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TECHNICAL PROGRESS REPORT

JANUARY 1 - MARCH 31, 1994

MANAGEMENT OF DRY FLUE GAS DESULFURIZATION
BY-PRODUCTS IN UNDERGROUND MINESCOOPERATIVE AGREEMENT
DE-FC21-93MC30252

BETWEEN

U. S. DEPARTMENT OF ENERGY

and

SOUTHERN ILLINOIS UNIVERSITY
AT CARBONDALE

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INTRODUCTION

The U.S. Department of Energy, Morgantown Energy Technology Center and Southern Illinois University at Carbondale entered into a cooperative agreement entitled "Management of Dry Flue Gas Desulfurization By-Products in Underground Mines" (DE-FC21-93MC30252) on September 30, 1993, in response to PRDA DE-RA21-92 MC 29244. Under the agreement, Southern Illinois University at Carbondale will develop and demonstrate several technologies for the handling and transport of dry coal combustion residues and for the underground placement in abandoned coal mines and assess associated environmental impacts.

Under the cooperative agreement, Dr. Yoginder P. Chugh, Director, Coal Combustion Residues Management Program, is named Program Director and Principal Investigator, and Mr. Edwin M. Thomasson is named Program Manager. Co-Principal Investigators are Dr. Steven Esling, Dr. Nader Ghafoori, Dr. Rick Honaker, Dr. Bradley Paul, Dr. Hasan Sevim, and Mr. Thomasson. For the U.S. Department of Energy, Mr. Jerry Harness is named the Contracting Officer's Representative (COR).

The overall program set forth in the cooperative agreement is for a period of four (4) years, beginning September 30, 1993. However, the program is divided into three phases, as follows:

Phase I -- 30 Months, Beginning September 30, 1993
Phase II -- 6 Months, Beginning April 1, 1996
Phase III -- 12 Months, Beginning October 1, 1996

This document sets forth the technical progress under the cooperative agreement for the second three-month period (January 1 - March 31, 1994) of Phase 1 of the overall program.

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SUMMARY

Although parts of the Residue Characterization portion of the program were delayed because residue samples were not obtained, other parts of the program are proceeding on schedule. The delays in obtaining residue samples were primarily caused by adverse weather conditions, the shut-down of one unit at the City Water, Light, and Power Company Plant for routing maintenance and problems due to conflicting schedules of utility and program personnel. However, by the end of the quarter most residue samples had been obtained, and the residue characterization studies were under way.

The completion of the test plan with its quality assurance/quality control protocols was a significant accomplishment during the quarter. The plan was a major effort for most of the Co-Principal Investigators as well as for the Program Director and Program Manager.

Visits to utility power plants by several Co-Principal Investigators gave them a much better understanding of the coal combustion residues handling and transport technologies and associated problems. Also, the "Management of High Sulfur Coal Combustion Residues" conference will increase the understanding of residue management technologies and problems.

In summary, much progress was made during the quarter ending March 31, 1994, although the Residue Characterization work fell somewhat behind schedule because of the inability to obtain needed residue samples. The residue characterization studies will be accelerated, so the delay will have little or no effect on the overall program schedule.

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"KICK-OFF" MEETING OF COOPERATING ORGANIZATIONS

A "kick-off" meeting of the Cooperating Organizations and the Co-Principal Investigators was held on January 5, 1994, in the Department of Mining Engineering facilities in Carbondale, Illinois. The purpose of the meeting was to acquaint fully the cooperating organizations with the overall program objectives and with the various technical aspects of the program. Dr. Y.P.Chugh, Program Director and Principal Investigator, opened the meeting by discussing in detail the overall problem of coal combustion residue management and the background that contributed to the joint DOE-SIUC cooperative agreement. Mr. Edwin Thomasson, Program Manager, presented an outline of the management plan for the program. The Co-Principal Investigators gave presentations detailing the scope of their individual work areas and the relationships between the various work areas. The Co-Principal Investigators also discussed the relations with the various cooperating organizations.

Mr. Lonny Baer of SEEC, Inc. also gave a technical presentation to the meeting group, outlining SEEC's methodology for handling and transporting coal combustion residues and the estimated times for various aspects of their proposed demonstration.

Following a luncheon at the SIUC Student Center, open discussion of various aspects of the overall program was held. The general comments by various attendees following the meeting showed that the meeting was quite informative and helpful to the cooperating organizations and gave them a better understanding of the program, its overall goals, and its technical and management structure and problems.

Due to a heavy snow storm in West Virginia, Mr. Jerry Harness, the Department of Energy Contracting Officer's Representative (COR) for the program was unable to attend the kick-off meeting.

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TEST PLAN - VOLUME I - ENVIRONMENTAL ASSESSMENT AND GEOTECHNICAL STABILITY AND SUBSIDENCE IMPACTS (Dr. S. Esling and Dr. Y.P. Chugh, Co-Principal Investigators)

The "Management of Dry Flue Gas Desulfurization By-Products in Underground Mines" program has, as its primary objective the development and demonstration of hydraulic and pneumatic technologies for backfilling abandoned coal mine workings with coal combustion residues and dry flue gas desulfurization by-products. Two subsidiary objectives are 1), to determine whether the placement of coal combustion placement technique or a "paste" hydraulic technique will control surface subsidence over the abandoned underground workings, and 2), to assess environmental impacts (land, water, and air) of underground management of FGD by-products.

A test plan was developed which outlines in detail the various tests and analytical procedures which will be performed to develop the baseline information necessary to establish environmental and subsidence conditions as they currently exist, prior to the placement of coal combustion residues in the underground mine workings. After underground placement is accomplished in Phase III of this program, similar tests and analytical procedures will be performed and the results compared to the baseline data here obtained. Such a comparison will determine whether the underground placement of coal combustion residues has any adverse environmental effects, and whether surface subsidence is alleviated or minimized.

Built into the test plan are the quality assurance/quality control procedures which will be followed and which will assure the accuracy and scientific validity of the data obtained. The quality assurance/quality control procedures are based on standardized, recognized test methods and laboratory and field procedures.

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TEST PLAN - VOLUME II - RESIDUE CHARACTERIZATION (Dr. B. Paul and Dr. N. Ghafoori, Co-Principal Investigators)

In order properly to manage coal combustion residues, particularly the increasing flue gas desulfurization (FGD) by-products, it is essential that the nature, composition, and properties of these residues is known and thoroughly understood. By knowing the chemical and engineering properties of the residues, handling and disposal technologies can be developed. However, if some of the properties of the residues are not known, the residues may react differently than expected, thus not properly fulfilling the role predicted and desired in the overall management and disposal program.

The Residue Characterization portion of the "Management of Dry Flue Gas Desulfurization (FGD) By-Products in Underground Mines" cooperative program is concerned with obtaining representative samples of coal combustion residues from electric generating power plants and with analyzing these residue samples to determine their composition and properties. Such analyses will use sound, recognized techniques and up-to-date equipment, and thus will yield accurate data concerning the residues composition and properties.

Equally important in the program is the composition and characteristics of leachates; i.e., the composition and characteristics of the resulting fluid after the residues have been subjected to a fluid and some material dissolved from the residues. It is easy to see the importance of this, for an actual practice coal combustion residues will be subject to wetting through natural forces. The leachate studies will give a sound foundation for predicting the composition, and thus the environmental effects, of the natural leaching of coal combustion residues.

Also under this portion of the overall program mixes of various coal combustion residues will be developed. Using the data obtained from various analyses, these mixes will be formulated to have the most desirable characteristics for placement in abandoned underground coal mine workings. The mixes will be subject to various tests and analyses to determine their composition and characteristics.

The Test Plan for Residue Characterization also contains the quality assurance/quality control procedures which will be followed to assure the accuracy and scientific validity of the data obtained.

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RESIDUE CHARACTERIZATION STUDIES (Dr. B. Paul, Co-Principal Investigator)

Due to extremely adverse weather conditions, the shut-down of an electrical power plant unit for routine maintenance, and the inability to establish dates suitable to all parties, no samples were obtained from the cooperating electric power generating facilities (Archer Daniel Midland Company, Decatur, Illinois and City Water, Light, and Power Company, Springfield, Illinois) until very late in the quarter. Accordingly, actual laboratory testing of samples and leachate could not begin until after April 1, 1994. The results of laboratory tests will be reported in the next Technical Progress Report.

ENVIRONMENTAL IMPACT ASSESSMENT LABORATORY STUDIES

During the quarter the Inductively Coupled Plasma Atomic Emission Spectrometer (ICP) purchased in December, 1993, was set up and placed in full operation. This included preparation of all the method files necessary to perform the analyses required by the program. The ICP laboratory analyzed approximately 400 samples from other research projects dealing with coal combustion residues, with most of the analyses involving tests identical or very similar to those required by this program. The results meet the quality control requirements for this program, and provided training and experience in the use of the ICP Spectrometer.

Also, the University provided two computers so that data can be stored in the laboratories and transferred from laboratory to another in electronic format as specified in the quality assurance/quality control plan. The computers are operational, with all required software and spreadsheets in place. The spreadsheet forms contain automatic quality control checks that alert the operator of a result that is out of protocol tolerance. The sample labeling system developed for this program was implemented for all other projects.

An Atomic Adsorption (AA) unit was donated to the Department of Mining Engineering, and will accompany the AA and ICP units already in the laboratory. A cold vapor analyzer for the unit was obtained so that high precision analysis can be performed for low mercury concentrations. The cold vapor analyzer and the AA unit have been received and, at the close of the quarter were being set up in the laboratory. The new AA unit will allow one AA unit to be available for dedicated mercury analysis, and the other for graphite furnace and flame photometry work. The availability of dedicated units allows samples to be analyzed and cross-checked quickly by multiple methods without machine set-up delays.

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Although samples of coal combustion residues collected in accord with the protocol of this program were not available during the quarter, samples from the same power plants and boiler units have been analyzed and tested under other projects. These analyses and tests indicate that no major environmental problems should be expected with underground management of coal combustion residues. For example, TCLP tests of Archer Daniel Midland Company (ADM) fly ash from an atmospheric fluidized bed combustion unit involving over 20 elements found that the material had no hazardous characteristics.* There is no reason to believe that samples collected under this program will differ significantly, and the absence of hazardous characteristics should aid in permitting under this program.

In another project ADM fly ash was mixed with coarse coal refuse. Except for trace levels of arsenic and selenium, which were found in individual tests of both coal refuse and the fly ash, the mixture of the two produced a cleaner leachate than either material alone. The arsenic and selenium levels were not higher than would have been the case for either material individually.*

In another experiment, a mixture of fly ash and bottom ash from the City Water, Light, and Power Company (CWLP) Dallman power plant has been leached in open percolation columns for two years, and has not shown any contamination in the leachate.* In this column experiment the combustion ash was leached with groundwater from a field demonstration site, and the groundwater exited the column in a cleaner state than when entering the column. The ash for this experiment came from all three units at the CWLP Dallman plant, rather than the PCC unit No. 3 which will be used in this program. Thus the results of these column experiments cannot be directly transferred to this program; however, similar results may be expected.

Scrubber sludge from the CWLP Dallman Plant has also been tested by ASTM, TCLP, and open column procedures, and found to be one of the cleaner leaching scrubber sludge tested.* It is particularly interesting to note that the leachate is low in boron, probably the most problematic element in other combustion residues. The test backfill at the Forsythe Energy No.5 surface mine, near Carterville, Illinois, used 1,200 tons of the Dallman Plant scrubber sludge. A well was placed directly under the Dallman scrubber sludge fill. Water samples collected from the well on February 25, 1994 show that the only elements that appear to be leaching are

* Unpublished research - Dr. B. Paul - 1994.

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calcium, a trace of molybdenum, and fairly high levels of boron. One of the other scrubber sludge in the fill was mixed with fly ash that, based on individual component testing, is probably responsible for the molybdenum and boron. Either scrubber sludge would be expected to leach

calcium. At this time, it has not been determined whether the water from the sample well originated from rain percolating through the fill or from lateral movement of groundwater. Water levels in other monitoring wells at the site suggest that the fill may have saturated quickly starting at the bottom, and this indicates that the water from the well under the Dallman plant fill came mostly from lateral groundwater movement. If this is true, then the fill is cleaning heavy metals from the groundwater, just as it did in the column experiments. For example, iron and manganese levels in the upstream groundwater average 80 and 15 ppm respectively; in the water under the fill both are in the tenth of a ppm range. There are other indications that minor heavy metals may also be cleaned from the site groundwater.

Although the Forsythe field demonstration differs from the DOE-SIUC Cooperative Agreement Program, the implications for non-adverse or perhaps even favorable impacts from underground placement of FGD by-products is good news.

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PHYSICO-CHEMICAL CHARACTERIZATION OF RESIDUES (Dr. N. Ghafoori, Co-Principal Investigator)

The physico-chemical properties of coal combustion residues were determined through a series of laboratory analyses. Samples of Fluidized Bed Combustion (FBC) fly ash and spent bed residues were obtained from the Archer Daniel Midland Company power plant, and PCC by-products residues were obtained from the City Water, Light, and Power Company Dallman power plant in Springfield, Illinois.

Chemical analyses of all by-products residues were conducted in accordance with ASTM C311. Free lime test (ASTM C25) was used to ascertain the presence of un-reacted lime in raw matrices. Size gradation, including hydrometer test, was conducted using ASTM C33 and D422. A pH analyzer was used to obtain the pH value of the raw materials. Specific gravity and absorption were determined using ASTM C128. Test on organic impurities was conducted using ASTM C40. The remaining tests relevant to the physical properties of the raw materials were carried in accordance with ASTM C311.

Table 1 reports on the chemical properties of the FBC spent bed and FBC fly ash. Both of the by-products residues have low pozzolan oxides. As expected a large quantity of unhydrated calcium oxide and sulfur trioxide were found in the FBC residues, thus, contributing to their high heat of hydration and subsequent volume expansion.

Physical properties of the FBC spent bed are shown in Table 3. The oven-dry (OD) and saturated surface dry specific gravity were 1.92 and 2.19, respectively. Such a value of specific gravity is typical for lightweight aggregates. The difference between the OD-specific gravity and the SSD-specific gravity is quite high and is indicative of the ability of the FBC spent bed to absorb a large amount of water. The actual absorption was calculated at 14.6%. Based on ASTM C40, no organic impurities were detected in the FBC spent bed. Size distribution of the FBC spent bed is shown in Figure 1.

Physical properties of the FBC fly ash are reported in Table 4. Water requirement, 7-day compressive strength, No. 325 sieve fineness, and autoclave expansion were all outside the limits required by ASTM C618. Size gradation of the FBC fly ash is illustrated in Figure 2.

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Table 2 presents the chemical properties of the PCC fly ash and bottom ash. Based on ASTM C618 specifications, these by-product residues are type "F" generated by the burning of Illinois bituminous coal. Tables 5 and 6 report on the physical characteristics of the PCC bottom ash and fly ash, respectively. Size distribution of the PCC fly ash is documented in Figure 2.

Chemical characteristics of the scrubber sludge are shown in Table 2. As expected, the main constituent is dihydrate calcium sulfate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). Its physical properties and size distribution are reported in Table 7 and Figure 2, respectively.

* * * * *

Table 1: Chemical Test Data of FBC Spent Bed and Fly Ash

Chemical Composition	"FBC" Spent Bed	"FBC" Fly Ash	Fly Ash Specifications (ASTM C618)
Silicon Oxide (SiO_2)	9.70	22.10	-----
Aluminum Oxide (Al_2O_3)	3.69	6.80	-----
Iron Oxide (Fe_2O_3)	2.16	6.67	-----
Total ($SiO_2 + Al_2O_3 + Fe_2O_3$)	15.55	35.57	50.0 Minimum, → Class C 70.0 Minimum, → Class F
Sulfur Trioxide (SO_3)	24.42	15.67	50.0 Maximum
Calcium Oxide (CaO)	53.10*	38.70*	Less than 10%, → Class F More than 10%, → Class C
Magnesium Oxide (MgO)	0.88	1.29	-----
Loss on Ignition (LOI)	0.80	5.46	6.0 Maximum
Free Moisture	0.00	0.11	3.0 Maximum
Water of Hydration	2.65	0.71	-----
Total Na_2O	0.16	0.50	-----
Total K_2O	0.39	1.12	-----
Others ($TiO_2 + P_2O_5 + SrO + BaO$)	2.04	0.83	-----
pH	12.00	12.20	-----

* Mostly unhydrated lime

Table 2: Chemical Test Data of PCC Bottom Ash, PCC Fly Ash, and Scrubber Sludge

Chemical Composition	"PCC" Bottom Ash	"PCC" Fly Ash	Scrubber Sludge	Fly Ash Specifications (ASTM C618)
Silicon Oxide (SiO_2)	50.90	55.90	0.45	-----
Aluminum Oxide (Al_2O_3)	13.60	15.40	BDL*	-----
Iron Oxide (Fe_2O_3)	22.20	16.10	BDL*	-----
Total ($SiO_2 + Al_2O_3 + Fe_2O_3$)	86.70	87.40	0.45	50.0 Minimum, → Class C 70.0 Minimum, → Class F
Sulfur Trioxide (SO_3)	0.41	1.15	58.73	50.0 Maximum
Calcium Oxide (CaO)	6.24	5.06	41.00	Less than 10%, → Class F More than 10%, → Class C
Magnesium Oxide (MgO)	0.72	0.78	BDL*	-----
Total Na_2O	1.01	1.48	BDL*	-----
Total K_2O	1.51	1.93	0.02	-----
LOI	1.09	0.58	0.00	6.0 Maximum
Free Lime**	0.07	0.10	0.23	-----
$CaSO_4$ ***	—	—	99.87	-----
$CaSO_3$	—	—	BDL*	-----
$CaCO_3$	—	—	BDL*	-----
pH	10.30	12.26	7.99	-----

* BDL = Below Detection Level

** % of total available lime

*** $CaSO_4$ is in the dihydrate form

— Not tested for

Table 3: Physical Properties of FBC Spent Bed

Fineness Modulus	Specific Gravity (OD)	Specific Gravity (SSD)	Absorption (%)	Organic Impurities
1.80	1.92	2.19	14.60	None

Table 4: Physical Properties of FBC Fly Ash

#325 Sieve Fineness		Specific Gravity	Autoclaved Expansion			Water Requirement		7-day Compressive Strength* (% of Standard Sample)		
Actual	Limit		Unhydrated	Hydrated	Limit			Actual	ASTM	AASHTO
40.2%	Max. 34%	2.61	0.12%	0.00%	0.80%	96.3%	Max. 105.0	61.20%	Min. 75%	Min. 60%

* Standard Sample Has 7-day and 28-day Compressive Strength of 4,567 and 5,647 psi, Respectively.

Table 5: Physical Properties of PCC Bottom Ash

Specific Gravity (OD)	Specific Gravity (SSD)	Absorption (%)	Organic Impurities
1.93	2.00	3.33	None

Table 6: Physical Properties of PCC Fly Ash

#325 Sieve Fineness		Specific Gravity	Autoclaved Expansion		Water Requirement		7-day Compressive Strength*			28-day Compressive Strength*		
Actual	Limit		Actual	Limit			Actual	ASTM	AASHTO	Actual	ASTM	AASHTO
16.70%	Max. 34%	2.36	0.06%	0.80%	97.5%	Max. 105.0	81.8%	Min. 75%	Min. 60%	92.6%	Min. 75%	Min. 60%

Table 7: Physical Properties of Scrubber Sludge

Specific Gravity	Water Requirement		7-day Compressive Strength*			28-day Compressive Strength*		
			Actual	ASTM	AASHTO	Actual	ASTM	AASHTO
2.66	134.7%	Max. 105.0	41.27%	Min. 75%	Min. 60%	44.50%	Min. 75%	Min. 60%

* Repeat as in Table 4

Figure 1: FBC Spent Bed Grading

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IDENTIFICATION AND ASSESSMENT OF HANDLING/TRANSPORTATION SYSTEMS FOR FGD RESIDUES (Dr. H. Sevim, Co-Principal Investigator)

System Identification

Systems that are currently used for handling the two types of FGD materials, dry alkaline material that is typified by fluidized bed combustion (FBC) residue and scrubber residue that has been mechanically or chemically treated to a dryness condition, have been investigated by conducting a literature survey. This was achieved by surveying the periodicals, books, and reports from the computerized library system of the Southern Illinois University (LINKS - Library Information Networks.) A list of publications that contains the most frequently referenced materials in this study for the purpose of materials handling/transportation is given at the end of this section.

In addition to the literature survey, the materials handling/transportation systems of the two collaborating power companies have been studied in detail. These plants are the City Water, Light and Power Company Dallman Power Plant, Springfield, Illinois and Archer Daniel Midland Company power plant, Decatur, Illinois. During the quarter the two power plants were visited to investigate the facilities and get a first hand, on site view of the facilities, particularly the coal combustion residues handling, transportation, and disposal systems. A brief description of these systems is given below.

Dallman Power Station

The fly ash handling system in Dallman Plant is a wet system. The fly ash is mixed with water and pumped through a pipeline to the settling ponds. Currently, the company is considering building a dry storage system so that the fly ash can be marketed.

The scrubber sludge from the drum type vacuum filter, about 85% solids and 15% water by weight, is stacked in the open using a stacker conveyor. Before filtering, the sludge is 55% solids and 45% water. The forced oxidation used in the process produces sulfates that can be filtered to a solid material. Without oxidation, sulfides, instead of sulfates, form and do not allow filtration. The company has recently stopped disposing the sludge into the landfill. Instead, the sludge is loaded into 20-ton rear dump trucks by a front end loader and transported to Granite City, Illinois on the Mississippi River. There, it is loaded into barges and transported to the Gulf of Mexico and then to a port near Houston, Texas. The sludge, which is about 98% gypsum, is delivered to US Gypsum Company and is used to manufacture wall board. City Water, Light, and Power Company only pays for the costs up to and including the loading of the sludge into the barges. This cost is estimated to be at least \$8/ton. In 1990, 65,000 tons of scrubber sludge was produced.

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The Dallman plant engineer in charge of materials handling is of the opinion that the scrubber sledge may create problems due to the change in engineering characteristics of the sludge upon slight compaction. The sludge will not set like concrete, but will pack and stick. It hangs up on the dumper of the trucks and the truck drivers have to use shovels to scrape it off. Problems of this nature are not foreseen with fly ash.

A total of 600,000 tons of coal with 10% ash and 3% sulfur is burned in the scrubbed unit (Dallman Unit 3) which has a generating capacity of 190 MW. The breakdown of ash in the coal is 80% fly ash and 20% bottom ash. This corresponds to an annual production of 48,000 tons of fly ash and 12,000 tons of bottom ash. The transportation of coal into the plant is by trucks. A railroad spur exists in the plant, but is not currently utilized. Reactivating the rail system would require an estimated 2 million dollars.

ARCHER DANIEL MIDLAND COMPANY PLANT (ADM)

The power plant at the ADM complex provides the necessary energy for the chemical processors utilized to produce ethanol and natural enzymes and grow lettuce in the greenhouse. The power plant has six fluidized bed combustion (FBC) type boilers with a total capacity of 260 MW of electricity. An additional 120 MW is purchased from outside. Construction for the seventh boiler with a capacity of 74 MW will start soon increasing the power generating capacity to 334 MW. ADM will continue purchasing 120 MW from the utilities after the seventh boiler is completed.

Approximately 1.5 million tons of coal and more than two (2) million discarded vehicle tires are burned annually at the plant, producing about 1,500 tons of ash daily. Of the ash produced, about 75-80 percent is fly ash (minus 300 mesh) and 20-25 percent is bottom ash (small yellow balls that are about 1/16 inches in diameter). The plant utilizes about 1,500 tons daily of Aglime (agricultural quality limestone). ADM did not disclose the cost of ash disposal, but 9 cents a ton-mile was expressed as a reasonable figure for transportation cost.

The fly ash recovered at the baghouse is transported pneumatically to the fly ash storage bin by a negative pneumatic system. A similar system is used for the bottom ash. The ash is backhauled to the mine using the same type of 25-ton trucks that are used to haul the coal and the limestone into the plant. The trucks are covered by tarps to alleviate fugitive dust. The tarp is covered and uncovered by a simple mechanism of sprockets. It is necessary to uncover the tarp to load the coal into the truck at the mine. The tarp is put back on after the coal is loaded. However, there is no need to remove the tarp to unload the coal. The truck backs into the dumping area and the back wheels are locked. Then, the front side of the bed is raised by a

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The transport methods that can be used for the two types of FGD materials are:

- Belt conveyors
- Trucks
- Rail
- Barge
- Pipeline (Slurry transport)
- Pneumatic conveyors
- Aerial Trams

System Assessment

Fugitive dust emissions, high initial temperature of some residue streams, self-hardening upon reaction with water, and temperature increases due to exothermic hydration reactions are some of the operational concerns associated with the transfer or transport of FBC waste in the open. In the following, a technical assessment of the transport methods is given:

Belt conveyors: The shortest length possible for a belt conveyor is approximately six feet. This is the minimum distance required to provide both a tail and head pulley. At the upper end the length of the belt is limited to the maximum tension allowable in the belt material. Lengths of 5 to 6 miles are not unusual but over 7 miles is rare. Belt conveyors are widely used for transporting the dry scrubber sludge, especially between the filters and the temporary storage piles. They can be used for longer distances, too. Fugitive dust formation, hardening, and high temperatures are prohibitive factors for the usage of belt conveyors in the transport of FBC residues. Belt conveyors are usually limited to conveying material with particle size greater than 1/8 inch. Dust problems tend to occur with finer particles at normal belt operating speeds of 500-600 feet/minute. Therefore, conveyor belts cannot be used to transport FBC residues without extra precautions, such as, conditioning with water, reduced belt speed, or enclosing the belt. In addition, the residues need to be cooled below 300.F before being loaded onto a conveyor belt. Belt conveyor capacities typically range from 8,000 pounds/hour to 10,000 tons/hour. Rates are determined by available belt widths and speed limitations. Belt conveyors are limited to 30 percent to 35 percent grades.

Trucks: Trucking is the most common mode of transporting the scrubber sludge and FBC ash today, mainly due to the flexibility of the operation. Dump trucks are the most widely used type of trucks in transporting scrubber sludge. At FBC facilities, dump trucks will probably be most feasible when waste conditioning (with water) is performed before transport. Using dump trucks may be risky, even if the FBC residues are conditioned. Seepage of rain water during transport or coal loading may cause overheating as well as hardening of the residue. Nondestructive removal of hardened residue may not be possible. The use of pneumatic trucks

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will allow waste conditioning to be accomplished at the disposal site rather than the plant. Since pneumatic backfilling is considered for the FBC residues in this project, pneumatic trucks would be ideal from the technical point of view. Both pneumatic and dump trucks are utilized in ADM's Decatur plant. Trucking can accommodate changes in the quantity of the material produced and the material can easily be carried to the injection site without requiring a temporary storage space at the mine site. The cost of trucking is very sensitive to wages and is not expected to decrease in the future. Dust, noise, and traffic congestion that may be caused may lead to opposition from the residents along the public roads used. Generally, the practical range for trucks starts at two miles. Truck transportation will rarely exceed 100 miles and the most likely economic upper limit is about 50 miles. Trucks are limited to grades less than 15 percent and preferably less than 10 percent.

Rail: Side-dumping cars have been effectively used at the Martin Lake Plant of the Texas Utilities Generating company to transport FGD by-products. Bottom dumping from hopper cars and rotary dumping are deemed possible but not proven. It is possible that the residue might bridge or arch and make it difficult to unload bottom-dump hopper cars. No specially designed sludge cars exist. Rail haulage requires well planned and continuous operation, as idle rail cars waiting for material may be very costly. Pneumatic rail cars have not been used for ash transport so far, despite the fact that they are ideal for the transportation of FBC ash from the technical point of view. However, the economics of such an operation is not very promising due to the fact that modifications would be necessary to accommodate coal haulage and pneumatic rail cars and the systems to load and unload them cost more. Railroad hauling can be done on either commercial or private lines. Commercial rail haulage is not competitive for distances less than 50 miles. Haulage on private lines may be viable at shorter distances. Grade for railroads rarely exceeds 1 percent.

Barge: Barge transport is viable on navigable waterways. Loading and unloading costs are quite significant and are justified only for distances in excess of 100 miles. The only known barge transportation of scrubber sludge in Illinois is from the Dallman power station as discussed above.

Pipeline: Pipelines are favored for wet disposal in conventional type of disposal systems. However, due to the high density of the slurry considered in this project, long distance transport of the sludge will not be technically and economically feasible. Nevertheless, this mode of transportation may be feasible to deliver the slurry from the mine site to the injection site. There is no slope limitation for slurry transport.

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Pneumatic conveyors: Essentially, there is no lower limit on particle size for pneumatic conveying. Small particles less than 1 μm , however, require additional power to move and difficult to filter out of the air. Particles larger than 25 μm can be removed with 100 percent efficiency using simple bag filters. The upper limit for pneumatic conveyor is one inch. Limits, however, vary depending on the density of the particles. Theoretically, there is no lower limit on the distance for conveying materials pneumatically. They are limited to 2000 feet without booster stations. This distance can be increased almost indefinitely using booster stations, but they are not economically efficient at distances greater than 7500 feet. Pneumatic conveyors are widely used for transferring FBC residues from collection devices to storage. However, there are no FBC generating stations presently using or planning to use pneumatic conveyors to transport waste to disposal sites over longer distances. One exception is the Long Island Lighting Company, which proposed to use a pneumatic pipeline to transport fly ash approximately 1.5 miles to their Port Jefferson Station. Pneumatic conveyor capacities typically range from 700 pounds/hour to 200 tons/hour. Economics tend to favor mechanical conveying at high rates. There is no slope limitation for pneumatic conveying. The material can be transported vertically, if desired.

Aerial trams: Aerial trams are not currently used by existing FBC or conventional type power stations. They can be cost competitive with belt conveyors and trucks in situations where they (a) are installed in a straight line, (b) cover a distance of 0.5 to 10 miles, (c) have a gradient of more than 15%, and/or (d) handle capacities approaching 1 million tons.

Their capital costs are about the same as conveyor belts. However, they can have lower overall costs, because operating and maintenance costs are lower. The same concerns are valid for transporting the FBC or other types residues without covering the tramcars. Aerial tram capacities typically range from 25 tons/hour to 1200 tons/hour and are most effective in areas of steep terrain. No known aerial trams operate in Illinois.

SYSTEMS FOR FIELD DEMONSTRATION

The choice of the materials handling/transportation system for residue disposal at existing facilities is site specific. The initial assessment has indicated that the economic feasibility of the mode of transportation of the FGD materials to the mine site from an existing plant depends on, among others, the following factors :

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- (i) Dusting, corrosion, abrasion, sticking, hardening, exothermic heat generation, and etc. ,
- (ii) The particle size consist of the material,
- (iii) The volume of materials,
- (iv) The transportation distance,
- (v) The profile of the haulage route (grades),
- (vi) Whether the material can be backhauled or not,
- (vii) Whether contractual haulage is possible or not,
- (viii) The presence or absence of waterway facilities,
- (ix) The presence or absence of railway facilities,
- (x) The existing handling facilities at the plant and the mine site, and
- (xi) The remaining life of the operation.

An in-depth analysis of the concept of underground injection of FGD materials indicated that a temporary storage facility at the mine site will be required. Interruption in injection may occur due to unforeseen reasons as well as planned breaks. However, the residues generation is continuous and the residues will keep coming to the mine site according to a mutually signed contract. The temporary storage at the mine site will prevent the costly delays of unloading the material. In the case of the use of SEEC, Inc.'s CICs, the material may be stored inside the CICs at the mine site. It has been thought that the CICs carrying FBC residues may directly be injected into the holes by means of an inverter. However, the SEEC representatives have indicated that the high cost of CICs would not allow such a system. Nevertheless, this alternative is worth evaluating. Otherwise, secondary handling/transportation can be done by means of a storage facility and any of the transportation systems mentioned above. The fact that the distance of the mine site storage facility and the injection hole will be short throughout the life of the operation should be born in mind in selecting the secondary transport system.

Selection of System for the Case Studies

The preliminary studies have indicated that truck and rail haulage are the most suitable modes of transporting the FGD residues from the plant to the mine site. The investigators are currently conducting economical analysis of these systems as well as the use of SEEC, Inc.'s CICs. To facilitate a thorough evaluation, a case study is being generated for the disposal of scrubber sludge using the Peabody #10 mine as the injection site. This case study and a similar one for FBC residues will be presented in a specific topical report.

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RESIDUE HANDLING AND TRANSPORT -- SEEC, INC. (Dr. J. Carpenter)

SEEC, Inc., of Marietta, Pennsylvania, is a cooperating organization concerned with the handling and transport of coal combustion residues, especially in the handling and transporting of residues from the electric generating power plant to the underground coal mine disposal site. SEEC has developed a unique system for transportation residues, and a part of the overall program is to demonstrate the system under actual operating conditions.

The SEEC system uses a collapsible container that can be transported by rail, by truck, or by barge. Originally SEEC was planning to use a container provided by Amfuel Corporation. However, beginning in the fall of 1993, SEEC conducted demonstration tests of these containers, such tests being concluded in January, 1994. The results of the tests showed that the SEEC system was viable, but demonstrated several serious shortcomings of the Amfuel container. Among these were the small size of the container, the small size of filling and venting ports, concerns about its strength and durability, concerns about its stability during transport and handling, and the concerns of the railroad about carrying a container that did not fit well in their cars. Because of these concerns, SEEC, in cooperation with several partners, began work to design a new container specifically to meet the needs of residues handling and transport. The new container is known as the "Collapsible Intermodal Container" or CIC.

SEEC's strategy for the CIC decision was to assemble several experts from key industries into a design team. Included on the team were representatives from SEEC, Engineered Fabrics Corporation, M-Jack Products, Inc. and SIMS Professional Engineers.

During the quarter a conceptual CIC design was completed and a small scale test using a model CIC and a rail car was conducted. The CIC is designed to efficiently and economically transport dry flowable materials, such as fly ash, in hopper rail cars, river barges, and flatbed trucks. The container is flexible enough to conform to the centersill and hopper bays of rail cars, and durable enough to withstand the rigors of use in the coal and railroad industries. One container fits each bay of a 3 or 4 bay hopper car. The CIC dimensions are 10 feet high and 9 feet 2 inches in diameter. (See Figure 3). The lifting apparatus is cast iron, and includes a hook that will lay on the top chord of the rail car. A 19 inch diameter filling and emptying port is built into the CIC, as are two additional ports, each six inches in diameter, for venting, vacuum, cleaning, and possible other uses.

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Also, SEEC is working with Mi-Jack Products to identify the most economical and efficient cranes to use for transferring filled CIC's to and from rail cars. Mi-Jack has made substantial progress on spreader bar design as well as the development of computer animation of the technology. It is expected that the spreader bar design and animation work will be completed during the second quarter of 1994.

Finally, SEEC has begun the development of a safety and training manual for use with the overall CIC technology. At the close of the quarter the manual was in the early draft stage. The manual will be reviewed by the Program Director and Program Manager upon completion of a final draft, and will be made part of the safety and health aspects of the overall program.

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Figure 3. -- Collapsible Intermodel Container

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PROGRAM MANAGEMENT

During the quarter all sub-accounts were established and the budgets for all Co-Principal Investigator's were finalized. Even though sub-accounts and budgets were put in place, fiscal authority for all accounts remains with the Program Director and Program Manager. Also, a financial tracking program was installed in the office of the Program Manager, allowing that office to track all program expenditures and maintain account balances. This program will not be used for formal accounting purposes, but rather as a management and control tool for administrative purposes. Formal accounting will be done through the University Office of General Accounting.

The Program Manager initiated a monthly News Letter, beginning January 1, 1994. The News Letter is a mechanism to keep all cooperating organizations and others interested in the program informed in a timely manner of significant program developments.

The Midwestern coal and electric utility industries, as well as State, University, and local officials, have expressed a great deal of interest in the cooperative program. In order to provide a readily available source of information for such inquiries, the Program Manager prepared a brief brochure describing the significant portions of the overall program. The brochure is designed so that it can be mailed in a standard business envelope. A number of brochures have been distributed, and have received favorable comment.

The Program Manager planned to attend the conference, "High Sulfur Combustion Residues Management: Current Issues and Practices", to be held in Springfield, Illinois, April 5-7, 1994. The conference will bring together researchers, engineers, and planners, mine operators, electric utility officials, environmental scientists, and State and Federal agency personnel to discuss current practices and problems associated with the management of high sulfur coal combustion residues. Co-Sponsors of the conference are Southern Illinois University at Carbondale, the Illinois Clean Coal Institute, the Illinois Department of Energy and Natural Resources, the Illinois Coal Association, and the U.S. Department of Energy. Mr. Douglas Uthus, Director, Coal Combustion and Control Technology, U.S. Department of Energy, will give the principal banquet address.

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NEXT QUARTER

As all residue samples have been collected, residues characterization studies can go forward at an accelerated pace. Solid data on residues and leachates composition and characteristics should be available by the end of the next quarter, i.e., by June 30, 1994. Also, in order to more rapidly determine the physical properties of residues, a small curing chamber will be constructed at the SIUC Carterville facility. The chamber will simulate the expected underground conditions of about 100° F. temperature and 90 - 100 percent relative humidity. Curing samples under these conditions should not only accelerate the curing time, but give results that more accurately reflect the conditions to be encountered in the actual disposal in abandoned underground mine workings.

A meeting and inspection visit to the underground disposal area will be held sometime about mid-May. The visit will determine the location of monitoring wells to be drilled as well as the location of subsidence monitoring stations.

Plans for the demonstration of the SEEC, Inc. Collapsible Intermodal Container (CIC) will be finalized during the quarter, with the expectation that the demonstration can be held in July or August. Also, the safety and health manual for the handling of the SEEC CIC will be completed and made a part of the safety and health plans and procedures of the overall program.

In the area of handling and transportation of coal combustion residues, work will proceed on the case studies and the computer modelling of various modes of residue handling, transportation, and disposal. The case studies will be reported in special topical reports.

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