AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910

301/587-8202

Centimeter

Inches

**MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.**

1 of 1

DOE/MC/30251-3782
(DE94004147)

RECEIVED
JUN 27 1994
OSTI

**High-Volume, High-Value Usage of Flue Gas
Desulfurization (FGD) By-Products in
Underground Mines
Phase 1: Laboratory Investigations**

**Quarterly Report
October - December 1993**

March 1994

Work Performed Under Cooperative Agreement No.: DE-FC21-93MC30251

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
University of Kentucky
Center for Applied Energy Research
Lexington, Kentucky

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

for

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, 175 Oak Ridge Turnpike, Oak Ridge, TN 37831; prices available at (615) 576-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161; phone orders accepted at (703) 487-4650.

This cover stock is 30% post-consumer waste
and 30% pre-consumer waste, and is recyclable.

DOE/MC/30251-3782

High-Volume, High-Value Usage of Flue Gas
Desulfurization (FGD) By-Products in Underground Mines
Phase 1: Laboratory Investigations

DOE

**High-Volume, High-Value Usage of Flue Gas
Desulfurization (FGD) By-Products in
Underground Mines
Phase 1: Laboratory Investigations**

**Quarterly Report
October - December 1993**

Work Performed Under Cooperative Agreement No.: DE-FC21-93MC30251

**For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880**

**By
University of Kentucky
Center for Applied Energy Research
3572 Iron Works Pike
Lexington, Kentucky 40511-8433**

March 1994

High Volume--High Value Usage of Flue Gas Desulfurization (FGD) By-Products in Underground Mines, Phase I: Laboratory Investigations

Cooperative Agreement No. DE-FC21-93MC30251

Quarterly Report for the Period October 1, 1993 to December 31, 1993

Introduction and Project Background

The Mining System It is proposed to use pneumatically or hydraulically emplaced dry-flue gas desulfurization by-products to backfill the adits left by highwall mining. Highwall mining represents a recent technologic breakthrough in coal recovery. The highwall mining system consists of a remotely controlled continuous miner coupled to a series of 40-foot long cars each equipped with a conveyor belt. Coal cascades from car to car and a launch vehicle allows cars to be added without the interruption of coal flow. Highwall mining systems are currently being manufactured by Mining Technologies, Inc. (a subsidiary of Addington Resources) and Joy Technologies, Inc. under license to MTI. The highwall miner removes an 11.5 foot wide panel, going back 1,000 feet back into the coal seam. An approximately 4-foot thick web of coal is left for roof support.

Backfilling highwall mine adits with dry-FGD materials is technically attractive. The use of an active highwall mine would allow the dry-FGD material to be brought in using the same transportation network used to move the coal out, eliminating the need to recreate the transportation infrastructure, thereby saving costs. The highwall mine is controlled entirely from the surface, and the filling and mining operations can be completely separated which simplifies logistics. The fully automated highwall mining system also provides a large factor of safety, as no personnel has to enter the mine.

Dry-FGD Materials The focus of the study is to demonstrate the emplacement of dry-FGD materials in highwall mines as a high value beneficial use. Dry-FGD material has cementitious properties, and relatively high compressive strengths have been measured for moisturized and cured materials. In addition, the materials are known to be expansive. This expansive characteristic will allow the FGD material to completely fill highwall mine tunnels and become a self-stressing roof support structure. Thus, the web of coal now left for roof support could be recovered. The emplaced material will prevent subsidence and also, possibly, will moderate acid drainage.

Desulfurization technologies which produce dry by-products can be categorized by application. Those primarily designed to retrofit existing power plants include lime injection multistage burner (LIMB), spray dryer and duct-injection. Those technologies which are applicable to new plants, or repowering older plants, include atmospheric fluidized bed combustion (AFBC) and pressurized fluidized bed combustion (PFBC).

Dry-FGD materials have several desirable characteristics for coal mine emplacement. The materials contain fly ash, calcium sulfate and sulfite, lime, and some re-carbonated calcium oxide. When wetted, these materials undergo cementitious reactions and develop high strengths. Concomitant with the increase in strength is a decrease in permeability. These properties suggest a low potential to contaminate ground, surface or mine water. Dry-FGD materials are also known to be expansive. This property, which is considered a liability for most applications, has the potential to be an asset in mine disposal. Heat release from hydration reactions represents a potential problem.

Research Plan The research is to be carried out over a 48 month period. There are two major phases of the proposed research. Phase I consists of laboratory studies to determine the physical and chemical characteristics of the materials as they relate to the mine emplacement. Geotechnical tests will be run to determine their strength, stability, heat release and expansive properties. Batch and column leaching extractions will be conducted to determine their water pollution potential. This information will be used to design the field demonstration.

Phase II is the field demonstration. The dry-FGD material will be transported and emplaced in highwall mine adits. The fill will be instrumented with thermal couples to monitor heat release, and with pressure cells to monitor expansion against the mine roof. Cores will be taken of the fills over time to determine changes in physical properties. A complete set of hydrologic monitoring wells will be installed and sampled throughout the period of research.

Part of Phase II will consist of data analysis and economic assessments. The economic assessments will contain both general and site specific cases. A technical advisory committee will be formed to provide realistic input into the economics and overall technical content of the program.

Summary of Progress for the Period of October 1, 1993 to December 31, 1993

Activities during the period included the negotiations leading to the final cooperative agreement for the project and the implementation of the necessary instruments at the University of Kentucky to administer the project. Early in the negotiations, a final agreement on a task structure was reached and a milestone plan was filed (Form 459B). A review was initiated of the original laboratory plan as presented in the proposal, and tentative modifications were developed (Task 1). Selection of a mine site (Subtask 4.1) was made early; the Pleasant Valley mine in Greenup County was chosen. Several visits were made to the mine site to begin work on the hydrologic monitoring plan. The investigation of the types of permits needed to conduct the project (Task 6) was initiated. Considerations concerning the acceptance and implementation of technologies led to the choice of circulating fluidized bed ash as the primary material for the study (Subtask 2.1). Finally, the membership of a Technical Advisory Committee (TAC) for the study was assembled.

ADMINISTRATIVE

Implementation of Cooperative Agreement A proposed cooperative agreement was forwarded from the U.S. Department of Energy's Morgantown Energy Technology Center (METC) to the University of Kentucky Office of Sponsored Projects. Negotiations took place during the month of October, and the University accepted the proposal with only very minor modifications at the end of the month. Ms. Marybeth Ashbaugh was selected by METC as the Contractor's Technical Representative for the project.

A final task plan and schedule was developed for the project (Figures 1 and 2). The project was divided into two distinct phases for both funding proposes and work scheduling. Phase I will consist primarily of the laboratory portion of the study; Phase II will focus on the field demonstration and monitoring. Because the laboratory work will be conducted in existing facilities, a categorical exclusion will be filled as part of the requirements of the National Environmental Policy Act (NEPA).

Technical Advisory Committee (TAC) The cooperative agreement calls for the formation of a technical advisory committee for the project. The project is relevant to coal producers, consumers, shippers, by-product management companies and regulatory authorities. A TAC was formed to reflect such a diverse membership. The following is a list of the committee members as of January 1994:

Mr. Carl Campbell, Deputy Commissioner of Surface Mining, Ky Natural Resources & Environmental Protection Cabinet
#2 Hudson Hollow, Frankfort, KY 40601

Mr. Steve Dixon, Louisville Gas & Electric
P. O. Box 32010, Louisville, KY 40232

Mr. Charles Jude, U.S. Bureau of Mines, Denver Research Center
P.O. Box 2508, Building 20, Denver Federal Center, Denver, CO 80225

Mrs. Shiela Shelton Medina, Manager, Research & Development, East Kentucky Power Cooperative, Box 707, Winchester, KY 40391-0707

Dr. Ishwar Murarka, Electric Power Research Institute
P. O. Box 10412, Palo Alto, CA 94303

Mr. Karl Siebert, Air Products & Chemicals, Inc.
7201 Hamilton Boulevard, Allentown, PA 18195-1501

Mr. Mike Woodall, CSX Transportation, Inc.
500 Water Street J842, Jacksonville, FL 32202-4057

Figure 1 Phase I Project Task Schedule

Figure 2. Phase II Project Task Schedule

Dr. Jack Lewnard, Air Products & Chemicals, Inc.
7201 Hamilton Boulevard, Allentown, PA 18195-1501

Mr. Robert Addington, Addington Resources, Inc.
P. O. Box 2189, Ashland, KY 41105-2189

Mr. Rudy Gerbus, President, Trans-Ash Inc.
P. O. Box 15396, Cincinnati, OH 45215

Dr. Milton Wu, CONSOL Research & Development, Inc.
4000 Brownsville Road, Library, PA 15129-9566

Mr. Bob Bedick, U.S. Department of Energy, Morgantown Energy Technology Center
P.O. 880, 3610 Collins Ferry Road, Morgantown, WV 26507-0880

Technical Working Group With the exception of students, the technical working group was formed for the project. This group includes the following individuals:

Mary Beth Ashbaugh (Contractors Technical Representative)

	US DoE-METC	304-291-4966
Tom Robl (PI)	UK CAER	606-257-0272
Uschi Graham	UK CAER	606-257-0299
Jack Groppo	UK CAER	606-257-0254
Scott Carter	UK CAER	606-257-0265
Jim Hower	UK CAER	606-257-0261
Gerald Thomas	UK CAER	606-257-0282
Morgan Yewell	UK CAER	606-257-0263
Frank Derbyshire	UK CAER	606-257-0306
Lyle Sendlein	UK Ky Water Res. Inst.	606-257-8636
Shelley Minns	Kentucky Geological Survey	606-257-5500
Jim Dinger	Kentucky Geological Survey	606-257-5500
Donn Hancher	UK Civil Eng	606-257-4856
Kevin Sutterer	UK Civil Eng	606-257-4857
Tommy Hopkins	UK Ky Transport Ctr	606-257-4516
Tony Beckham	UK Ky Transport Ctr	606-257-4527
Rick Sweigard	UK Mining Eng	606-257-1173
Jeff Sartaine	Mining Technologies Inc	606-928-6644
Larry Compton	Mining Technologies Inc	606-928-3433

TASK 1 LABORATORY TEST PLAN

The engineering activities in the preliminary stages of the project included review of the proposed testing program to characterize the materials. Our objective is to develop revisions of that program to provide more representative specimen preparation and testing for the expected placement procedures. The originally proposed, and revised, testing programs are discussed below.

It is understood that one or two dry-FGD materials that will be available for the field study will be tested in the study. These materials will be mixed at different ratios with a locally available fly ash and water in an effort to optimize the strength. The tests will consist of two phases. The first phase will be conducted to provide a general characterization of the materials and to bound the expected range of water and fly ash ratios to achieve the desired performance of the mix. The second phase will draw on the findings of the first phase to identify an optimum mixing ratio for the materials selected. It is expected that the second phase will begin during July 1994. Material selection is under way at the time of this report, and it is expected that the materials will be available to begin Phase I testing in February.

It is understood that the significant final material characteristics are a minimum unconfined compressive strength of 1000 psi and a minimum free swell of 7 percent. Low permeability is also important, although a specific threshold level has not been specified. Permeabilities on the order of 10^{-4} to 10^{-7} cm/sec have been typical of mixtures with FGD materials in the past. The actual permeability achieved could be of a similar order for the specimen preparation used for this project. There is some indication that lower permeability is achieved during confined swelling, so the amount of swell sufficient to fill the adit and establish confined conditions will be important.

The free swell of compacted specimens using FGD materials has been known to exceed 10 percent of the total specimen volume. However, there is no significant data indicating the expected swell of the material proposed in this study, as the expected placement methods will result in lower initial densities and thus potentially lower free swell.

The density may also have an effect on the strength that is achieved in the material. Relatively high strengths have been found with similar materials for curing times in excess of 28 days for specimens that have been subjected to significant compaction. However, uncompacted specimens will result in lower strengths.

The following revisions are still under consideration by the engineering group, and may be revised prior to the first Technical Advisory Committee meeting. In addition, due to the lack of significant data characterizing the materials that will be used for the project, it is likely that the testing program will be revised as the testing proceeds to accommodate unexpected material behavior. The scope of the testing matrix will depend on the results of preliminary tests, which are expected to be under way in February.

Specimen Preparation The original testing program was developed to characterize materials that would be emplaced with some significant compactive effort, but further review of the material transport technologies that are most likely to be used verified that either pneumatic emplacement or pumping under pressure will probably be used. These placement technologies do not involve significant compactive effort unless the material can be vibrated in place after placement. Thus, specimen preparation will focus on methods that create a lower density that would be representative of the in place density. Specifically, it is expected that a flow cone procedure will be employed for specimen preparation.

Index Testing The proposed index testing remains appropriate for the FGD materials. However, several additional index tests, including specific gravity and absorption, will be considered in addition to those originally proposed.

Strength Testing The proposed testing program included unconfined, triaxial, direct shear, and CBR testing to characterize the strength of the mix. However, further study of the placement procedures and expected material characteristics has shown that not all of these tests are appropriate for the expected material properties. Therefore, it is recommended that the strength testing focus on unconfined compression testing and that the direct shear and CBR tests be eliminated from the testing matrix, and that the triaxial testing be used only in the case where material fracturing is believed to be significantly impacting the measured unconfined compressive strengths. The advantage of the triaxial testing is that it provides confined conditions during testing. The unconfined compression testing will provide acceptable strength characterization and will allow direct correlation with the results of the extensive unconfined compression testing that is routinely performed for conventional concrete and for coal seam testing.

Swell Testing The swell testing in Phase I will consist of measurements of free swell of the specimens during curing. This will provide adequate characterization of the approximate free swell expected in place. Similar measurements will be made during the Phase II testing, but additional testing of free swell under lateral confinement is also under consideration. Confined swell after 7 percent free swell may also be performed to permit estimation of the swelling pressures that may be expected after the adit has been closed by the swell of the materials. There has been some indication that confined swell will result in reduced permeability.

Permeability Testing Permeability testing is not currently planned for Phase I. However, this will be a significant part of the Phase II program. The means of measurement of permeability will depend on the specimen characteristics, which will not be known until after Phase I is well under way. A standard for measurement of concrete permeability has not been developed, although many procedures have been used in the past. It is expected that the permeability tests will be performed using the flexible wall permeability equipment in the Kentucky Transportation Research Center Laboratories.

TASK 2 LABORATORY STUDIES

Subtask 2.1 Materials Acquisition

Selection of Materials We focused primarily on the type of material to select for the study. It was decided that bed and fly ash from circulating fluidized bed combustors (CFBC) were the best candidate materials. As an alternate material, spray dryer ash may also be considered. Of the technologies which produce dry FGD materials, CFBC has the most systems operational. Other systems such as pressurized fluidized bed combustion units (PFBC) and lime-injection multistage burner (LIMBs) were not chosen, as they are either not sufficiently mature or, in the case of latter, are not expected to see widespread implementation.

Two organizations who operate CFBC's were contacted during the quarter. These were the Pontiac Motor Division of General Motors and the P. H. Glatfelter Company of Spring Grove, Pennsylvania.

TASK 4 BACKGROUND FOR FIELD STUDIES

Subtask 4.1 Mine Selection

The Pleasant Valley Mine
After consultation with personnel from Addington, Inc., the Pleasant Valley mine was selected for the project. The mine is one of two potential sites presented in the original proposal. It is located in the northcentral section of the Argillite quadrangle, in Greenup County, Kentucky (Figures 3 and 4). The geology of the quadrangle was mapped by Sheppard and Ferm (1962).

The mine is considered to be "typical" of those located in this area (Princess Coal Reserve District) of northeastern

Figure 5. Stratigraphic Column of Mine Area.

A diagram showing a grid of squares. A thick black line outlines a specific area within the grid. An arrow points to a dot labeled "SITE" within the outlined area.

9

Figure 4. Topographic Location of Mine.

Kentucky. The mine will be developed in the Princess No. 3 coal bed. The coal is being highwall mined by Addington elsewhere on the property. The Princess No. 3 is an important resource in this area.

Mine Reconnaissance The mine was visited several times during December of 1993 to acquaint the research group with the site, to sample coal, to measure and log the stratigraphy, and, to initiate plans for a hydrologic monitoring plan.

The coal bed where sampled is 102 cm thick with a 37 cm upper split, a 31 cm thick claystone parting, and a 34 cm lower bench (Figure 5). The floor is a plastic clay. The immediate roof is a ~5 m black to gray shale overlain in succession by ~1.5 m gray claystone, a ~0.3 m coal, ~2 m sandstone, ~0.3 m coal, and ~2 m sandstone. The roof appears to be more competent on the southwest side of the bench, furthest removed from the natural outcrop of the coal.

The prospect of mining in the latter portion of the highwall has hydrologic advantages. In addition to being associated with a more competent roof, that portion of the bench is removed from the drainage pond constructed on the site in early December 1993. It will be advantageous for the monitoring wells located in the highwall to be as far from the pond as possible.

TASK 6 INFORMATION FOR THE NATIONAL ENVIRONMENTAL POLICY ACT

Efforts in this task centered on reviewing the permits necessary to conduct the project. The highwall mining system is classified by the Division of Surface Mining of the Kentucky Natural Resources Cabinet, as well as the Federal Office of Surface Mining, as a surface mining technology. As Kentucky has primacy, the permitting for the project will be handled through this office. A request was made and granted to hold open the highwall at the Pleasant Valley mine for a period of thirty months. This will allow a period of both pre and post emplacement monitoring. The Kentucky Legislature is considering passing additional regulations for the emplacement of combustion by-products on the coal mine site. If approved, we will also provide the appropriate information under those rules as well. The proposed regulations have experimental practices clauses, and we believe that we will not have difficulty obtaining a permit.

DATE

FILMED

7/21/94

END