, evaluating proposals, and recommending funding levels. Projects were assigned to the Technology Center and reviewed by representatives from each of the coordinating offices. The program is expected to continue and to expand further into the areas of coal conversion (the reduction of coal to liquid and gaseous forms suitable as substitutes for natural gas and petroleum fuels) and end use. C-79

Brookhaven National Laboratory, Upton, NY - The purpose of this project was to assess the feasibility of a rotating fluidized-bed contacting device containing limestone, which is used to desulphurize hot combustion gases derived from coal combustion. The device was assembled and test runs were made at room temperature. High temperature components have been designed and are being assembled for testing. C-80

Argonne National Laboratory, Argonne, IL - The purpose of this project was to develop low-cost plastic heat exchangers to be used to conserve low-temperature waste heat. Tasks included selecting and modifying plastics, and innovating heat exchanger component production processes and designs. Some of the designs, performance, and costs were identified, potential suppliers of raw plastics were found, and the experiences of two commercial suppliers of plastic heat exchangers were evaluated. C-81

Argonne National Laboratory, Argonne, IL - The purpose of this project was to test segmentally baffled shell-and-tube heat exchangers and to quantify tube vibration data, in order to avoid water flow vibration problems in the finished product. A test heat exchanger was selected and about 500 tubes were ordered. The first test was planned, with the tubes to be arranged in an equilateral triangular array. C-82

Westinghouse Electric Corporation, Pittsburgh, PA - The purpose of this program was to evaluate and optimize the resistance of this program was to evaluate and optimize the resistance to hydrogen and temper (harden and strengthen) embrittlement susceptibility of chromium-molybdenum steels for use as structural materials in coal conversion pressure vessels. Initially, the degradation of properties of an American Petroleum Institute material from embrittlement effects was defined. Currently, the focus of the research is concentrated on the identification of compositions and microstructures with maximum freedom from embrittlement effects. C-83

Bureau of Mines, Albany Metallurgy Research Center, Albany, OR - The objective of this project was to develop and identify improved wear-resistant materials that can be used for valve trim by making tests on both experimental and commercial materials. The need for improved wear-resistant materials in coal conversion systems has been demontrated by frequent valve failures in gasification and liquefaction demonstration pilot plans. Another objective of the project was the production of valve trim and hardware of these wear-resistant materials for actual facility testing. C-84

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PROGRAM ACTIVITIES NARRATIVE DESCRIPTION

- INSTRUMENTATION AND CONTROLS -

Midwest Research Institute, Kansas City, MO - Data from this research program were used to identify gaseous alkali metals that may contribute to corrosion. Direct mass spectrometric probes were also developed for sampling such material from small-scale coal combustors. Such a system was designed, constructed, and tested for use with the combustors at the Morgantown Energy Research Center. C-85

Science Applications, Inc., La Jolla, CA - The purpose of this program was to design, fabricate, and test two concentration sensors, used for accurate measurement of coal/refuse/water concentrations in hydraulic transport pipelines. A sensor for a 6-inch diameter pipeline was developed, tested, and modified to improve performance. Results were satisfactory, and further testing and development of both 6- and 18-inch diameter pipeline concentration sensors was conducted. C-86

Morgantown Energy Technology Center, Morgantown, WV - A sulfur monitor was sent to England in exchange for one of England's ash monitors to be tested with U.S. coal. Problems were encountered with the British ash meter because of differing applications. The British use the meter to help blend dry, high-ash coal; its use in the U.S. is with clean, typically wet, low-ash coal. Measurements by the ash meter were to be compared to conventional analyses. C-87

Morgantown Energy Technology Center, Morgantown, WV - The objective of this project was to develop a technique for direct determination of the composition of coal minerals as a basis for continuous monitoring of the heat value of coal. The information produced is useful for quality control and for increasing thermal efficiencies of power plants. The information was to be associated with the testing of the British ash monitor. C-88

Pittsburgh Energy Technology Center, Bruceton, PA - Research performed during this project was an effort to deduce the mechanisms by which catalysts deactivate after a period of use. Emphasis was placed on catalysts used in the direct conversion of coal to environmentally acceptable liquid fuels. Factors considered were the effects of compounds adsorbed on the surface of such catalysts and the effect of promoters (chemicals which are themselves feeble catalysts, but which greatly increase the activity of a given catalyst). C-89

Ames Laboratory, Mountain View, CA - Instrumentation for determining the amount of sodium and potassium in cleaned low-Btu gas derived from coal was designed and built during this program. The ultimate objective was the analysis of hot uncleaned gas. Turbine failure is related to sodium and potassium in the gas stream. The Morgantown Energy Research Center is building a special "clean room" to house the instrumentation, and sodium and potassium measurements will begin upon its completion. C-90

X. SUMMARY OF UNIVERSITIES PARTICIPATING IN COAL RESEARCH

(DOE AGREEMENTS AS OF JANUARY 1, 1980)

SRS

COLLEGES AND UNIVERSITIES

(PERFORMING ENERGY R&D FOR DOE AS OF JANUARY 1, 1980)

Amherst College
Arizona State University
Auburn University
Boston University
Brandeis University
Brigham Young University
Brown University
California Institute of Technology
California State University (Fullerton)
Carnegie Mellon University
Case Western Reserve University
Colorado School of Mines
Colorado State University
Columbia University
Cornell University
Dartmouth College
Denison University
Drexel University
Duke University
Florida State University
George Washington University
Georgetown University
Georgia Institute of Technology
Harvard University
Howard University
Illinois Benedictine College
Illinois Institute of Technology
Illinois State University
Iowa State University
Johns Hopkins University
Kansas State University
Kent State University
Lehigh University
Louisiana State University
Loyola University (Chicago)
Marquette University
Massachusetts Institute of Technology
Michigan State University
Michigan Technological University
Middleburg College
Mississippi State University
Montana State University
Mt. Holyoke College
New York University
New York Univ. - Medical College
Niagara University
North Carolina State University
Northeastern University
Northern Illinois University
Oakland University (Michigan)
Ohio University
Ohio State Research Foundation
Oklahoma State University
Oregon College of Education
Oregon State University
Pennsylvania State University
Princeton University
Purdue Research Foundation
Rensselaer Polytechnic Institute
Rice University
Rutgers University
Stanford University
State Univ. of New York Research Foundation (New York)
Syracuse University
Temple University
Texas A&M University
Thomas Jefferson University
Tufts University
University of Alabama
University of Alaska
University of Arizona
University of California (Berkeley)
University of Chicago
University of Cincinnati
University of Colorado
University of Connecticut
University of Dayton
University of Delaware
University of Denver
University of Florida
University of Georgia
University of Hawaii
University of Houston
University of Illinois
University of Indiana

COLLEGES AND UNIVERSITIES

(PERFORMING ENERGY R&D FOR DOE AS OF JANUARY 1, 1980)

University of Iowa
University of Kansas
University of Maine
University of Maryland
University of Massachusetts
University of Miami (Florida)
University of Michigan
University of Minnesota
University of Missouri
University of Montana
University of Nebraska
University of Nevada
University of New Hampshire
University of New Mexico
University of North Carolina
University of Notre Dame
University of Oklahoma
University of Oregon
University of Pennsylvania
University of Pittsburgh
University of Rhode Island
University of Rochester
University of Southern California
University of Tennessee
University of Texas
University of Utah
University of Vermont
University of Virginia
University of Washington
University of West Virginia
University of Wisconsin (Madison)
University of Wisconsin (Milwaukee)
University of Wisconsin (Whitewater)
University of Wyoming
Vassar College
Virginia Polytechnic Institute and State University
Washington State University
Washington University (St. Louis)
Wayne State University
Wesleyan University (Connecticut)
Williams College
Wright State University
Yale

XI. WEST GERMAN COAL GASIFICATION RESEARCH AND DEVELOPMENT

MATERIALS, PROBLEMS AND RESEARCH IN GERMAN COAL GASIFICATION PROJECTS

- MOST PROJECTS SPONSORED BY GERMAN GOVERNMENT
- R&D REQUIREMENTS BASICALLY SAME AS U. S. REQUIREMENTS
- MAIN PROJECTS
  - LURGI
  - TEXACO
  - SAARBERG/OTTO
  - SHELL-KOPPERS
  - WINKLER
- KEY PROBLEMS
  - MATERIALS PROBLEMS IN ALL PROCESS STEPS EXCEPT COAL PREPARATION
  - REFRACTORY PROBLEMS IN THE GASIFICATION STEP
  - OTHER PROBLEMS SUCH AS SOLIDS FILTERS
- "THE GERMAN DEVELOPING COMPANIES ARE CONVINCED TO SOLVE MOST MATERIAL PROBLEMS BY CHOOSING ALLOYS AND REFRACTORY MATERIALS, WHICH ARE TODAY AVAILABLE ON THE MARKET"

XII. PROBLEMS FACING THE COAL CONVERSION INDUSTRY

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COAL CONVERSION INDUSTRY

(ILLUSTRATIVE)

- **PROCESS DEVELOPERS**
  - Exxon
  - Shell
  - Texaco
  - IGT
  - Rockwell
  - Westinghouse
  - Koppers
  - Lurgi
  - Moble
  - HRI
  - B & W
  - Winkler

- **ARCHITECTURAL AND ENGINEERING FIRMS**
  - Flour
  - C. F. Braun
  - Pullman Kellogg
  - Bechtel
  - Foster Wheeler
  - Lummus
  - Brown & Root
  - Dravo
  - Ralph M. Parsons

- **SYSTEM/EQUIPMENT/COMPONENT MANUFACTURERS**
  - Ingersoll Rand
  - Worthington
  - LaBour Pumps
  - Airco Cryogenics
  - Allis Chalmers
  - Crane
  - Delaval Turbine
  - Dover
  - Steinmueller

- **ENGINEERS**
  - Chemical
  - Mechanical
  - Petrochemical
  - Petroleum
  - Mining
  - Civil
  - Construction
  - Industrial
  - Environmental

- **SKILLED CRAFTSMEN**
  - Pipefitters
  - Welders
  - Boilermakers
  - Electricians
  - Iron Workers
  - Concrete Finishers
  - Maintenance Mechanics
  - Carpenters
  - Machinists

PROBLEMS FACING THE COAL CONVERSION INDUSTRY

- OVER THE NEAR TERM FIRST GENERATION PROCESSES WOULD HAVE TO BE USED TO MAXIMIZE RELIABILITY
  - COMMERCIAL PLANTS STILL EXPERIENCE SHAKE DOWN/START-UP PROBLEMS
  - PROBLEM RESOLUTION CAN REQUIRE EXTENDED PERIODS
- LIMITATIONS MUST BE RECOGNIZED AND WORK AROUNDS INCORPORATED INTO PLANT DESIGNS
  - SINGLE/DOUBLE/MULTISTREAM UNITS (IN CONTRAST WITH MODERN SINGLE-STREAM PETROCHEMICAL PLANTS)
  - USE OF FEWER STREAMS WOULD REQUIRE SIZE SCALEUP BEYOND RANGE OF PROVEN EQUIPMENT
  - LOW RELIABILITY OF EQUIPMENT, COMPONENTS, MATERIALS
  - CAPABILITY FOR STABLE OPERATION WITH MAJOR UNITS DOWN TO AVOID COMPLETE PLANT SHUTDOWN (E.G. PROBLEMS WITH GASIFIERS, BOILERS, COAL MILLS, GAS COMPRESSORS, ETC.)
- MAJOR SYSTEM/EQUIPMENT/COMPONENT DEFICIENCY AREAS
  - <u>PRESSURE LET-DOWN DEVICES AND VALVES</u>
    - VALVE LIFE IS SHORT
    - NO SATISFACTORY VALVES TO WITHSTAND THE COMBINATION OF TWO OR THREE PHASE GAS-SOLID-LIQUID FLOWS, HIGH PRESSURE DROP, AND HIGH TEMPERATURE HAVE BEEN DEVELOPED
    - "HARDER MATERIALS" DO NOT NECESSARILY INCREASE LIFE-NEW DESIGNS ARE NEEDED
  - <u>LOCK HOPPERS</u>
    - LOCK HOPPERS ARE RUGGED AND RELIABLE BUT ARE ALSO HIGH MAINTENANCE ITEMS
    - LOCK HOPPERS ARE NOT AVAILABLE TO PROVIDE THE LARGE THROUGHPUTS REQUIRED IN SOME CASES
    - ARE CAPABLE OF A PRESSURE DIFFERENTIAL OF ABOUT 500 PSI - FOR HIGHER PRESSURE SYSTEMS TWO OR THREE LOCK HOPPERS IN SERIES WOULD BE REQUIRED - THESE WOULD HAVE TO BE CONTROLLED BY A COMPLICATED AUTOMATIC CONTROL SYSTEM

PROBLEMS FACING THE COAL CONVERSION INDUSTRY

- MAJOR SYSTEM/EQUIPMENT/COMPONENT DEFICIENCY AREAS (CONT'D)
  - COAL SLURRY PUMPS
    - o SLURRY CONCENTRATIONS GREATER THAN 40 WT.% SOLIDS REQUIRE RECIPROCATING PUMPS
    - o A HIGH CAPACITY, HIGH PRESSURE, MULTISTAGE CENTRIFUGAL PUMP IF DEVELOPED COULD REPLACE THREE TO FIVE POSITIVE DISPLACEMENT PUMPS AT SIGNIFICANTLY LOWER COST
    - o CENTRIFUGAL PUMPS ARE LIMITED TO ABOUT 600-800 PSIG WITH MAXIMUM AVAILABLE PRESSURE PER STAGE OF ABOUT 100 PSI (TECHNOLOGY IMPROVEMENTS NEEDED)
    - o ONE YEAR CONTINUOUS OPERATION CENTRIFUGAL PUMPLIFE IS NOT AVAILABLE AT PRESENT
    - o MATERIALS EROSION/CORROSION IS PROBLEM WITH ALL SLURRY PUMPS
  - OXYGEN COMPRESSORS
    - o LIMITED BY DISCHARGE PRESSURES OF ABOUT 600 PSIA AND CAPACITY OF ABOUT 2600 TPD
    - o DICTATES MULTIPLE UNITS WITH REQUIRED ADJACENT CONTROL SYSTEMS & COMPONENTS
  - INSTRUMENTATION AND CONTROLS
    - o AVAILABLE EQUIPMENT HAS HIGH MAINTENANCE (OR REPLACEMENT) REQUIREMENTS
    - o MUCH OF REQUIRED CONTROLS & INSTRUMENTATION DO NOT EXIST
    - o MASS FLOW RATE IN MIXED-PHASE PROCESS STREAMS
    - o ON LINE COMPOSITION MONITORING
    - o LEVELS OF FLUIDIZED BEDS
    - o TEMPERATURE IN REACTION VESSELS AND ON REACTOR WALLS

XIII. ASSESSMENT OF COAL CONVERSION INDUSTRY CAPABILITY

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ASSESSMENT OF COAL CONVERSION INDUSTRY CAPABILITY

- INDUSTRY ALONE CANNOT GEAR UP SUBSTANTIAL NEW SYN FUEL CAPACITY RAPIDLY ON ITS OWN BECAUSE OF HUGE CAPITAL INVESTMENTS REQUIRED
- MOST CONSTRUCTION INDUSTRY EXECUTIVES INDICATE CAPABILITY EXISTS TO MEET PRESIDENT CARTER'S GOALS ("FOR ANY OF THE BIG U. S. CONSTRUCTION COMPANIES, BUILDING FIVE PLANTS A YEAR SHOULD EASILY BE TAKEN IN STRIDE" -- JAMES A. FINNERMAN, V.P. - PULLMAN KELLOGG)
- EQUIPMENT AVAILABILITY/OBTAINABILITY RECOGNIZED AS A POTENTIAL PROBLEM
  - SHORT SUPPLY OF DISTILLATION TOWERS, HEAT EXCHANGERS, COMPRESSORS. LARGE PUMPS THICK-WALLED PRESSURE VESSELS (SIMILAR TO NUCLEAR INDUSTRY WHEN ORDERS INCREASED RAPIDLY DURING EARLY 1970'S AND SUPPLIERS NOT ABLE TO PRODUCE ENOUGH PRESSURE VESSELS)
  - STUDIES INDICATE SHORTAGES COULD BE OVERCOME BY GIVING NECESSARY TIMELY INCENTIVES TO INDUSTRY
- AVAILABILITY OF CRITICAL MATERIALS SUCH AS COBALT, NICKEL, MOLYBDENUM NOT CONSIDERED A BARRER (CHROMIUM COULD BE A PROBLEM BECAUSE IT IS CURRENTLY IMPORTED AND DEMAND COULD REACH 7% OF TOTAL NATIONAL DEMAND)
- MINING INDUSTRY HAS EXPANSION CAPABILITY TO MEET PRODUCTION REQUIREMENTS
- SYN FUELS PROCESSES REQUIRE SIGNIFICANTLY MORE ENGINEERING DESIGN MANPOWER PER UNIT OF CAPACITY THAN COMPARABLE REFINERIES
  - TO MEET COAL LIQUIDS GOALS WILL REQUIRE ADDITIONAL 1300 ChE'S BY 1984 OR A 65% INCREASE
  - GROWTH IN CHEMICAL PETROCHEMICAL, NUCLEAR-FUEL PROCESSING WILL COMPETE FOR SAME ENGINEERING TALENT
- GREATEST RISK IDENTIFIED WITH OBTAINING REQUIRED EQUIPMENT PERFORMANCE AND/OR SCALE UP

ASSESSMENT OF COAL CONVERSION INDUSTRY CAPABILITY (CONT'D)

- INDUSTRY RECOGNIZES PERFORMANCE RISKS INVOLVED IN USING COMMERCIALLY AVAILABLE EQUIPMENT TO SUPPORT COMMERCIALIZATION EFFORTS
  - SIGNIFICANT DEVELOPMENT EFFORTS REQUIRED FOR SOME EQUIPMENT
  - INDECISION OVER WHETHER TO COMMERCIALIZE FIRST OR SECOND GENERATION TECHNOLOGY IS A BARRIER TO COMMERCIALIZATION (OPPOSED BY SOME COMPANIES WHICH ARE DEVELOPING SECOND GENERATION PROCESSES F.G. GULF)
- INDUSTRY IS NOT PRESENTLY MOTIVATED TO PERFORM THE NEEDED SYSTEMS, COMPONENTS, INSTRUMENTATION DEVELOPMENT REQUIRED FOR VIABLE LARGE SCALE COAL CONVERSION IN U. S.
  - LARGE NUMBER OF PROCESSES (WITH UNIQUE OPERATING CONDITIONS ASSOCIATED WITH EACH) UNDER DEVELOPMENT
  - COMMERCIAL MARKET FOR IMPROVED PRODUCTS (E.G. IMPROVED VALVES, SEALS, PUMPS, COMPRESSORS, MATERIALS, ETC.) DOES NOT EXIST
- COAL CONVERSION INDUSTRY DOES NOT HAVE THE ESTABLISHED INFRASTRUCTURE FOR RAPID COAL CONVERSION IMPLEMENTATION
  - MANY LARGE FIRMS HAVE EXTENSIVE PETROLEUM REFINING EXPERIENCE BUT LIMITED SYN FUELS BACKGROUND
  - HAVE ATTEMPTED TO ADAPT PETROLEUM RELATED EQUIPMENT AND SYSTEMS TO COAL CONVERSION
  - DO NOT HAVE BROAD TECHNICAL EXPERTISE BASE NECESSARY TO SOLVE ALL DEVELOPMENT PROBLEMS
- INDUSTRY WILL NOT INVEST THE NECESSARY AMOUNTS OF THEIR OWN R&D $'S OVER THE NEAR TERM
  - MARKET WILL HAVE TO DEVELOP FIRST
  - PROFITABILITY POTENTIAL WILL HAVE TO BE QUANTIFIABLE
- CURRENT SITUATION SOMEWHAT ANALOGIOUS TO EARLY HISTORY OF AVIATION AND AEROSPACE INDUSTRY
  - CLEAR NEED FOR GOVERNMENT TO TAKE LEAD IN DEVELOPING IMPROVED EQUIPMENT FOR COAL CONVERSION
  - GOVERNMENT (WITH FOCUSED R&D PROGRAMS) WORKING WITH INDUSTRY AS A PARTNER CAN SIGNIFICANTLY INCREASE THE RATE, QUANTITY, AND QUALITY OF HARDWARE DEVELOPMENT

XIV. OBSERVATIONS AND SUMMARY

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MATERIALS AND EQUIPMENT FOR COAL CONVERSION

OBSERVATIONS:

- 2ND AND 3RD GENERATION PROCESSES TYPICALLY OPERATE AT HIGH PRESSURES AND TEMPERATURES THAN 1ST GENERATION
  - PROMOTES IMPROVED EFFICIENCY AND ECONOMY
  - SEVERE CONDITIONS PRODUCE GREATER EROSION AND CORROSION (MAINLY VALVES, PUMPS AND SEALS)
  - MULTIPHASE FLOWS PRODUCE UNIQUE ENVIRONMENT FOR COMMERCIAL EQUIPMENT (UNLIKE PETROLEUM PROCESSING) AND HAS PRODUCED SERVICE LIFE OF NEAR INSTANT FAILURE TO HOURS
- MUCH OF THE EQUIPMENT THAT HAS BEEN TESTED HAS FAILED
- TOUGHEST PROBLEMS ARE IN PROCESS CONTROL
  - PRESSURE LETDOWN
  - FLOW CONTROL VALVES
- MECHANICS OF THREE-PHASE FLOW NOT UNDERSTOOD
  - VALVES SUFFER HIGH VELOCITY OF PARTICLES AND SURFACE FATIGUE DUE TO FLASHING OF GASES
  - HYDROGEN EMBRITTLEMENT OF METAL ALSO A PROBLEM
  - VALVE SUCCESS SO FAR HAS BEEN BY TRIAL AND ERROR
- EFFORTS TO DEVELOP EQUIPMENT WHICH WILL WITHSTAND THESE ENVIRONMENTS HAS BEEN HAPHAZARD TO DATE
- COMPANIES PARTICIPATING IN COAL CONVERSION PROJECTS ARE ORDERING DUPLICATES OF FAILURE-PRONE UNITS (WITH RESULTING HIGH COST, REDUCED RELIABILITY, ETC.)
- EXCHANGING INFORMATION ON EQUIPMENT IS DIFFICULT
  - FIRMS ARE NOT EAGER TO PUBLICIZE THEIR PROBLEMS
  - DOE IS NOT FREE TO DISCLOSE WHAT IT KNOWS ABOUT INDIVIDUAL FIRMS (PROPRIETARY DATA)

MATERIALS AND EQUIPMENT FOR COAL CONVERSION

OBSERVATIONS:

- PUMP WEAR IS MAJOR PROBLEM
  - EXXON (EDS) USING IMPELLERS AND CASING LININGS MADE OF HARD IRON (SELECTIVE WEAR/REPLACEMENT)
  - LUMMUS HAS USED IMPELLERS AND LININGS OF TUNGSTEN CARBIDE
  - ANOTHER APPROACH (SRCII) IS PROCESS-DESIGN TRADEOFFS
- MAIN CONCERN IS NOT SHUTTING PROCESS DOWN, IN GENERAL, STEADY STATE CONDITIONS DIFFICULT TO ATTAIN
- VALVE AND PUMP MANUFACTURERS HAVE NOT MADE CONCERTED EFFORTS TO DEAL WITH COAL CONVERSION PROBLEMS
  - U. S. HAS NOT COMMITTED TO A SPECIFIC TECHNOLOGY
  - RELUCTANCE TO INVEST TO DEVELOP NEW DESIGNS
  - SOME PROGRESS HAS BEEN MADE (ESPECIALLY THOSE SIMILAR TO OIL-PRODUCING TECHNOLOGY)
- SKIRTING PROBLEMS WITH FAILING VALVES AND PUMPS WILL CONTINUE TO BE RULE
  - DUPLICATION WILL REMAIN
  - HEAVIER SPARING IN CRUCIAL AREAS (ESPECIALLY WHERE VALVES HAVE BEEN FAILING IN A MATTER OF HOURS)

COAL GASIFICATION TECHNOLOGY DEVELOPMENT REQUIREMENTS

SUMMARY

- TECHNOLOGY IS AVAILABLE FOR 1ST GENERATION COMMERCIAL PLANTS, BUT ALL COMMERCIAL SCALE PLANTS HAVE EXPERIENCED PROBLEMS WHICH IN SOME CASES REQUIRED YEARS TO SOLVE OR CONTROL

- 1ST GENERATION FOREIGN TECHNOLOGY START UP/OPERATIONAL PROBLEMS ARE SIMILIAR TO PROBLEMS EXPERIENCED IN U. S. DEMO PLANTS

- IMPEDIMENTS TO TECHNOLOGY ARE RECOGNIZED IN PUBLISHED LITERATURE BUT PROGRESS TOWARD RESOLVING THESE IMPEDIMENTS IS SLOW

- RECENT CONTACTS WITH DOE-GRI SPONSORED COAL GASIFICATION EVALUATION CONTRACTORS INDICATE THAT THERE HAVE BEEN NO REAL SOLUTIONS TO ANY OF THE SIGNIFICANT PROBLEMS IN RECENT YEARS

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