

15:05:02

OCA PAD INITIATION - PROJECT HEADER INFORMATION

07/15/88

Active

Project #: ~~E-19-554~~  
Center #: 05847-OAO

Cost share #: E-19-218  
Center shr #: B5847-OAO

Rev #: 0  
OCA file #:  
Work type : INST  
Document : GRANT  
Contract entity: GIT

Contract #: ~~G1184113~~  
Prime #:

Mod #:

Subprojects ? : N  
Main project #:

Project unit: CHE Unit code: 02.010.114  
Project director(s):  
CLAYFIELD E J CHE

Sponsor/division names: US DEPT OF INTERIOR / BUR OF MINES  
Sponsor/division codes: 111 / 003

Award period: 880701 to 890630 (performance) 890930 (reports)

Sponsor amount	New this change	Total to date
Contract value	89,601.00	138,000.00
Funded	89,601.00	89,601.00
Cost sharing amount		276,000.00

Does subcontracting plan apply ?: N

Title: PROPOSAL FOR 88/89 FUNDING - GA MINING & MINERAL RESOURCES INSTITUTE

PROJECT ADMINISTRATION DATA

OCA contact: William F. Brown 894-4820

Sponsor technical contact	Sponsor issuing office
DR. RONALD A. MUNSON (202)634-4700 DEPT OF THE INTERIOR-BUREAU OF MINES 2401 E STREET, N.W. WASHINGTON, D.C. 20241	JANICE D. JOHNSON, CONTRACT. OFFICER (202)634-4700 DEPT OF THE INTERIOR-BUREAU OF MINES 2401 E STREET, N.W. WASHINGTON, D.C. 20241

Security class (U,C,S,TS) : U	ONR resident rep. is ACO (Y/A)
Defense priority rating : N/A	N/A supplemental sheet
Equipment title vests with: Sponsor	GIT X
SEE ARTICLE VII OF GRANT.	



Administrative comments -

→ INITIATION OF E-19-554. FOLLOW-ON TO E-19-539. FUNDED AMOUNT DOES NOT INCLUDE \$48,399 FOR FELLOWSHIPS WHICH IS COVERED UNDER T-87-217.

GEORGIA INSTITUTE OF TECHNOLOGY  
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 11/29/89

Project No. E-19-554 \_\_\_\_\_ Center No. 05847-0A0 \_\_\_\_\_

Project Director MATTESON M J \_\_\_\_\_ School/Lab CHE \_\_\_\_\_

Sponsor US DEPT OF INTERIOR/BUR OF MINES \_\_\_\_\_

Contract/Grant No. G1184113 \_\_\_\_\_ Contract Entity GIT\_

Prime Contract No. \_\_\_\_\_

Title PROPOSAL FOR 88/89 FUNDING - GA MINING & MINERAL RESOURCES INSTITUTE \_\_\_\_\_

Effective Completion Date 890630 (Performance) 890930 (Reports)

Closeout Actions Required:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	Y	890630
Final Report of Inventions and/or Subcontracts	Y	890630
Government Property Inventory & Related Certificate	Y	_____
Classified Material Certificate	N	_____
Release and Assignment	Y	_____
Other _____	N	_____

Comments \_\_\_\_\_

Subproject Under Main Project No. \_\_\_\_\_

Continues Project No. E-19-539 \_\_\_\_\_

Distribution Required:

Project Director	Y
Administrative Network Representative	Y
GTRI Accounting/Grants and Contracts	Y
Procurement/Supply Services	Y
Research Property Management	Y
<del>Research Security Services</del>	N
Reports Coordinator (OCA)	Y
GTRC	N
Project File	Y
Other _____	N
_____	N

NOTE: Final Questionnaire sent to PDPI.

e 19577



Georgia Institute of Technology  
School of Chemical Engineering  
Atlanta, Georgia 30332-0100  
(404) 894-

DESIGNING TOMORROW TODAY

January 13, 1989

Mr. Doyne W. Teets  
Contracting Officer  
Bureau of Mines  
United States Department of the Interior  
2401 E. Street, NW  
Washington, D. C. 20241

Re: Allotment Grant Number G1174113

Dear Mr. Teets:

Enclosed please find two copies of the Final Report for the period July 1, 1987 - June 30, 1988. Forms 6-1608-A, 6-1605-A, 6-1606A, and SF 269 have been sent separately.

Sincerely,

Eric J. Clayfield  
Director, GMMRI

Enclosure: Form 6-1607-A

EJC:lkh



**GEORGIA MINING AND MINERAL RESOURCES INSTITUTE**

**GMMRI**

**GEORGIA INSTITUTE OF TECHNOLOGY**

**FINAL AND ANNUAL STATUS REPORT 1987/1988**

**GRANT NO. G 1174113**

**Eric J. Clayfield  
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 1987/1988

### 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 of 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 1987/88 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 1987/1988 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:

**"Design Optimization of Geosynthetic-Reinforced Embankments for Tailings"**

This research is directed towards applications of geosynthetics in conjunction with mine tailing wastes: The three areas of specific study are: stability of mine tailing slopes placed on geomembrane liners, the application of geosynthetics for mine tailing slope stability improvement, and the application of geosynthetics in containment-dike extension over soft mine tailing deposits.

The initial results of this work were reported in a paper presented at the seminar on very soft soil stabilization at Drexel University in October 1987. The paper is specifically directed at the methodology of determining the optimum amount of reinforcing material to place within an embankment. Although this report is written for all soft soils, it is particularly relevant to the very soft soil conditions encountered when constructing embankments over mine tailing deposits.

Continuing research work is on the evaluation of the use of geosynthetics in the construction of mine tailing containment-

dike extensions. The research involves: a literature review on the theories behind slope stability analysis of embankments over soft soils, characterization of mine impoundment waste properties, and construction of three embankment models for observing load failure mechanisms.

In this work, frictional characteristics of a variety of mine tailing wastes with various geosynthetics are evaluated in laboratory testing, and a number of analytical techniques reviewed in terms of their application to design. Interactive cooperation with mining industries is providing appropriate mine tailings material for analysis in this program. In return for the provision of tailing samples a report of the test results and a copy of the final research paper will be provided. In addition, if there is a disposal site currently under design or evaluation, consideration will be made to enlarge the research scope to include a stability analysis of that specific site.

M.S. work, Mr. Lucas S. van't Hoog, Civil Engineering.

### **"Surfactant-Enhanced Electro-osmotic 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 on the 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 1987/88 period, Ms. Christine Grant presented papers on the progressive development of this work at the National Conference of the Society of Women Engineers, Puerto Rico, at the National Organization of Black Chemists and Chemical Engineers Conference, Philadelphia, and at the Summer meeting of the Fine Particle Society, Santa Clara, CA. 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 Helgesen, 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 papers on this research development at the Summer 1987 Meeting of the Fine Particle Society, Boston.

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

A listing of primary GMMRI Research Publications 1985/1986 is as follows:

1. "Particle Adhesion Evaluation Using a Rotating Disc Method", E.J. Clayfield, Particulate Science and Technology, 1987.
2. "Coalescence of Secondary Dispersions: Effect of Fiber and Droplet Size, Bed Properties, Electrolyte Concentrations", E.J. Clayfield, Colloids and Surfaces, 1987.
3. "Surfactant-Enhanced Electro-osmotic Dewatering in Mineral Processing", C.S. Grant and E.J. Clayfield, Proc. Fine Particle Soc., 1987.
4. "Surfactant-Enhanced Electro-osmotic Dewatering in Mineral Processing", C.S. Grant and E.J. Clayfield, in Interfacial Phenomena in Biotechnology and materials processing, Y.A. Attia and B.M. Moudgil and S. Chander, eds., Elsevier Science Publishers, Amsterdam, 1988.



Georgia Institute of Technology  
School of Chemical Engineering  
Atlanta, Georgia 30332-0100  
(404) 894-

DESIGNING TOMORROW TODAY

April 6, 1989

Dr. Ronald A. Munson  
Chief, Office of Mineral Institutes  
United States Department of the Interior  
Bureau of Mines  
2401 E. Street, NW  
Washington, D. C. 20241

Dear Mr. Munson:

Enclosed please find two copies of the Performance Report for July 1, 1988 through December 31, 1988. The Report of Funded Scholarships, Fellowships and Assistantships is also enclosed.

Sincerely,

Eric J. Clayfield  
Director, GMMRI

EJC:lkh

Enclosures



MI3

PERFORMANCE REPORT

"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."

<b>1. Grant Recipient</b>	<b>Type of Report</b>	<b>Reporting Period</b>	<b>Grant Number:</b>
Georgia Institute of Technology	<input type="checkbox"/> Semi Annual	Allotment Grant	<u>G1174113</u>
	<input type="checkbox"/> Final	<input checked="" type="checkbox"/> Jul 1 - Dec 31	
		<input type="checkbox"/> Jan 1 - Jun 30	<b>Date Report Prepared:</b>
		Research Grant	March 31, 1989
		<input type="checkbox"/> Oct 1 - Mar 31	
	<input type="checkbox"/> Apr 1 - Sep 30		

**2. Project Title:**  
Allotment grant for State Mining and Mineral Resources Institute

<b>3. Principal Investigator:</b>	<b>Address:</b>	<b>Telephone No.</b>
Professor Eric J. Clayfield	<u>Georgia Mining &amp; Min. Res. Institute</u> <u>Georgia Institute of Technology</u> <u>Atlanta, GA 30332-0100</u>	<u>404/894-2876</u>

**4. Summary:** During this reporting period the research, technical advisory and education development activities of Professor Eric Clayfield as Director of GMMRI, effectively aided by GMMRI part-time administrative secretary Linda Hoard, included the following:

Several papers were presented which detailed GMMRI research developments. These included

American Institute of Chemical Engineers, Washington, D.C., December 5-8, 1988.

American Association for Aerosol Research, Chapel Hill, N.C., October 10-14, 1988.

Fine Particle Society, Santa Clara, CA July 19-22.

Provided technical advice and research program assistance to Georgia-based mineral companies requesting information and experimental work on mineral processing problem areas, including mica ultrafines development for polymer composite systems, mineral fines dewatering and value particulates recovery.

Directed or coordinated the on-going development, and

effective presentation and reporting, of fellowship research projects at Georgia Tech funded by earned GMMRI awards with developing axillary industry support, including:-

"Surfactant-enhanced Electro-osmotic Dewatering of Mineral Ultrafines", Ms. Christine Grant, Chemical Engineering, Ph.D. work. This research deals with the effect of charge modification by the addition of surfactants which enhances the removal of water from mineral ultrafines undergoing electro-osmosis.

"Electrocapillary Enhancement of Liquid-Liquid Extraction", Mr. Frank Watts, Chemical Engineering, Ph.D. work. This work is oriented towards enhancing mass transfer rates in mineral processing extraction unit operations. The work is showing that the enhancement of mass transfer is primarily a function of increasing the interfacial area between phases and that the presence of surfactants considerably lowers the potential required for markedly increasing the mass transfer rate.

Mr. Frank Watts will present a paper on his work at the annual meeting of the American Institute of Chemical Engineers in December, 1988.

"Electrocoagulation Concept for Ultrafines Separation", Ms. Regina Dobson, Chemical Engineering, M.S. work. 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.

Performance Report 3/31/89 p. 3 of 3  
Eric J. Clayfield

"Porous Polymer Structures through Liquid-Liquid Phase Separation", Mr. Mark Smartt, Chemical Engineering, Ph.D. work. 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.



MI4

**REPORT OF FUNDED  
 SCHOLARSHIPS, FELLOWSHIPS  
 AND ASSISTANTSHIPS**

"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."

Name of Institute Grant Number:  
 Georgia Mining and Mineral Resources Institute, Georgia Inst. of Tech. G1174113  
 Atlanta, GA 30332-0100

Reporting period: July 1, 1988 to ~~June 30, 1988~~ December 31, 1988

DEGREE FIELDS	ACADEMIC LEVELS					
	Undergraduate		Graduate		Post-Doctoral	
	No. of Receipts	Total Amount	No. of Receipts	Total Amount	No. of Receipts	Total Amount
1. Mining Engineering						
2. Extractive Metallurgy						
3. Ceramic (Process) Engineering						
4. Mineral Processing						
5. Petroleum & N.G. Eng.						
6. Mineral Economics						
7. Fuel Science						
8. Please List Other Fields						
Civil Engineering			1	\$ 1,479.00		
Chemical Engineering			3	13,596.00		
9. TOTAL student support awarded to date from this Grant				\$15,075		

# FINANCIAL STATUS REPORT

(Follow instructions on the back)

<b>1. FEDERAL AGENCY AND ORGANIZATIONAL ELEMENT TO WHICH REPORT IS SUBMITTED</b> U. S. Department of the Interior - Bureau of Mines	<b>2. FEDERAL GRANT OR OTHER IDENTIFYING NUMBER</b> G1184113	<b>OMB Approved</b> No. 80-RO180	<b>PAGE</b> 1
--	---	-------------------------------------	------------------

**3. RECIPIENT ORGANIZATION (Name and complete address, including ZIP code)**  
 Georgia Institute of Technology  
 Grants and Contracts Accounting  
 Lyman Hall/Emerson Building  
 Atlanta, Georgia 30332-0259

<b>4. EMPLOYER IDENTIFICATION NUMBER</b> 58-6002023	<b>5. RECIPIENT ACCOUNT NUMBER OR IDENTIFYING NUMBER</b> E-19-554/218/T-87-217	<b>6. FINAL REPORT</b> <input type="checkbox"/> YES <input checked="" type="checkbox"/> NO	<b>7. BASIS</b> <input checked="" type="checkbox"/> CASH
<b>8. PROJECT/GRANT PERIOD (See instructions)</b>		<b>9. PERIOD COVERED BY THIS REPORT</b>	
<b>FROM (Month, day, year)</b> 07/01/88	<b>TO (Month, day, year)</b> 06/30/89	<b>FROM (Month, day, year)</b> 10/01/88	<b>TO (Month, day, year)</b> 12/31/88

10. STATUS OF FUNDS							
PROGRAMS/FUNCTIONS/ACTIVITIES ▶	(a)	(b)	(c)	(d)	(e)	(f)	TOTAL (g)
a. Net outlays previously reported	\$	\$	\$	\$	\$	\$	\$ 74,583
b. Total outlays this report period							92,210
c. Less: Program income credits							- 0
d. Net outlays this report period (Line b + minus line c)							92,210
e. Net outlays to date (Line a + line d)							166,793
f. Less: Non-Federal share of outlays							89,268
g. Total Federal share of outlays (Line e + minus line f)							77,525
h. Total unliquidated obligations							148,091
i. Less: Non-Federal share of unliquidated obligations shown on line h							124,441
j. Federal share of unliquidated obligations							23,650
k. Total Federal share of outlays and unliquidated obligations							101,175
l. Total cumulative amount of Federal funds authorized							138,000
m. Unobligated balance of Federal funds							36,824

<b>11. INDIRECT EXPENSE</b>	<b>a. TYPE OF RATE</b> (Place "X" in appropriate box) <input checked="" type="checkbox"/> PROVISIONAL <input type="checkbox"/> PREDETERMINED <input type="checkbox"/> FINAL <input type="checkbox"/> FIXED			
	<table border="1"> <tr> <td><b>b. RATE</b> 60.0%</td> <td><b>c. BASE</b> MTDC</td> <td><b>d. TOTAL AMOUNT</b> \$62,075.95</td> <td><b>e. FEDERAL SHARE</b> - 0 -</td> </tr> </table>	<b>b. RATE</b> 60.0%	<b>c. BASE</b> MTDC	<b>d. TOTAL AMOUNT</b> \$62,075.95
<b>b. RATE</b> 60.0%	<b>c. BASE</b> MTDC	<b>d. TOTAL AMOUNT</b> \$62,075.95	<b>e. FEDERAL SHARE</b> - 0 -	

**12. CERTIFICATION**  
 I certify to the best of my knowledge and belief that this report is correct and complete and that all outlays and unliquidated obligations are for the purposes set forth in the award documents.

<b>SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL</b>  David V. Welch, Director Grants and Contracts Accounting	<b>DATE REPORT SUBMITTED</b> 01/12/89
<b>TYPED OR PRINTED NAME AND TITLE</b>	<b>TELEPHONE (Area number and ext.)</b> (404) 894-26

**13. REMARKS:** Attach any explanations deemed necessary or information required by Federal sponsoring agency in compliance with governing legislation.  
 Questions pertaining to this report should be directed to: Dale C. Turner (404) 894-5521

# FINANCIAL STATUS REPORT

(Follow instructions on the back)

<b>1. FEDERAL AGENCY AND ORGANIZATIONAL ELEMENT TO WHICH REPORT IS SUBMITTED</b> U. S. Department of Interior - Bureau of Mines	<b>2. FEDERAL GRANT OR OTHER IDENTIFYING NUMBER</b> G1174113	<b>OMB Approved</b> No. 80-RO180	<b>PAGE</b> 1	<b>OF</b> 1
--	---	-------------------------------------	------------------	----------------

<b>3. RECIPIENT ORGANIZATION (Name and complete address, including ZIP code)</b> Georgia Institute of Technology Grants and Contracts Accounting Lyman Hall/Emerson Building Atlanta, GA 30332-0259	<b>4. EMPLOYER IDENTIFICATION NUMBER</b> 58-6002023	<b>5. RECIPIENT ACCOUNT NUMBER OR IDENTIFYING NUMBER</b> E-19-539/217/T-87-216	<b>6. FINAL REPORT</b> <input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	<b>7. BASIS</b> <input checked="" type="checkbox"/> CASH <input type="checkbox"/> ACCT
	<b>8. PROJECT/GRANT PERIOD (See instructions)</b>		<b>9. PERIOD COVERED BY THIS REPORT</b>	
	<b>FROM (Month, day, year)</b> 07/01/87	<b>TO (Month, day, year)</b> 06/30/88	<b>FROM (Month, day, year)</b> 07/01/87	<b>TO (Month, day, year)</b> 06/30/88

PROGRAMS/FUNCTIONS/ACTIVITIES ▶	STATUS OF FUNDS						TOTAL (g)
	(a)	(b)	(c)	(d)	(e)	(f)	
a. Net outlays previously reported	\$	\$	\$	\$	\$	\$	\$ 362,556.43
b. Total outlays this report period							10,321.65
c. Less: Program income credits							- 0 -
d. Net outlay: this report period (Line b plus line c)							10,321.65
e. Net outlay: to date (Line a plus line d)							372,878.08
f. Less: Non Federal share of outlays							255,260.30
g. Total Federal share of outlays (Line e minus line f)							117,617.78
h. Total unliquidated obligations							- 0 -
i. Less: Non Federal share of unliquidated obligations shown on line h							- 0 -
j. Federal share of unliquidated obligations							- 0 -
k. Total Federal share of outlays and unliquidated obligations							117,617.78
l. Total cumulative amount of Federal funds authorized							138,000.00
m. Unobligated balance of Federal funds							20,382.22

<b>11. INDIRECT EXPENSE</b>	<b>a. TYPE OF RATE</b> (Place "X" in appropriate box) <input checked="" type="checkbox"/> PROVISIONAL <input type="checkbox"/> PREDETERMINED <input type="checkbox"/> FINAL <input type="checkbox"/> FIXED			
	<b>b. RATE</b> 60%	<b>c. BASE</b> MTDC	<b>d. TOTAL AMOUNT</b> \$137,262.34	<b>e. FEDERAL SHARE</b> - 0 -

**13. CERTIFICATION**  
I certify to the best of my knowledge and belief that this report is correct and complete and that all outlays and unliquidated obligations are for the purposes set forth in the award documents.

<b>SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL</b>  TYPED OR PRINTED NAME AND TITLE David V. Welch, Director Grants and Contracts Accounting	<b>DATE REPORT SUBMITTED</b> 11/10/88  <b>TELEPHONE (Area number and extension)</b> (404) 894-2627
--	--

**12. REMARKS:** Attach any explanations deemed necessary or information required by Federal sponsoring agency in compliance with governing legislation.  
Questions pertaining to this report should be

directed to: Dale C. Turner (404) 894-5521



L 11 24

**Georgia Institute of Technology**  
School of Chemical Engineering  
Atlanta, Georgia 30332-0100  
(404) 894- 2876

DESIGNING TOMORROW TODAY

---

November 13, 1989

Dr. Ronald A. Munson, Chief  
Office of Mineral Institutions  
Bureau of Mines  
United States Department of the Interior  
2401 E. Street, NW  
Washington, D. C. 20241

Re: Allotment Grant Number G1184113

Dear Mr. Munson:

Enclosed please find two copies of the Final Report for the period July 1, 1988 - June 30, 1989. Also enclosed are forms SF-269 and 6-1607-A.

Sincerely,

Michael J. Matteson  
Director, GMMRI

Enclosure: Forms 6-1607-A  
SF-269

MJM\bcc

# FINANCIAL STATUS REPORT

(Follow instructions on the back)

<b>1. FEDERAL AGENCY AND ORGANIZATIONAL ELEMENT TO WHICH REPORT IS SUBMITTED</b> U. S. Department of Interior - Bureau of Mines		<b>2. FEDERAL GRANT OR OTHER IDENTIFYING NUMBER</b> G1184113	<b>OMB Approved</b> No. 80-RO180	<b>PAGE</b> 1	<b>OF</b> 1	<b>PAGES</b>
<b>3. RECIPIENT ORGANIZATION (Name and complete address, including ZIP code)</b> Georgia Institute of Technology Atlanta, Georgia 30332-0259		<b>4. EMPLOYER IDENTIFICATION NUMBER</b> 58-6002023	<b>5. RECIPIENT ACCOUNT NUMBER OR IDENTIFYING NUMBER</b> E-19-554/218/T-87-217	<b>6. FINAL REPORT</b> <input checked="" type="checkbox"/> YES <input type="checkbox"/> NO		<b>7. BASIS</b> <input checked="" type="checkbox"/> CASH <input type="checkbox"/> ACCRUAL
<b>8. PROJECT/GRANT PERIOD (See instructions)</b>			<b>9. PERIOD COVERED BY THIS REPORT</b>			
<b>FROM (Month, day, year)</b> 07/01/88		<b>TO (Month, day, year)</b> 06/30/89	<b>FROM (Month, day, year)</b> 07/01/88		<b>TO (Month, day, year)</b> 06/30/89	

10. STATUS OF FUNDS							
PROGRAMS/FUNCTIONS/ACTIVITIES ▶	(a)	(b)	(c)	(d)	(e)	(f)	TOTAL (g)
a. Net outlays previously reported	\$	\$	\$	\$	\$	\$	\$ 300,913.48
b. Total outlays this report period							96,861.09
c. Less: Program income credits							-0-
d. Net outlays this report period (Line b minus line c)							96,861.09
e. Net outlays to date (Line a plus line d)							397,774.57
f. Less: Non-Federal share of outlays							262,233.93
g. Total Federal share of outlays (Line e minus line f)							135,540.64
h. Total unliquidated obligations							-0-
i. Less: Non-Federal share of unliquidated obligations shown on line h							-0-
j. Federal share of unliquidated obligations							-0-
k. Total Federal share of outlays and unliquidated obligations							135,540.64
l. Total cumulative amount of Federal funds authorized							138,000.00
m. Unobligated balance of Federal funds							2,459.36

<b>11. INDIRECT EXPENSE</b>	<b>a. TYPE OF RATE</b> (Place "X" in appropriate box) <input checked="" type="checkbox"/> PROVISIONAL <input type="checkbox"/> PREDETERMINED <input checked="" type="checkbox"/> FINAL <input type="checkbox"/> FIXED				<b>13. CERTIFICATION</b> I certify to the best of my knowledge and belief that this report is correct and complete and that all outlays and unliquidated obligations are for the purposes set forth in the award documents.	<b>SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL</b>  David V. Welch, Director Grants & Contracts Accounting	<b>DATE REPORT SUBMITTED</b> 10/06/89
	<b>b. RATE</b> 1. FY89 60.0%	<b>c. BASE</b> MTDC	<b>d. TOTAL AMOUNT</b> \$148,701.29	<b>e. FEDERAL SHARE</b> -0-			

**12. REMARKS:** Attach any explanations deemed necessary or information required by Federal sponsoring agency in compliance with governing legislation.

209-102    2. FY90    62.5%

Questions pertaining to this report should be directed to:  
Dale C. Turner    (404) 894-5521

STANDARD FORM 269 (7-76)  
Prescribed by Office of Management and Budget  
Cir. No. A-110

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



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 Georgia Mining and Mineral Resources Institute	B. ADDRESS 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 Michael J. Matteson	F. GOVERNMENT TECHNICAL PROJECT MONITOR 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.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

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 11/13/89

Signature [Signature]  
 Title Project Director GMD/PS

**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-osmotic 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 on the 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 facil-

itates 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.