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Management of Dry Flue Gas Desulfurization By-Products in Underground Mines

Quarterly Report January - March 1995

Y. Chugh
D. Dutta
S. Esling
N. Ghafoori
B. Paul
H. Sevim
E. Thomasson

April 1995

Work Performed Under Contract No.: DE-FC21-93MC30252

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

By
Southern Illinois University
at Carbondale
Carbondale, Illinois

MASTER

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Morgantown Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880

By
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at Carbondale
Department of Mining Engineering
Carbondale, Illinois

April 1995

**MANAGEMENT OF DRY FLUE GAS DESULFURIZATION
BY-PRODUCTS IN UNDERGROUND MINES**

Technical Progress Report -- January 1 - March 31, 1995

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**MANAGEMENT OF DRY FLUE GAS DESULFURIZATION
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SECTION I

INTRODUCTION AND SUMMARY

**MANAGEMENT OF DRY FLUE GAS DESULFURIZATION
BY-PRODUCTS IN UNDERGROUND MINES**

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INTRODUCTION AND SUMMARY

On September 30, 1993, the U.S. Department of Energy, Morgantown Energy Technology Center and Southern Illinois University at Carbondale (SIUC) entered into a cooperative research agreement entitled "Management of Dry Flue Gas Desulfurization By-Products in Underground Mines" (DE-FC21-93MC 30252). Under the agreement Southern Illinois University at Carbondale will develop and demonstrate several technologies for the placement of coal combustion residues in abandoned coal mines, and will assess the environmental impact of such underground residues placement.

Previous quarterly Technical Progress Reports have set forth the specific objectives of the program, as well as the management plan and the test plan for the overall program, and a discussion of these will not be repeated here. Rather, this report will set forth the technical progress made during the period January 1 through March 31, 1995.

The demonstration of the SEEC, Inc. technology for the transporting of coal combustion residues was completed with the unloading and final disposition of the three Collapsible Intermodal Containers (CIC). The loading and transport by rail of the three CIC's was quite successful; however some difficulties were encountered in the unloading of the containers. A full topical report on the entire SEEC demonstration is being prepared. As a result of the demonstration some modifications of the SEEC concept may be undertaken.

Also during the quarter the location of the injection wells at the Peabody No. 10 mine demonstration site were selected. Peabody Coal Company has developed the specifications for the wells and sought bids for the actual drilling. It is expected that the wells will be drilled early in May.

The apparatus for the Rapid Aging Testing of both the pneumatic placement mixture and the hydraulic placement mixture was assembled during the quarter. The actual Rapid Aging Tests will begin early in the next quarter. These tests will continue for more than a year.

Work under the Materials Handling and System Economics area continued, particularly in refining the systems configuration in light of the SEEC demonstration and in the economic evaluation of various systems using refined cost data. Short-term characterization testing of various mixes was essentially completed, and emphasis shifted to long term testing.

SECTION II

ENVIRONMENTAL CHARACTERIZATION

DR. BRADLEY PAUL

CO-PRINCIPAL INVESTIGATOR

MANAGEMENT OF DRY FLUE GAS DESULFURIZATION BY-PRODUCTS IN UNDERGROUND MINES

Technical Progress Report – January 1 - March 31, 1995

ENVIRONMENTAL CHARACTERIZATION

BACKGROUND

Environmental characterization is a service and assurance activity. The main purpose of which is to ensure that all the mixes considered for underground placement do not have any leaching characteristics that could adversely affect the groundwater quality should the groundwater ever come into contact with the mixes placed underground. Environmental characterization is also expected to determine the long term permeability changes and material breakdown trends that could impact long term leachate volumes and characteristics.

Another characterization activity that runs parallel with the environmental characterization program is the determination of mixes that have the required strength and rigidity properties to provide the necessary restraint against surface subsidence. The purpose of this activity also includes the durability or the long term sustenance of the designed strength and rigidity properties.

STATUS OF THE PROJECT

The results of the preliminary mix screening have been reported in previous reports. Also, the Technical Progress Report for the period October 1 - December 31, 1994 discussed in detail the protocol for the Rapid Aging Testing, including a description of the Rapid Aging Apparatus. This test emphasizes the changes in permeability and mix mineralogy that may impact the leachate volume and character. During this quarter the apparatus was assembled and, at the end of the quarter for operation. Figure 1 is a photograph of the apparatus.

Based on the previous characterization studies, two mixes have been identified for rapid aging testing. The pneumatic mix is 80% FBC fly ash and 20% FBC spent bed. The hydraulic mix consists of 55% scrubber sludge, 40% F-type fly ash, and 5% lime or lime waste. The rapid aging tests of the mixes will commence early in the next quarter.

RESEARCH PROBLEMS AND PLANS

Building the apparatus meant acquiring a large number of small components from different vendors. This created some accounting problems as different commodities had to be ordered under different purchase orders to keep in line with the university's accounting system. However, all the ordered commodities have been received and all the accounting problems have been overcome. Specific problems of bottlenecks with regard to the rapid aging tests are foreseen at this time.

SECTION III

MATERIALS HANDLING & SYSTEM ECONOMICS

DR. H. SEVIM

CO-PRINCIPAL INVESTIGATOR



MANAGEMENT OF DRY FLUE GAS DESULFURIZATION BY-PRODUCTS IN UNDERGROUND MINES

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MATERIAL HANDLING AND SYSTEM ECONOMICS

OBJECTIVES

The objectives of the material handling research are: 1) To identify the systems that are technically, economically, and environmentally feasible in handling and transporting the coal combustion residues from the power plant to the injection site, and 2) To build a material handling design model using the features of the identified systems, and incorporate this model into the economic evaluation model. The objectives of the system economics research are: 1) To conduct an economic analysis of the selected materials handling and underground residue placement systems, and 2) To develop a generalized "Economic Evaluation" model that can be used in evaluating various types of material handling and placement systems for different distances and capacities.

SUMMARY OF PAST ACTIVITIES

In the past, many alternatives have been examined, out of which three were identified for an in depth study. These alternatives were:

1. Pneumatic trucks (PT)
2. Pressure differential rail cars (PD-car)
3. Collapsible intermodal containers (CIC)

In the past quarter, these transportation alternatives were economically evaluated using the "equipment leasing" option. All three alternatives were evaluated for 9 cases formed by the combination of transportation distances of 30, 100, and 200 miles and annual capacities of 100,000, 200,000, and 300,000 tons. The outcomes were compared with those obtained using "equipment purchasing" option. It was observed that the prices per ton of material transported were lower in the "equipment leasing" option compared to the "equipment purchase option", for all nine cases. However, the amount of price reduction from equipment purchasing option to equipment leasing option differed substantially from one alternative to another. The average reduction over a range of 30 to 200-mile distance is given in Table 1 for all three alternatives at three different capacities. For example, the \$6.80 reduction reported for PD-car alternative at 100,000-ton annual capacity is the average reduction for 30, 100, and 200 miles of transportation distance. As seen in this table, the average price reductions for the PD alternative are the most pronounced of all three. The average reductions for the PT alternative were the smallest.

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MATERIAL HANDLING AND SYSTEM ECONOMICS (Continued)

Table 1. Average Price Reduction in Residue Transportation Alternatives When Leasing Option is Selected Over Purchasing Option (\$/ton)

Production (tons/year)	Pneumatic Truck	PD-car	CIC
100,000	0.90	6.80	3.24
200,000	0.90	2.94	1.62
300,000	0.66	1.65	1.08

The above mentioned economic evaluations excluded the operating and capital costs of the fly ash filling station at the power plant site, the emptying systems at the mine site, and the residue placement system. These components were excluded because of the lack of engineering and cost data.

ACTIVITIES DURING THE QUARTER OF JANUARY 1 - MARCH 31, 1995

In this quarter, one (1) fly ash handling and disposal facility and three (3) bulk material handling equipment manufacturers were visited in order to obtain engineering and cost data for fly ash filling and emptying systems. This information will be used to complete the missing segments of the engineering and economic analysis model. Below, a brief description of the disposal site and the specialization of manufacturers are given.

1) **Ash disposal site in Blacksville, West Virginia:** This site is operated by Greenon Coal Co. which is a sister company of Consol. The facility is an excellent match to the type of system and operating scenarios that has been developed for the PD-car alternative in our research. The fly ash is loaded into 100-ton PD cars at a co-generation plant in New Jersey. In each trip, about 10 to 15 PD cars are attached to the unit train returning empty to West Virginia coal mines. At the Greenon facility, the PD cars are pushed to the emptying station, two at a time, by a track mobile. At the station, the PD-car is hooked up to two sets of a pair of pressurized air lines; a 5 inch line to pressurize the car at about 13-15 psi, and an 8 inch line to provide the drag to transport the ash about 60 feet horizontally and 90 feet vertically to the top of a 240-ton

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MATERIAL HANDLING AND SYSTEM ECONOMICS (Continued)

silo. This silo is equipped with a baghouse to prevent fugitive dust. It takes about 45 minutes to empty a 100-ton PD-car. From the silo, the fly ash is loaded into a 30-ton dump truck which delivers the load to the surface disposal area. To prevent fugitive dust, fly ash is treated with water in a pugmill before it is loaded in to the truck (about 52 gallons of water is used for every ton of ash). At this operation, approximately 70,000 tons of fly ash was handled and disposed of during 1994.

2) **Drum Industries Inc., Louisville, Kentucky:** This company specializes in designing and manufacturing blowers that can deliver up to 14 PSIG single stage or 50 PSIG multistage, with ratings from 4 cfm to 8000 cfm. The blowers used in pneumatic trucks are approximately 1000 cfm capacity. For a stationary operation, such as the one in Greenon facility, a 3000 to 4000 cfm blower might be necessary. Such a blower would cost approximately \$20,000 to \$25,000.

3) **Wilson Manufacturing and Design Inc., Cecilia, Kentucky:** This company specializes in designing and manufacturing "permanent undertrack direct rail-to-truck transfer systems" and "portable direct rail-to-truck transfer equipment." Both systems may be incorporated into fly ash handling and transfer system configurations that we may want to evaluate in the next quarter. Especially, the portable transfer equipment which is an articulated loader-conveyor system might become handy if grain cars are used in the transportation of fly ash. The capacity of the unit may range from 50 tph to 150 tph depending on the type of material conveyed. Such a unit would cost approximately \$90,000. This company also specializes in designing and constructing complete bulk powder storage terminals that can be fed from undertrack bins.

4) **Walton/Stout, Inc., Lithonia, Georgia:** This company specializes in designing and manufacturing pneumatic conveying systems. The scope of our project was presented to company engineers and chief operating officer at their headquarters in Lithonia. A request was made to them to assist us in equipment sizing and costing of the fly ash filling and emptying systems. The request was well received. It was agreed that a detailed description of the information requested should be sent to the company so that they can estimate the time necessary to put the information together. The description is currently being written.

MANAGEMENT OF DRY FLUE GAS DESULFURIZATION BY-PRODUCTS IN UNDERGROUND MINES

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MATERIAL HANDLING AND SYSTEM ECONOMICS (Continued)

Another activity performed during the quarter was the writing of the first draft of the descriptions of line items in the spread sheets used in economic evaluations. Samples of these spread sheets were given in the previous reports. Each line item is either a value entry which is based on engineering computations or a simple data entry. In the newly prepared document, the source of the data entry, or the assumptions and steps of the engineering computations, are given in detail so that the reader can verify and understand the logic of the spread sheets developed for the economic evaluation of all the alternatives.

PLANS FOR THE NEXT QUARTER

In the next quarter, the information obtained from Walton/Stout and other manufacturers and engineering companies will be incorporated into the engineering and economic evaluation model. Also, it is expected that the engineering and cost data for injection systems will be available from the investigators in charge of the development of these systems. With the addition of all these information, the evaluation model will be complete. The three transportation alternatives will be re-evaluated using the refined data and updated model. The possibility of using grain cars to transport the fly ash will also be investigated in conjunction with the transfer systems of the Wilson Manufacturing and Design Inc.

Also in the next quarter, a window version of the computer model is planned to be developed. The window version will bring menus to the screen to facilitate and simplify the design and the evaluation of different transportation alternatives for varying distances and capacities.

SECTION IV

**ENVIRONMENTAL ASSESSMENT
AND GEOTECHNICAL STABILITY**

DR. S. ESLING

CO-PRINCIPAL INVESTIGATOR

**MANAGEMENT OF DRY FLUE GAS DESULFURIZATION
BY-PRODUCTS IN UNDERGROUND MINES**

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**ENVIRONMENTAL ASSESSMENT AND GEOTECHNICAL STABILITY
AND SUBSIDENCE IMPACTS**

Drilling Plans

Drilling was again delayed until late May or early June, 1995. Technical difficulties in selecting target panels was the main reason for this latest delay. The packer for conducting hydrologic testing has been ordered and the Illinois State Geological Survey (ISGS) has developed a working document for conducting packer and slug tests at the site.

Data Acquisition Software

To effectively use their time this past quarter, the Environmental Assessment Team prepared the software for data acquisition in the field, and in particular the programs for taking vibrating wire transducer readings in the monitoring wells and processing these readings into hydraulic head. Four programs are included in an appendix to this report entitled Unit 1, Unit 2, Loot, and Pillage. The function of each of these programs is summarized below:

Unit 1:

This program controls a CR10 data logger. The code instructs the CR10 to take pressure and temperature readings from four vibrating wire transducers at one hour intervals. Four readings of temperature and pressure from each transducer are taken in succession every hour and averaged prior to storage. One of the vibrating wire transducers will monitor atmospheric pressure at the site. The other three will be in groundwater monitoring wells.

Unit 2

This program also controls a CR10 data logger and readings are taken as described above for Unit 1. Three of the four vibrating wire transducers will be installed in groundwater monitoring wells. The fourth transducer will monitor head in the panel targeted for hydraulic injection.

Loot

This program takes the raw file in printer format and splits the different instruments into separate files within a folder labeled by the retrieval date. The program converts day and hour data from the data logger into a decimal day.

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**ENVIRONMENTAL ASSESSMENT AND GEOTECHNICAL STABILITY
AND SUBSIDENCE IMPACTS (CONTINUED)**

Pillage

This program converts raw data on temperature and pressure collected from the vibrating wire transducers into pressure in centimeters of water. Data are also corrected relative to atmospheric pressures. Pillage only reads files that have first been processed with the program Loot. The program converts the data for the vibrating wire transducers into a two column format (with one column holding time and the other pressure) that can be read by a graphics program.

The programs described above have had some debugging, but detailed analysis requires installation of the CR10 units and transducers in the field.

Program Unit 1

Vibrating Wire Transducers for the atmospheric pressure and three monitoring wells;

Allocate 17 for input memory

Labels:

- 2: vibrating wire transducer (vwt) readings
 - 1: atmosphere
 - 2: well 2
 - 3: Well 1
 - 4: Well 3

Short term measurement from atmospheric pressure vibrating wire transducer.

*1

120

Take vwt measurement

Set counter for loop at 0

P30

0

0

25 (counter 1 is stored in location 25)

Loop to take four measurements from the vwt

P87

00

4

Increment counter

P32

25

Take temperature measurement from atmospheric vwt

P4

1

15

1 (in channel 1H) **HOOK-UP**

1 (excitation channel 1E) **HOOK-UP**

1

2500

1 (memory location 1)

0.001

0

Take pressure measurements from atmospheric vwt

P28

1

2 (in channel 1L) **HOOK-UP**

1 (excitation channel 1E) **HOOK-UP**

26

41

500

500

5 (memory location 5)

0.5 (actual multiplier should be 1, double values in memory, done for resolution purposes)

0

Average temperature and vwt measurements

```
P89      25
         i
         4
         10
P80      3
         1 (input location for results of the averaging)
P71      1 (average 1 measurement and put it in locations 1)
         1
P80      3
         5 (input location for results of the averaging)
P71      1 (average 1 measurements and put it in location 5)
         5
P95 End loop
P86 Set output flag low
         20
```

At this point memory locations 1 and 5 contain the average temperature and pressure for vwt 1, respectively.

Check to see if pressure value changes within 0.002 with a loop
Subtract old and new value. Old value is in location 9.

```
P35      5
         9
         13 (subtract and put the result in 13)
Take absolute value of the result which is in location 13
P43      13
         13
Check Tolerance
P89      13
         3
         .002
         30
```

```
P86 Set output flag high
         10
```

Output this value along with a label, the temperature, and the time.

```
Set label
P80      1
         2 (vwt measurement array label)
P30      1
         0
         26 (location 26 has the value 1)
P70      1
         2 (label for vwt)
```

```

P70      1
         1
P70   1
         5
P77      110
P31 Move new value to old value location
         5
         9
P95 End if
Set the output flag low
P86      20
End of the program for atmospheric vwt

```

Long term measurement from vibrating wire transducers.
Locations 1, 5, 9, 13 are used

```

*2
3600
Take vwt measurements
Set counter for loop at 0
P30      0
         0
         27. (counter 3 is stored in location 27)
Loop to take four measurements from each vwt
P87      0
         4
Increment counter
P32      27
Take Temperature Measurement from 3 well vwts
P4       3
         15
         3 (in channel 2H, 2L, 3H)   HOOK-UP
         1 (excitation channel 1E)  HOOK-UP
         1
         2500
         5 (memory locations 2 through 4)
         0.001
         0

```

Take pressure measurements from atmospheric and well vwt

P28

3

6 (in channel 3L, 4H, 4L) **HOOK-UP**

1 (excitation channel 1E) **HOOK-UP**

26

41

500

500

6 (memory locations 6 through 8)

0.5 (actual multiplier should be 1, double values in memory, done for resolution purposes)

0

Average temperature and vwt measurements

P89

27

1

4

10

P80

3

2 (input location for results of the averaging)

P71

2 (average temperature measurements and put them in locations 2, 3, 4)

2

P80

3

6 (input location for results of the averaging)

P71

2 (average pressure measurements and put them in locations 6, 7, 8)

6

P95 End loop

P86 Set output flag low

20

At this point memory locations 2, 3, 4 contain the average temperature for vwt 2 through 4 and memory locations 6, 7, 8 contain the average vwt measurements for vwt 2 through 4.

Check to see if pressure values change within 0.002 with a loop for vwt 2 through 4

Set counter to 1

P30

1

0

28

Start loop

P87

0

3

Increment counter

P32

28 (counter now has the value 2)

Subtract old and new values. Old values are in locations 10,11,12.

P35

6--

10--

14--(subtract locations and put the result in 14,15,16)

Take absolute value of the results which are in locations 14, 15, 16

P43

14--

~~14~~

Check Tolerance

P89

14--

3

.002

30

P86 Set output flag high

10

Output this value along with a label, the temperature, and the time.

P80

1

2 (vwt measurement array label)

P70

1

28 (label for vwt)

P70

1

2--

P70

1

6--

P77

110

P31 Move new value to old value location

6--

10--

P95 End if

Set the output flag low

P86

20

P95 End loop

End of the Program for vwt

P10

17 (battery voltage)

Program Unit 2

Vibrating Wire Transducers for four monitoring wells

Allocate 27 for input memory

Labels:

2: vibrating wire transducer (vwt) readings (5-8)

Available memory: 29,902 spaces

Long term measurement (vwts in wells)

*1

3600 seconds

Set counter for loop at 0

P30

0

0

25 (counter 1 is stored in location 25)

Loop to take four measurements from each vwt

P87

0

4

Increment counter

P32

25

Take Temperature Measurement from vwts

P4

4

15

1 (in channel 1H, 1L, 2H, 2L)

HOOK-UP

1 (excitation channel 1E)

HOOK-UP

1

2500

1 (memory locations 1,2,3,4)

0.001

0

Take pressure measurements from vwts

P28

4

5 (in channel 3H, 3L, 4H, 4L)

HOOK-UP

1 (excitation channel 1E)

HOOK-UP

26

41

500

500

5 (memory locations 5,6,7,8)

0.5

0

Average temperature and vwt measurements

P89

25

1

4

```

P80 10
      3
      1 (input location for results of the averaging)
P71 8 (average 8 measurements and put them in locations 1-8)
      1
P86 20
P95 End loop

```

At this point memory locations 1 through 4 contain the average temperature for vwt 5 through 8 and memory locations 5 through 8 contain the average vwt measurements for vwt 5 through 8. Compare the new values to the old values

Check to see if values change within 0.002 with a loop for all vwts
Set counter to 0

```

P30 0
      0
      26 (location of the second counter)
P87 0
      4

```

Increment counter

```

P32 26

```

Subtract old and new values. Old values are in locations 9,10,11,12.

```

P35 5--
      9--
      13--(subtract locations 5 and 9 and put the result in 13)

```

Take absolute value of the results which are in locations 13,14,15,16.

```

P43 13--
      13--

```

Check Tolerance

```

P89 13--
      3
      .002
      30

```

```

P86 10

```

Output value along with a label, the temperature, and the time.

```

P80 1
      2 (lysimeter vwt measurement array label)
P70 1

```

```

      26
P70 1
      1-- (temperature)

```

P70
1
5-- (vwt measurement)
P77
110
P31 Move command
5--
9--
P95 End if
Set the output flag low
P86
20
P95 (end loop)
End of the Program for vwt
Take battery voltage
P10
27

Program Loot;

{This program takes the raw file dumped from the CR10 and splits the different instruments into separate files within a folder labeled by the retrieval date. The program also converts day and hour data from the data logger into a decimal day.}

uses sane;

var

results, time_equation, vwt1_equation, vwt_equation,
subtraction, spacer, string_year: string;

temporary: decstr;

infile1, outfile1, outfile2, outfile3, outfile4, outfile5, outfile6,
outfile7, outfile8, outfile9, outfile10, outfile11, outfile12:text;

value, temperature, pressure, day, hour, level, correction, correction1,
correction2, correction3, realid: extended;

id, id2, n, i, year: longint;

tab, digit: char;

ying, integral, comma, bogus, wampus, legit: boolean;

procedure assign_vwt;

begin

 case n of

 1: temperature:=value;

 2: pressure:=value;

 3: begin

 day:=value;

 case id2 of

 1, 2, 3, 4: correction:=correction1;

 5, 6, 7, 8: correction:=correction2;

 end;

 end;

 4: begin

 hour:=trunc(value/100)+(value/100-trunc(value/100))/0.6;

 day:=day+hour/24+correction;

 end;

 end;

end;

procedure check_legit;

```
begin
```

```
comma:=false;
```

```
legit:=false;
```

```
if digit='0' then legit:=true;
```

```
if digit='1' then legit:=true;
```

```
if digit='2' then legit:=true;
```

```
if digit='3' then legit:=true;
```

```
if digit='4' then legit:=true;
```

```
if digit='5' then legit:=true;
```

```
if digit='6' then legit:=true;
```

```
if digit='7' then legit:=true;
```

```
if digit='8' then legit:=true;
```

```
if digit='9' then legit:=true;
```

```
if digit='.' then legit:=true;
```

```
if digit=',' then legit:=true;
```

```
if digit=' ' then comma:=true;
```

```
if not legit then n:=6;
```

```
end;
```

```
procedure build_number;
```

```
begin
```

```
    bogus:=false;
```

```
    temporary:='';
```

```
    while not (bogus) do begin
```

```
        read(infile1, digit);
```

```
        check_legit;
```

```
        if legit then begin
```

```
            if comma or (seekeoln(infile1)) then bogus:=true;
```

```
            if not comma then temporary:=temporary+digit;
```

```
        end
```

```
        else begin
```

```
            temporary:='0';
```

```
            n:=6;
```

```
        end;
```

```
    end;
```

```
    value:=str2num(temporary);
```

```
end;
```

```
procedure read_vwt;
```

```
begin
```

```
while ((n<4) and not (seekeoln(infile1))) do begin
```

```
    build_number;
```

```
    n:=n+1;
```

```
    if n<6 then assign_vwt;
```

```
end;
```

```
if not(seekeoln(infile1)) then readln(infile1);
```

```
end;
```

```
procedure write_vwt;
```

```
begin
```

```
  case id2 of
```

```
    1: writeln(outfile1, temperature:6:3, tab, pressure:6:3,  
      tab, day:6:3);
```

```
    2: writeln(outfile2, temperature:6:3, tab, pressure:6:3,  
      tab, day:6:3);
```

```
    3: writeln(outfile3, temperature:6:3, tab, pressure:6:3,  
      tab, day:6:3);
```

```
    4: writeln(outfile4, temperature:6:3, tab, pressure:6:3,  
      tab, day:6:3);
```

```
    5: writeln(outfile5, temperature:6:3, tab, pressure:6:3,  
      tab, day:6:3);
```

```
    6: writeln(outfile6, temperature:6:3, tab, pressure:6:3,  
      tab, day:6:3);
```

```
    7: writeln(outfile7, temperature:6:3, tab, pressure:6:3,  
      tab, day:6:3);
```

```
    8: writeln(outfile8, temperature:6:3, tab, pressure:6:3,  
      tab, day:6:3);
```

```
  end;
```

```
end;
```

```
procedure check_id2;
```

```
var
```

```
temp:string;
```

```
begin
```

```
temp:='';
```

```
n:=0;
```

```
read (infile1, digit);
```

```
check_legit;
```

```
if legit then begin
```

```
  temp:=digit;
```

```
  read (infile1, digit);
```

```
  check_legit;
```

```
  if legit then begin
```

```
    if comma then begin
```

```
      realid:=str2num(temp);
```

```
      id2:=num2integer(realid);
```

```
      read_vwt;
```

```
      if n=4 then write_vwt;
```

```
    end
```

```
  else begin
```

```
    temp:=temp+digit;
```

```

    read (infile1, digit);
    check_legit;
    if comma then begin
        realid:=str2num(temp);
        id2:=num2integer(realid);
        read_vwt;
        if n=4 then write_vwt;
    end
    else begin
        readln(infile1);
    end;
end;
end
else begin
    readln(infile1);
end;
end
else begin
    readln(infile1);
end;
end;

end;

procedure continue_processing;

begin

wampus := true;
if id = 2 then check_id2;
if (id=2) then wampus:= false;
if wampus then readln(infile1);

end;

procedure enter_data;

var
    filename1, filename2: string;

begin

writeln ('Beginning split process. ');
writeln;
write('Enter the name of the file folder that will receive the output files: ');
readln(filename1);
writeln;
write ('Input file name: ');
readln (results);
reset (infile1, results);
writeln;

write ('Enter the time correction for Computer 1: ');
readln(correction1);

```

```

write ('Enter the time correction for Computer 2: ');
readln(correction2);

filename1:='main:doe:processed data:'+filename1+'.';

rewrite (outfile1, filename1+'vwt1');
rewrite (outfile2, filename1+'vwt2');
rewrite (outfile3, filename1+'vwt3');
rewrite (outfile4, filename1+'vwt4');
rewrite (outfile5, filename1+'vwt5');
rewrite (outfile6, filename1+'vwt6');
rewrite (outfile7, filename1+'vwt7');
rewrite (outfile8, filename1+'vwt8');

end;

```

```

begin {main program}

tab:= char(9);

enter_data;

writeln;
writeln('Program is running, please wait. ');
writeln;

legit:=false;
comma:=false;

while not (eof(infile1)) do
begin
  read (infile1, digit);
  check_legit;
  if legit then begin
    realid:=str2num(digit);
    id:=num2integer(realid);
  end
  else begin
    readln(infile1);
  end;

  if legit then read (infile1, digit);
  check_legit;
  if legit then begin
    if comma then continue_processing;
    if not comma then readln(infile1);
  end;
end;
end;

```

```
close (infile1);  
close (outfile1);  
close (outfile2);  
close (outfile3);  
close (outfile4);  
close (outfile5);  
close (outfile6);  
close (outfile7);  
close (outfile8);
```

```
writeln;
```

```
writeln('Program is complete.');
```

```
writeln;
```

```
writeln ('Press return to leave the program.');
```

```
readln;
```

```
end.
```

Program Pillage;

{This program adjusts vwt data to atmospheric pressures.
It only reads files that have first been processed with the program entitled Looor.
The program converts the data for the vibrating wire transducers into a
two column format that can be read by a graphics program.}

uses sane;

var

results, filename1, filename2, vwt1_equation,
vwt_equation, subtraction, time_equation: string;

infile1, infile2, outfile1, outfile2:text;

value, temperature, pressure, day, hour, level, difference,
temperature1, pressure1, hour1, day1,
temporary, water_level, water_level1,
time, A1, B1, C1, yang: real;

intday1, intday, i, code, total_vwt, ying, year: longint;

tab: char;

not_file_end, first_write, first_call, already_written: boolean;

procedure write_dummy_temp;

begin

A1:=temperature;

B1:=pressure;

case i of

- 2: water_level:=((-1.54*2*B1+23.48)-0.0063*((-104.78+378.11
*A1-611.59*A1*A1+544.27*A1*A1*A1-240.91
*A1*A1*A1*A1+43.089*A1*A1*A1*A1*A1)-19));
- 3: water_level:=((-0.91*2*B1+12.996)-0.0081*((-104.78+378.11
*A1-611.59*A1*A1+544.27*A1*A1*A1-240.91
*A1*A1*A1*A1+43.089*A1*A1*A1*A1*A1)-19));
- 4: water_level:=((-1.61*2*B1+27.1446)+0.0055*((-104.78+378.11
*A1-611.59*A1*A1+544.27*A1*A1*A1-240.91
*A1*A1*A1*A1+43.089*A1*A1*A1*A1*A1)-19));
- 5: water_level:=((-1.27*2*B1+19.477)-0.0124*((-104.78+378.11
*A1-611.59*A1*A1+544.27*A1*A1*A1-240.91
*A1*A1*A1*A1+43.089*A1*A1*A1*A1*A1)-19));
- 6: water_level:=((-1.33*2*B1+21.78)-0.0021*((-104.78+378.11*A1-611.59
*A1*A1+544.27*A1*A1*A1-240.91*A1*A1*A1*A1
+43.089*A1*A1*A1*A1*A1)-19));
- 7: water_level:=((-0.91*2*B1+11.208)-0.0071*((-104.78+378.11
*A1-611.59*A1*A1+544.27*A1*A1*A1-
240.91*A1*A1*A1*A1+43.089*A1*A1*A1
*A1*A1)-19));

```

8: water_level:=((-1.32*2*B1+20.0772)-0.0037*((-104.78+378.11
*A1-611.59*A1*A1+544.27*A1*A1*A1-
240.91*A1*A1*A1*A1+43.089*A1*A1*A1*A1
*A1)-20));
end;

water_level1:=temporary;

case i of
  2,3,4,5,6,7,8: water_level:=(water_level-water_level1)*70.3077;
end;

time:=day;

writeln(outfile1, water_level:6:3, tab, time:6:3);

already_written:=true;

end;

procedure write_dummy;

begin

A1:=temperature;
B1:=pressure;

case i of
  2: water_level:=((-1.54*2*B1+23.48)-0.0063*((-104.78+378.11
*A1-611.59*A1*A1+544.27*A1*A1*A1-240.91
*A1*A1*A1*A1+43.089*A1*A1*A1*A1)-19));
  3: water_level:=((-0.91*2*B1+12.996)-0.0081*((-104.78+378.11
*A1-611.59*A1*A1+544.27*A1*A1*A1-240.91
*A1*A1*A1*A1+43.089*A1*A1*A1*A1)-19));
  4: water_level:=((-1.61*2*B1+27.1446)+0.0055*((-104.78+378.11
*A1-611.59*A1*A1+544.27*A1*A1*A1-240.91
*A1*A1*A1*A1+43.089*A1*A1*A1*A1)-19));
  5: water_level:=((-1.27*2*B1+19.477)-0.0124*((-104.78+378.11
*A1-611.59*A1*A1+544.27*A1*A1*A1-240.91
*A1*A1*A1*A1+43.089*A1*A1*A1*A1)-19));
  6: water_level:=((-1.33*2*B1+21.78)-0.0021*((-104.78+378.11*A1-611.59
*A1*A1+544.27*A1*A1*A1-240.91*A1*A1*A1*A1
+43.089*A1*A1*A1*A1)-19));
  7: water_level:=((-0.91*2*B1+11.208)-0.0071*((-104.78+378.11
*A1-611.59*A1*A1+544.27*A1*A1*A1-
240.91*A1*A1*A1*A1+43.089*A1*A1*A1
*A1*A1)-19));
  8: water_level:=((-1.32*2*B1+20.0772)-0.0037*((-104.78+378.11
*A1-611.59*A1*A1+544.27*A1*A1*A1-
240.91*A1*A1*A1*A1+43.089*A1*A1*A1*A1
*A1)-20));
end;

```

```

water_level1:=pressure1;

case i of
  2,3,4,5,6,7,8: water_level:=(water_level-water_level1)*70.3077;
end;

time:=day;

writeln(outfile1, water_level:6:3, tab, time:6:3);

already_written:=true;

end;

procedure switch_files;

begin

reset (infile1, filename1+'dummy');

case i of
  1: rewrite (outfile1, filename1+'vwt1');
  2: rewrite (outfile1, filename1+'vwt2');
  3: rewrite (outfile1, filename1+'vwt3');
  4: rewrite (outfile1, filename1+'vwt4');
  5: rewrite (outfile1, filename1+'vwt5');
  6: rewrite (outfile1, filename1+'vwt6');
  7: rewrite (outfile1, filename1+'vwt7');
  8: rewrite (outfile1, filename1+'vwt8');
end;

while not(eof(infile1)) do
begin

  readln(infile1, water_level, time);

  writeln(outfile1, water_level:6:3, tab, time:6:3);

end;

close (infile1);
close (outfile1);

end;

procedure compare_day;

begin

difference:= day1-day;
if difference > 0.0208 then code:=1;
if difference < -0.0208 then code:=2;
if (difference <= 0.0208) and (difference >= -0.0208) then code:=3;
end;

```

```
procedure enter_data;

begin

writeln ('Beginning correction process. ');
writeln;

write('Enter in the name of the folder containing data to be processed: ');
readln(filename1);
writeln;

filename1:=('main:doe:processed data:'+filename1+');

end;

procedure set_file;

begin

reset (infile1, filename1+'vwt1');

case i of
  2: reset (infile2, filename1+'vwt2');
  3: reset (infile2, filename1+'vwt3');
  4: reset (infile2, filename1+'vwt4');
  5: reset (infile2, filename1+'vwt5');
  6: reset (infile2, filename1+'vwt6');
  7: reset (infile2, filename1+'vwt7');
  8: reset (infile2, filename1+'vwt8');
end;

rewrite (outfile1, filename1+'dummy');

end;

procedure process_atmospheric_pressure;

begin

reset (infile1, filename1+'vwt1');
rewrite (outfile1, filename1+'dummy');
while not(eof(infile1)) do begin

readln(infile1, temperature, pressure, day);

B1:=pressure;
A1:=temperature;
```

```

water_level1:=((-0.98*2*B1+12.348)-0.0025*((-104.78+378.11*A1-611.59*A1
*A1+544.27*A1*A1*A1-240.91*A1*A1*A1*A1+
43.089*A1*A1*A1*A1*A1)-19));

```

```

writeln(outfile1, water_level1:6:3, tab, day:6:3);

```

```

end;

```

```

close (infile1);
close (outfile1);

```

```

i:=1;
switch_files;

```

```

end;

```

```

{main body of program}

```

```

begin

```

```

tab:= char(9);

```

```

enter_data;

```

```

total_vwt:=8;

```

```

writeln;
writeln('Program is running, please wait. ');
writeln;

```

```

process_atmospheric_pressure;

```

```

for i:=2 to total_vwt do

```

```

begin

```

```

first_call:=true;

```

```

set_file;

```

```

if not(eof(infile2)) then readln(infile2, temperature, pressure, day);
readln(infile1, pressure1, day1);

```

```

not_file_end:=true;
already_written:=false;

```

```

while not_file_end do

```

```

begin

```

```

if eof(infile1) then not_file_end:=false;

```

```

compare_day;

case code of
  1: if not already_written then write_dummy_temp;
  2: begin
      temporary:=pressure1;
      end;
  3: begin
      if not already_written then write_dummy;
      temporary:=pressure1;
      end;

end;
case code of
  1: begin
      if not eof(infile2) then
      begin
      readln(infile2, temperature, pressure, day);
      already_written:=false;
      end;
      if eof(infile2) then readln(infile1, pressure1, day1);
      end;
  2: readln(infile1, pressure1, day1);
  3: begin
      if not eof(infile2) then
      begin
      readln(infile2, temperature, pressure, day);
      already_written:=false;
      end;
      if eof(infile2) then readln(infile1, pressure1, day1);
      end;
end;

end;

close (infile2);
close (infile1);
close (outfile1);

switch_files;

end;

close (infile1);
close (infile2);
close (outfile1);

erase (filename1+'dummy');

writeln;

```

```
writeln('Program is complete.');
```

```
writeln;
```

```
writeln ('Press return to leave the program.');
```

```
readln;
```



```
end.
```

SECTION V
GEOTECHNICAL STUDIES
DR. D. DUTTA
CO-PRINCIPAL INVESTIGATOR

MANAGEMENT OF DRY FLUE GAS DESULFURIZATION BY-PRODUCTS IN UNDERGROUND MINES

Technical Progress Report – January 1 - March 31, 1995

GEOTECHNICAL STUDIES

OBJECTIVES

The geotechnical characterization of mixes for pneumatic and hydraulic placements is intended to determine of their short and long term strengths, elastic moduli, stress-strain curves, swelling and slump characteristics, linear expansions, heat of reactions, mass loss at extreme temperatures, and density. Hydraulic placement of coal combustion residues (CCR) and FGD by-products into abandoned mine workings may negatively impact stability of mine workings and may tend to increase surface subsidence, as Illinois coal seams are generally associated with thick (2-4 ft), and weak (300-1000 psi) floor strata. Short-term subsidence due to wet backfilling can cause damage to surface structures and impact land use patterns. In addition, underground bulkhead stability may be negatively impacted due to hydraulic and active pressures imposed by hydraulic or pneumatic placement of coal combustion by-products. The immediate floor strata associated with No. 6 coal seam (Herrin Seam) at Peabody No 10 demonstration mine are known to be weak (Chugh et al., 1989). Hence, objectives of the geotechnical assessment also include: 1. analysis of the stability of abandoned mine workings prior to and after disposal of combustion by-products; 2. estimation of the surface movements and their characteristics due to wet disposal of by-products; 3. assessment of the stability of isolation structures such as bulkhead to withstand pressures due to the disposal of FGD by-products; 4. monitoring of long term surface and sub-surface movements prior to and after backfilling of coal combustion by-products. The results of the demonstration studies at Peabody No. 10 mine will be generalized for other areas within the Illinois Coal Basin.

TASKS WORKED ON DURING THE QUARTER

During the period January 1 to March 31, 1995, long term geotechnical characterization of the pneumatic mixes was undertaken. Out of 16 initial trial mixes, four mixes of different proportions were selected for the long-term geotechnical characterization. The mixes were 80-20 and 70-30 FBC fly ash and spent bed with 25% and 30% moisture. Initial tests on trial mixes show the average demolded densities as 71 and 73 pcf for 80-20 and 70-30 mixes, respectively, with 25% nominal moisture. The same mixes with 30% nominal moisture have average densities of 71 and 75 pcf, respectively. The 28-day compressive strengths of 80-20 and 70-30 mixes with 25% nominal moisture are 11 and 3 psi, respectively. The same mixes with 30% nominal moisture have average strengths of 92 and 34 psi, respectively. Though the increase in average demolded density of the mixes due to the increased water content is trivial, the strength increase is highly significant (Annual Report, October 1, 1993-September 30, 1994). The characterization of two mixes with two different proportions of water content was conducted at 25 psi compacted pressure.

MANAGEMENT OF DRY FLUE GAS DESULFURIZATION BY-PRODUCTS IN UNDERGROUND MINES

Technical Progress Report – January 1 - March 31, 1995

GEOTECHNICAL STUDIES (Continued)

During the quarter, 18 cylindrical samples, three inches diameter and six inches long, were prepared and left for 180 days curing in the curing chamber. More samples are being prepared for determining short term strengths and modulus of elasticity. The long term characterization will involve the determination of compressive and tensile strength and modulus of elasticity. Linear expansion, stress-strain diagrams, sulfate expansion, swelling, and mass loss at extreme temperatures will also be determined.

It was reported in the last quarterly report (Technical Progress Report, October 1, 1994-December 31, 1994) that 5% lime is needed to activate the pozzolanic characteristics of PCC fly ash in the hydraulic mix containing PCC fly ash and scrubber sludge. Cost calculations indicate very high costs for 5% lime in the mix. As the cost may be a deterrent to hydraulic placement, alternative materials were sought, and it was finally decided to add 5% lime waste to 35-45% PCC fly ash and 60-50% scrubber sludge.

A few samples of different proportions of fly ash, scrubber sludge, lime waste, and water were prepared and their paste characteristics were observed. Finally, 29-30% water seems to give a pumpable paste without any bleed off. However, slump tests have not yet been performed on those trial mixes.

Additionally, eight samples consisting of 40% fly ash, 55% scrubber sludge, and 5% lime waste were made, which were mixed with 29% water. They were divided into 3 groups according to the different curing time, as shown in Table 1.

Mechanical tests for determining the ultimate axial compressive strength and Young's modulus of the samples were conducted. The tests are given in Figures 1 through 3.

**MANAGEMENT OF DRY FLUE GAS DESULFURIZATION
BY-PRODUCTS IN UNDERGROUND MINES**

Technical Progress Report – January 1 - March 31, 1995

GEOTECHNICAL STUDIES (Continued)

Table 1. Samples and their curing time

No. of sample	Group	Days keeping in fresh	Curing days	Days in steam chamber	Days in oven at 40 C
A	1	2	9	0	0
B	1	2	9	0	0
C	1	2	9	0	0
11	2	2	1	2	1
33	2	2	1	2	1
A1	3	2	3	2	1
A2	3	2	3	2	1
A3	3	2	3	2	1

The water contents of sample group 2 and group 3 were measured during different curing stages (see Table 2).

Table 2. Water contents of sample group 2 and group 3 at different curing stages

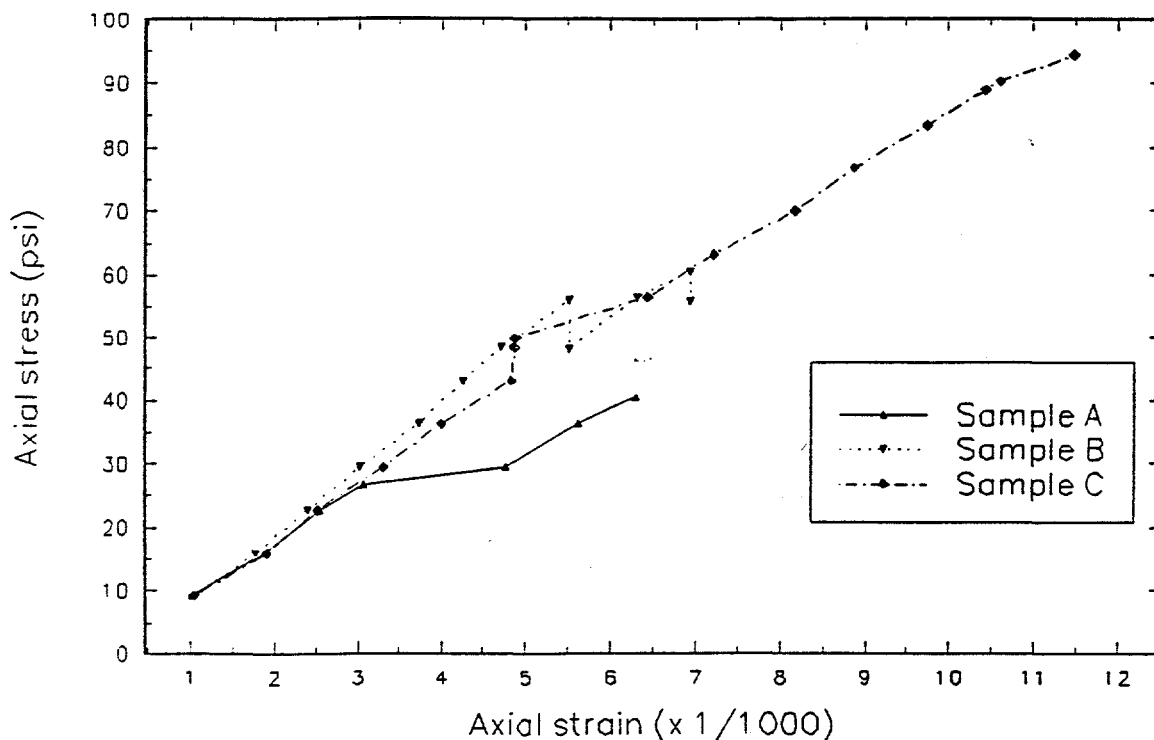
No. of sample	Group	When made	After keeping fresh	After curing	After keeping in steam chamber	After keeping in oven	After test
11	2	29%	24.38%	22.75%	26.94%	16.63%	16.63%
33	2	29%	23.92%	21.38%	25.85%	14.38%	14.38%
A1	3	29%	21.11%	19.98%	24.54%	13.75%	13.75%
A2	3	29%	21.00%	20.68%	24.37%	14.36%	14.36%
A3	3	29%	21.18%	20.35%	23.96%	11.71%	11.71%

MANAGEMENT OF DRY FLUE GAS DESULFURIZATION
BY-PRODUCTS IN UNDERGROUND MINES

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GEOTECHNICAL STUDIES (Continued)

Figure 1 Stress-Strain relationship curve of sample group 1
(40% F.A. , 55% S.S., 5% L. W. , mixed with 29% water)

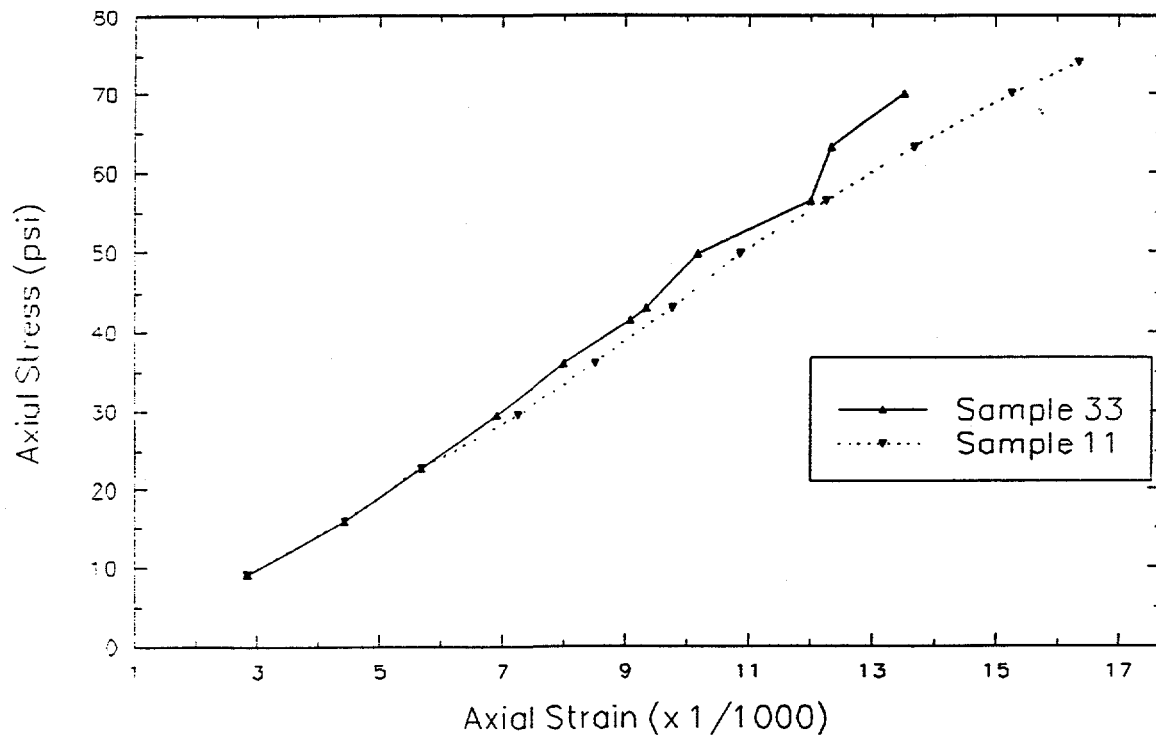


MANAGEMENT OF DRY FLUE GAS DESULFURIZATION
BY-PRODUCTS IN UNDERGROUND MINES

Technical Progress Report – January 1 - March 31, 1995

GEOTECHNICAL STUDIES (Continued)

Figure 2 Stress-strain relationship curve of sample group 2
(40% F.A., 55% S.S., 5% L.W., mixed with 29% water)

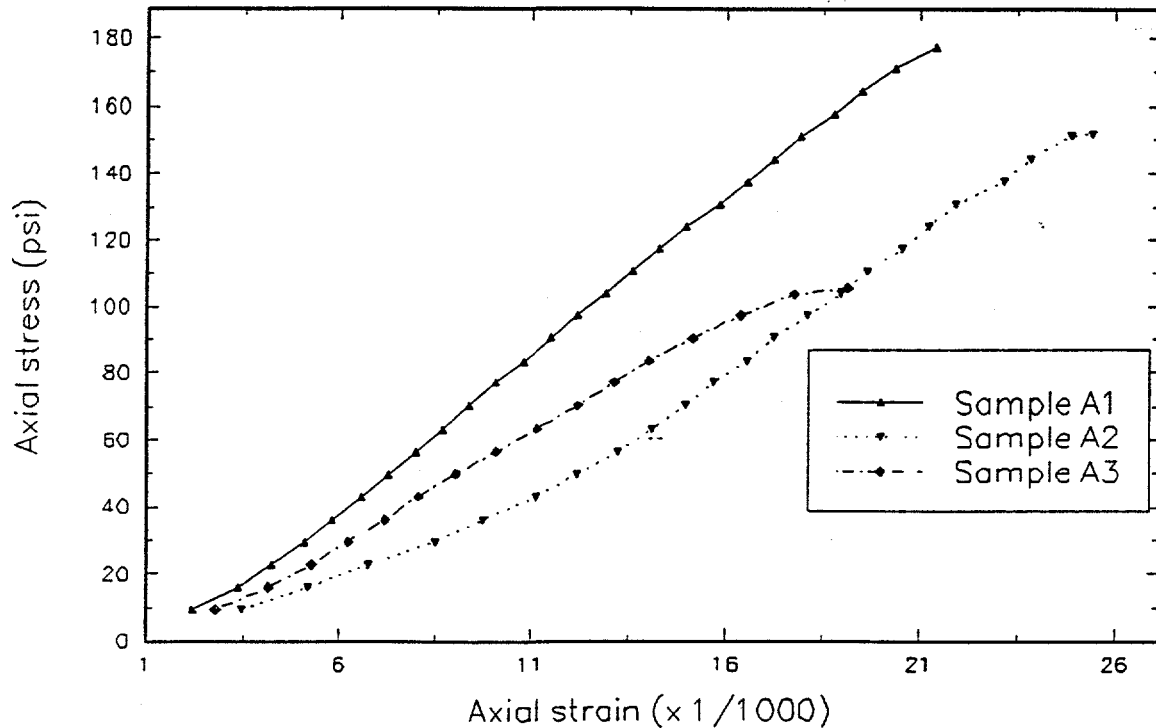


MANAGEMENT OF DRY FLUE GAS DESULFURIZATION BY-PRODUCTS IN UNDERGROUND MINES

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GEOTECHNICAL STUDIES (Continued)

Figure 3 Stress-strain relationship curve of sample group 3
(40% F.A., 55% S.S, 5% L.W., mixed with 29% water)



The mean ultimate compressive strength is 63.2 psi for group 1; 72.01 for group 2; and 144.806 psi for group 3. The mean Young's modulus is 8500 psi for group 1; 4250 psi for group 2; and 5100 psi for group 3. It is obvious that the samples which were put into steam chamber and oven increases ultimate compressive strength, but reduced Young's modulus. The reason for the reduction of Young's modulus is that after being put into steam chamber at a temperature of about 80 C for 2 days and then put into oven at a temperature of 40° C for 1 day, many small fissures developed in the samples, and therefore the samples had a much larger deformation and a more obvious hardening phenomenon than those which were not put into steam chamber and oven.

As the stress-strain curve for the new hydraulic mix has not been fully developed yet, no finite element analyses could be carried out in this quarter.

MANAGEMENT OF DRY FLUE GAS DESULFURIZATION BY-PRODUCTS IN UNDERGROUND MINES

Technical Progress Report – January 1 - March 31, 1995

GEOTECHNICAL STUDIES (Continued)

PLANS FOR THE NEXT QUARTER

More samples will be prepared for long term characterization of the pneumatic mixes, and additional testing will be performed. Sample preparations and characterization of hydraulic mixes will be done for some selected mixes with 5% lime waste. As soon as the stress-strain curve of few samples are obtained, more time dependent finite element models will be run to analyze the effects of backfilling on pillar stability, amount of pillar punching into the floor, and roof-to-floor convergence in the entries. Borehole instrumentation and installation of surface subsidence monuments will start as soon as the drilling of injection bore holes is completed.

REFERENCES

Chugh, Y. P., J. Daugherty, et al. (1989) Laboratory characterization of weak floor strata associated with coal seams in Illinois, *Final Report to Illinois Mine Subsidence Research program*, Champaign, IL.

SECTION VI
NEXT QUARTER

**MANAGEMENT OF DRY FLUE GAS DESULFURIZATION
BY-PRODUCTS IN UNDERGROUND MINES**

Technical Progress Report -- January 1 - March 31, 1995

THE NEXT QUARTER

Two major tasks should be accomplished in the next quarter. First, the injection wells and monitoring wells should be completed at the Peabody Coal Company Number 10 mine injection site. Completion and instrumentation of the wells will permit the gathering of baseline data for further on-site environmental studies.

A topical report on the complete SEEC, Inc. demonstration of the Collapsible Intermodal Containers (CIC) will also be completed during the next quarter. Final preparation of the report will complete SEEC, Inc. work as outlined in the cooperative agreement.

Also, the long-term Rapid Aging Tests will get under way during the next quarter. The test apparatus is complete, the mixes selected, and no barriers to the testing is anticipated.

Laboratory testing of the pneumatic technology, involving both Eric Powell and Associates and the University of Pittsburgh will have a very high priority during the quarter. The laboratory-scale testing of the pneumatic technology is essential prior to developing firm plans for the full-scale pneumatic placement.

Work will continue on the engineering and economic evaluation model, including the development of a window version of the model.

In the management and administrative area, up-dated budgets for the various research areas will be prepared. This is necessary because of the close of the University fiscal year on June 30, 1995. Additionally, planning will begin for the annual DOE review of the SIUC, University of West Virginia, and University of Kentucky projects. The review is presently scheduled for October 31 -- November 1, 1995, and will be held on the SIUC campus.

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