Form 6–1607–A
Mineral Institutes (5–83)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
WASHINGTON, D.C. 20241

Form Approved
O.M.B. No. 1032-0116

SUMMARY REPORT OF INVENTIONS AND SUBGRANTS

"The Paperwork Reduction Act of 1980 (44 U.S.C. 35) requires us to inform you that. The information is being collected to monitor a Federal grant program. This information will be used to ensure grantee compliance with the governing provisions of OMB Circular A-110, Treasury Circular 1075 and policies and procedures of 30 CFR Part 890. The obligation to respond is required to obtain a benefit."

The following report must be submitted as part of the interim or final report as provided for by the REPORTS and/or PATENT ARTICLE in the grant.

GRANT DATA

A. NAME OF GRANTEE	B. ADDRESS
Georgia Mining and Mineral Resources Institute	Georgia Institute of Technology Atlanta, GA 30332-0100

C. GRANT NUMBER
G1184113

TITLE:
Georgia Mining and Minerals Resources Institute

D. DESCRIPTION OF WORK
Education and Research in Mineral Engineering

E. GRANTEE'S PRINCIPAL INVESTIGATOR	F. GOVERNMENT TECHNICAL PROJECT MONITOR
Michael J. Matteson	Dr. Ronald Munson

(Check appropriate boxes)

1. Type of Report:

☐ Interim { From ______________, 19____ / To ______________, 19____ }

☒ Final.

2. Interim Report Data:

A. Invention made ☐ not made ☐, during interval of (1).

B. If invention(s) made, provide the following information:
☐ Previously fully disclosed in Invention Disclosures. Give dates submitted, and Grantee's docket numbers.

______________ ______________ ______________ ______________

______________ ______________ ______________ ______________

☐ Invention Disclosures attached herewith. Give Grantee's docket numbers.

______________ ______________ ______________

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OVER

3. Final Report Data

	Date Submitted	Grantee's Docket Number
A. Invention(s) previously reported—		
B. Invention(s) reported herewith—		

C. Others *(explain)*—

D. No inventions were made under the grant. ☒

4. Patent application(s) filed and contemplated to be filed by Grantee under the terms of the grant:

Application Serial No.					
Date of filing					
Grantee's Docket No.					

5. Subgrants containing patent rights article:

☐ None. ☐ Listed below are subgrantees.

Name of Subgrantee	Address	Subgrant Number	Date Executed
(1)			
(2)			
(3)			
(4)			

6. Attach a copy of the patent rights article employed in each Subgrant set forth in 5.

7. Grantee certification.

I certify that this Summary Report of Inventions and Subgrants including any attachments is correct to the best of my knowledge and belief.

Date 11/13/79

Signature [illegible]

Title Project Director [illegible]

Georgia Mining and Mineral Resources Institute
GMMRI
Georgia Institute of Technology

Final and Annual Status Report 1988/1989
Grant No. G 1184113

Michael J. Matteson
Director, GMMRI
Professor, Chemical Engineering
Chairman, Multidisciplinary
Mineral Engineering Program

Organization

The Georgia Mining and Mineral Resources Institute (GMMRI) is an integral part of the College of Engineering at Georgia Tech. Designated by the U.S. Department of the Interior, Office of Surface Mining, it was activated April 1980 when OSM funding became available, at the initial allocation rate of $150,000 per year plus required matching funding. In 1982 administration of the developing GMMRI program was transferred from the Office of Surface Mining to the Bureau of Mines.

The Board of Directors of GMMRI, the external advisory board, consists of mineral industry representatives of whom:

a. three are appointed by the Georgia Mining Association, three by the President of Georgia Tech; these six members serve on a staggered rotational basis, and

b. two serve as permanent members–the Executive Vice President of the Georgia Mining Association and the Executive Secretary of the Georgia Crushed Stone Association.

Ex-officio members involved are one representative each from the Georgia Geological Survey, the University of Georgia, the U. S. Bureau of Mines, and Georgia Institute of Technology.

An internal guidance committee consists of one representative each from the following degree programs at Georgia Tech–Ceramic Engineering, Chemical Engineering, Civil Engineering, Geophysical Sciences, Metallurgy, Nuclear Engineering, and

Health Physics, plus a minority representative.

Activities 1988/1989

Education Program

The GMMRI program provides improved education and concurrent research in mineral engineering established on an on-going 'industry needs' basis, with research activities as well as the education program selectively targeted to cover the required spectrum of mining and mineral technologies. This involves relevant and effective application of the exceptionally strong multidisciplinary expertise available within the College of Engineering schools at Georgia Tech.

With such resources, in our education program the multidisciplinary Mineral Engineering Certificate enables appropriate emphasis of mining for civil engineers, mineral processing for chemical engineers, mining and processing of non-metallic minerals for ceramic engineers, extractive/chemical metallurgy for metallurgists, and exploration for geophysical scientists. A student in the Schools of Civil Engineering, Chemical Engineering and Ceramic Engineering may obtain a Mineral Engineering Certificate at the bachelor's, master's, or doctoral level; in Metallurgy and Geophysical Sciences a certificate may be obtained in the master's or doctoral level. Certificate requirements include a minimum total of 18 hours in mineral engineering approved courses which must include core courses in mining and mineralogy, mineral processing and extractive metallurgy. At the graduate level, research for a degree must be in an appropriately relevant area of mineral engineering and a minimum grade of "B" is required for all courses counting toward the certificate. A student must also meet all degree requirements of the School's degree programs where he is enrolled. Appropriate GMMRI scholarships and/or graduate research fellowships are awarded to particularly well- qualified students.

In 1988/89 this progressive emphasis of the mineral engineering education program was again well maintained.

Notable appreciation was expressed and documented from student evaluations and state mineral industry contacts, of the particular value added to the multidisciplinary Mineral Engineering Certificate Program by the inclusion of more advanced mining and mineral engineering core course material. This included state-of-the-art theory and applications of soil and rock mechanics, and further emphasis on interfacial concepts of governing importance in separation technology. This continuing incorporation of significant research and technology developments was again on a selective basis involving close GMMRI/industry interactions. Appropriately in line with present mineral industry requirements, a realistically limited quantity of considerably high quality students have been admitted to this interdisciplinary program to gain approved mineral engineering certification.

As a multidisciplinary study area, the Mineral Engineering Certificate Program is not ABET-evaluated as such, but comprises Georgia Tech engineering schools courses which satisfy ABET requirements in their accreditation of these schools' degree programs.

Furthermore, a significant "educational activity" of broadening importance was the appreciable number of invited presentations given on GMMRI research developments and student training opportunities, at international, national and local state meetings and symposia.

Research Program

Initially, the rapid generation of a substantial GMMRI research program, covering a wide range of technology problem areas in mineral industries operations, was achieved by making appropriate use of the extensive multidisciplinary skills and facilities existing throughout the College of Engineering at Georgia Tech. In 1988/1989 our program development placed a primary emphasis on applying and exploiting our acquired capability strengths in the area of mineral processing R & D. This selective focusing of our mineral engineering research activities, continuing from its successful development during the previous fiscal year, is particularly based on demonstrated expertise in the innovative application of surface science concepts to critical S/L separation processes involving ultrafines material. Research in this problem area is of major importance to our mineral industries in view of the growing need to develop cost-effective processes for dealing with the finer particle-size material inevitably involved as domestic ore grade decreases, and for premium ultrafine products developments in Georgia kaolin and industrial minerals operations.

This GMMRI program is continuing to stimulate significant industry interest in co-operative research involvements, with complementary support including research fellowship award funding and new equipment donation for our graduate students.

Status summaries of primary research projects in this program, directed or coordinated by GMMRI and supported by GMMRI fellowship, state and industrial funding, are as follows:

"Surfactant-Enhanced Electro-osmatic Dewatering of Mineral Ultrafines"

In mineral processing an issue of growing importance is the effective dewatering of mineral ultrafine suspensions. This finer sized material is inevitably produced as the ore grade decreases. The feasibility of a given dewatering technique is dependent ont he following parameters: final moisture content to be attained, cost per unit of slurry dewatered and, critically, upon porosity- which is proportional to particle size.

Conventional methods of dewatering become ineffective when fine particles are present, reducing the hydraulic permeability. Thus the necessity here is for the development of unconventional methods of dewatering which are independent of particle size. Theoretically, electrokinetic flow is relatively insensitive to particle size, and consequent pore size, of the packed bed. Therefore electro-osmosis is an attractive concept for ultrafine dewatering, provided an appreciable electro-osmotic effect can be effectively produced, and controlled.

With the ochre pigment system involved in this ultrafines dewatering work, as with many value ultrafines systems, there is no significant charge naturally present on the particles and thus no electro-osmotic effect. In this research, a particular and promising innovation is the use of specific surfactant adsorption to generate the required surface electrical properties of the iron oxide ultrafines.

Furthermore, this research exploits the marked synergistic effect resulting with the ionogenic additive systems selected, with emphasis on associated development of a physical model and theoretical treatment of the experimental results obtained.

In this 1988/89 period, Ms. Christine Grant presented papers on the progressive development of this work at North Carolina State University, in Raleigh and at the Graduate Student Symposium at Georgia Tech. Her research project was featured in the *J. National Society of Black Engineers*, December 1988 and March 1989. Such presentations, with related external publications, generated notable response to, and recognition of, this GMMRI research.

Ph.D. work, Ms. Christine Grant, Chemical Engineering.

"Aerosol Particle Deposition on Cylinder Arrays"

Reliable predictions of the concentration distribution of ultrafine particles in the turbulent shear flow around and behind cylinders are of fundamental importance to the characterization of filtering and scrubbing operations in mineral processing. Particle removal efficiencies may be enhanced in these basic unit operations if the turbulent transport coefficients and mixing characteristics of both the scalar quantity and the momentum are predictable under a range of particle sizes and flow conditions.

In this work, the mixing and diffusion of monodisperse aerosols from a turbulent free stream into the wake created by cylindrical collectors was studied experimentally and analytically. Experimental measurements with regard to wake velocity profiles and momentum transport were taken in a tubular flow system by hot-wire and laser doppler anemometry. Particle concentration profiles, measured in the wake by means of a laser doppler technique, were used to calculate mixing and diffusion parameters for the aerosols used. Experimental results were obtained for the mean velocity and particle concentration profiles, wake centerline velocity and particle concentration, wake velocity and concentration half widths, and momentum and particle diffusivities. It is shown that the experimental behavior may be effectively described in terms of two phenomenological theories, i.e., Prandtl's mixing length, and constant diffusivity in the radial cross section of the wake. Certain departures from predicted concentration behavior are empirically analyzed, resulting in the ability to predict overall particle mixing and diffusion characteristics in a turbulent wake.

This successful research work is of fundamental importance in problems related to pollution and contaminant dispersion, slurry and sediment transport, and many particulate control and removal systems.

Ph.D. work, Mr. James Helgensen, Chemical Engineering.

"Electrocapillary Enhancement of Liquid-Liquid Extraction"

There can be marked differences in the behavior between charged and uncharged liquid drops falling through an immiscible liquid phase; charged drops translate more quickly in an electric field, oscillate more readily and exhibit a lower interfacial tension and resulting drop volume. Thus mass transfer rates to or from charged drops are expected to be greater than for uncharged drops. This work, oriented towards the appreciable improvement of mineral leaching processes, is exploring this electrocapillary enhancement of mass transfer rates. The relevant experimental system involved is that of aqueous solution drops in a hydrocarbon continuous phase. Initial stages of this research successfully addressed the critical problem of determining charge leakage rate from charged drops in a dielectric medium, and developed a theoretical treatment quantitatively explaining the type of charge discharge signals resulting from such drops approaching the grounded lower aqueous phase in the bottom of the extraction cell. Preliminary analysis results have already shown that this electrocapillary effect can achieve a several-fold increase in mass transfer rate.

Mr. Frank Watts has presented a paper on this research development at the 1989 Georgia Tech Graduate Student Symposium.

Ph.D. work, Mr. Frank Watts, Chemical Engineering.

"Electrocoagulation Concept for Ultrafines Separation"

Conventional methods for the removal of suspended ultrafine particulates in industrial effluents and wastewater treatment frequently involve the bulk addition of inorganic coagulants (e.g. aluminum or ferric salts), followed by sedimentation to obtain a clarified supernatant liquid. The larger size of the coagulated material facilitates such solid-liquid separation.

The electrocoagulation concept involves the in-situ generation of coagulant ions by electrolysis. The process involves the continuous generation of coagulating ions close to the anode, and concentrating the particulate in this region electrophoretically. Through the control of the electric current, there also exist possibilities to control reagent addition and to optimize the process. The current experimental research will evaluate the effective performance of an electrocoagulation technique for Georgia clay suspensions, using a batch stirred cell system. Particular attention will be focused on determining the transport properties for the cell system, as these properties will determine the optimum cost effectiveness for a scaled up process. Future investigation may include closer study of the electrode processes and the material from which the electrode is made, the possibility of optimizing the power ratio for a given electrode type, and extensive analysis of sediment composition versus electrode alloys composition. The combined phenomena of electrocoagulation and electrodeposition have promising applications and warrant further development.

M.S. work, Ms. Regina Dobson, Chemical Engineering.

"Porous Polymer Structures through Liquid-Liquid Phase Separation"

Homogeneous melt solutions of certain polymer/high boiling liquid mixtures can produce solid structures with as much as 90% void volume upon cooling and extraction of the liquid phase. The void volume generally consists of "cells" on the order of

1 micron in diameter, connected by much smaller "throats". This type of structure has enormous potential for microfiltration, reverse osmosis, controlled release, catalyst carrying, and porous fiber (i.e., breathable clothing) applications. The objective of the research is to define the factors affecting the formation of such porous structures, as well as the properties of the structures themselves. The dependence of the resulting structures on these factors can be explained through an understanding of the thermodynamics and kinetics of both liquid-liquid phase separation and polymer crystallization.

Ph.D. work, Mr. Mark Smartt, Chemical Engineering.

A listing of primary GMMRI Research Publications and Presentations 1988/1989 is as follows:

Publications

1. "Particle Deposition in Wakes - Inertial and Coulombic Effects on Capture by Single and Multiple Spheres in Line", accepted by *Aerosol Sci. and Tech.*, with M. B. Prince.
2. "Particle Mixing in the Turbulent Wake of Spheres", accepted by *Aerosol Science and Technology*, with D. E. Jacober.
3. "The Deposition of Aerosols from Air Streams by Impaction on Multiple Cylindrical Targets", accepted by *Experiments in Fluids*, with J. K. Helgesen.

Presentations

1. "The Deposition of Aerosols from Air Streams by Impaction on Multiple Cylindrical Targets", 19th Annual Meeting of the Fine Particle Society, Santa Clara, CA, July 19-22, 1988, with J. K. Helgesen.
2. "Particle Mixing and Diffusion in the Turbulent Wake of a Cylinder", Annual Meeting American Association for Aerosol Research, Chapel Hill, N.C., October 10-14, 1988, with J. K. Helgesen.

3. "The Deposition of Aerosols from Air Streams by Impaction on Multiple cylindrical Targets", 11th Symposium on Turbulence, University of Missouri, Rolla, October 17-19, 1988, with J. K. Helgesen.

4. "Electrostatically Enhanced Mass Transfer in Liquid-Liquid Extraction", AIChE 1988 Annual Meeting, Washington, D.C. November 27–December 2, 1988, with F. Watts, E. J. Clayfield.