Disposal of Fluidized-Bed Combustion Ash in an Underground Mine to Control Acid Mine Drainage and Subsidence

Quarterly Report
June 1 - August 31, 1996

Work Performed Under Contract No.: DE-FC21-94MC29244

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
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MASTER

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Progress Report

for the Period of

June 1, 1996 to August 31, 1996

Project - ETD05 "Disposal of Fluidized Bed Combustion Ash in an Underground Mine to Control Acid Mine Drainage and Subsidence"
DE-FC21-94MC29244

During Phase I (first 18 months) the project is segregated into four areas of reporting: A) Grout Formulation, B) Grout Characterization, C) Water Quality Monitoring, D) Subsidence Control & Contaminant Transport. The first component involves formulating a grout mixture with appropriate flowability to be used in filling complex mine voids. The Grout Characterization component will determine the flow characteristics of the formulated grout. The Water Quality component involves background monitoring of water quality and precipitation at the Phase III (Longridge) mine site. The last component involves evaluating the strength requirements and the migration of contaminants through the candidate grouts.

This report separately discusses progress on all components of the program in order of project subtask. The subtasks are arranged according to the network diagram on the following page.
A. Grout Development

1.0 Task Description:

Grout Development

The purpose of this task is to develop a grout formulation that will be capable of filling complex mine voids while displaying strength great enough to prevent subsidence. This task involves the physical mixing and testing of grouts while keeping in close communication with Dr. Siriwardane's and Dr. Gray's research teams. Dr. Siriwardane's team will evaluate the strength requirements needed for subsidence control while Dr. Gray's team will be responsible for grout rheology.

2.0 Summary of Accomplishments

2.1. Monitoring of long-term strength development of various grout mixtures continued; updated plots of strength versus time are attached.

2.2. Monitoring of the affects on compressive strength of changes in ash composition as reflected by time of acquiring ash samples at the plant site was continued.

2.3. Various commercially available admixtures were assessed to determine if such products were useful in enhancing grout strength and/or flow.

2.4. Plans were made for a full-scale field installation of approximately 1000 cubic yards of grout.

2.5. Grout Field Placement was successfully demonstrated.

3.0 To-Date Accomplishments

As noted above.

4.0 Technical Progress Report

A technical progress report is being prepared and will be included in the Phase II Topical Report due at the end of the Phase II contract period.

5.0 Plans for Next Quarter

5.1. Continue Monitoring of Long-Term grout strength development.

5.2. Continue laboratory permeability testing of selected grout.
5.3 Sample and test cores taken from field placement of ash at the Fairfax Mine in Preston County.

5.4 Prepare Phase II Topical Report.
B. Grout Rheology

1.0 Task Description

1.1 Literature Search: This task will involve both manual and computer searches of the literature on several topics. This task will insure that the latest advances in grout technology are incorporated into this project and that no effort is wasted in the duplication of results.

1.2 Grout Characterization: In this task, appropriate viscometric tests will be conducted to determine the relationship between stress and rate of strain, as a function of time and composition of the grout mixture.

1.3 Analytical Modeling: This task is the development of an analytical model to describe the rheology of the grout. This task will provide a constitutive relation that describes the behavior of the grout in agreement with the laboratory results.

1.4 Numerical Modeling: This task includes the adaptation of commercially available fluid modeling software to incorporate the rheological model developed in task 1.3. This task will enable the placement of grout to be modeled numerically.

2.0 Summary of Accomplishments & Significant Events

Literature Search: 100% complete
Grout Characterization: 85% complete
Analytical Model: 80% complete
Numerical Model: 70% complete

3.0 To Date Accomplishments

The literature search may be considered complete, but new information about the project is continually being revealed. No other tasks are complete to date.

4.0 Technical Progress Report

A technical progress report is being prepared and will be included in the Phase II Topical Report due at the end of the Phase II contract period.
C. Water Quality Monitoring

1.0 Task Description

Baseline Water Quality Monitoring

The purpose of this task is to monitor the baseline water quality of the acid mine drainage (AMD) from the Longridge and Fairfax Mines prior to and during grouting. A flow monitoring and sampling station has been set up at the Longridge mine and a precipitation gauge has been established between the two mines.

2.0 Summary of Period's Accomplishments & Significant Events

Water quality monitoring and sampling continued as planed. Data is presented and discussed in some detail below for the reporting period of approximately three months. Flow from the Longridge Mine was relatively high during the period; ranging from 90 to 251 gpm and averaging 149 gpm. Average flow for the period was the highest noted since data collection began in November of 1994. The peak was due to the heavy precipitation.

In past quarters, high average flow rates typically resulted in significantly lower pollutant concentrations due to dilution. This same trend continued during this period. For example, the iron concentration during this period averaged 85.0 mg/l (149 gpm) as compared to 178 mg/l for quarter ending 5/31/95 (58.8 gpm) as expected however, the actual mass of pollutants leaving the mine was higher this period due to the higher flows. The average acid load leaving the mine rose from 567 lbs/day (5/31/96) to 1087 lbs/day.

Sampling from the well located below the Fairfax Mine coal seam was initiated. Data will be presented in the Topical report for Phase II that will be presented at the end of the Phase II contract period.

3.0 Accomplishments to Date

Accomplishments to date include choice of parameters to sample, design of the sampling station, procurement of equipment, site preparation, installation and shake down of equipment, initiation of sampling and data analysis.

4.0 Technical Progress Report

The technical progress report is attached.

5.0 Plans for next Quarter
5.1 Continue monitoring the Longridge mine for water quality and flow.

5.2 Continue to monitor Fairfax borehole for possible contamination from grout.
4.0 TECHNICAL PROGRESS REPORT: Water Quality Monitoring

Results of monitoring flow, precipitation and water quality are discussed below. In addition, issues related to monitoring activities are the site are described.

4.1 Flow and Precipitation Monitoring

Average weekly flow (gpm) from the Longridge Mine is shown in Table 1 and Figure 1. Flow from the Longridge Mine was quite high during the reporting period (approximately 3 months) due to a prolonged period of heavy rainfall. Flow varied from a low of about 90 gpm to a high of about 251 gpm and averaged 149 gpm during the period. As noted on Table 1, a total of 16 samples were taken during the period (#'s 76 to 91). However, the values noted for the last four flow measurements (samples 88 to 91) are too high due to problems with the flow meter and the data taken for these samples has not been utilized in calculation of the average values or included in the figures which follow. A number of attempts have been made to solve the flow measurement problem (working with the manufacturer). It is anticipated that the flow meter will be back on-line in late July or early August.

Table 2 compares the average flow during the present period with that measured in previous quarters. It may be noted that the average flow this period was the highest experienced thus far. Rainfall for the period was also the highest noted thus far and averaged 1.17 inches per sample period. As may be seen from Table 1, the number of days between samples varies somewhat and is typically about 7 to 9 days. It should be noted that all of the rainfall values were taken from the Morgantown Lock and Dam since the raingage is not functioning and funds are not available for its repair.

4.2 Water Quality Analysis

4.2.1 Longridge Mine

Analysis of the weekly composite AMD samples is presented in Table 1. In addition to the values for each sample period, the average value for all the samples (76 to 87) is presented for each of the 15 parameters measured. As noted earlier, the data for weeks 88 to 91 were not utilized in calculation of the average values.

Examination of Table 1 shows that the AMD from the Longridge Mine had a pH ranging from 2.5 to 2.7 and an average acidity of 621 mg/L during the period. Other parameters reflecting the acid load include sulfate and iron which averaged 1011 and 85 mg/L respectively. Because of the high flows experienced, these values are significantly lower than in other quarters. Figure 2 shows sulfate, acidity and iron as a function of flow. It may be observed that all three parameters fall off as flow increases due to dilution. This same trend has been noted in earlier reports. However, as shown in Figure 3, while the concentration of acidity decrease with increasing flow, the actual mass of acid (lbs/D) discharged per day actually increases as flow increases. It may be noted that the acid leaving
the mine increased from about 775 to 1600 lbs/D while the flow increased from about 90 to 250 gpm.

The average concentration of the trace elements As, Se, and Pb, are presented in Figure 4 for each sample. The average concentrations of As, Se, and Pb for the period were (Table 1) respectively 0.46, 0.37, and 0.14 mg/L showing significant levels of these elements in the AMD.

In Table 2, selected water quality parameters are compared for this period and the previous periods. It may be seen that the general trend is for the concentration of the pollutants to decrease with flow. For example, the concentrations of acidity and iron are plotted in Figure 5 for the entire project period showing significant decreases in concentration as flow increases.

Table 2. Selected Average Values for Each Period of Study

<table>
<thead>
<tr>
<th>End Period</th>
<th>Flow (gpm)</th>
<th>Fe (mg/L)</th>
<th>Al (mg/L)</th>
<th>SO₄ (mg/L)</th>
<th>As (mg/L)</th>
<th>Pb (mg/L)</th>
<th>Acidity (mg/L)</th>
<th>Acidity (lbs/d)</th>
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<td>11/30/94</td>
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<td>195</td>
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<td>0.29</td>
<td>1134</td>
<td>336</td>
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<tr>
<td>2/28/95</td>
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<td>174</td>
<td>47</td>
<td>1421</td>
<td>0.66</td>
<td>0.23</td>
<td>980</td>
<td>564</td>
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<tr>
<td>5/31/95</td>
<td>58.8</td>
<td>138</td>
<td>57</td>
<td>1429</td>
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<td>567</td>
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<tr>
<td>8/31/95</td>
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<td>151</td>
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<td>168</td>
<td>77</td>
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<td>1011</td>
<td>0.46</td>
<td>0.14</td>
<td>621</td>
<td>1087</td>
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</tbody>
</table>

4.2.2 Fairfax Mine

A well was drilled to allow sampling of water in the Fairfax Mine and sampling was initiated this period. Water is collected from the surface by bailing the well with a long rope and a plastic sample bottle. At this time, it is planned to sample the well about once or twice per month. The sampling depth below the surface is about 150 feet. Table 2 presents sampling results for the first three samples collected. It may be noted that the water is actually alkaline with a pH of about 7. The levels of iron, sulfate, and trace elements are in a typical range for groundwaters. Hence, the samples collected are probably simply groundwater.

4.3 Miscellaneous Issues Related to Monitoring Activities

As noted above, problems this period were experienced with the flow monitoring device. The flow meter has been shipped back to the manufacturer for repair. The raingage is also out of service and no funds are available for repair of this unit. Problems were also experienced due to occasional power loss at the site.
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<thead>
<tr>
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<td>650</td>
<td>643</td>
<td>630</td>
<td>649</td>
<td>682</td>
<td>608</td>
<td>666</td>
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<td>691</td>
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<td>15.1</td>
<td>15.5</td>
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<td>Ba (mg/L)</td>
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*precip. data taken from Morgantown Lock and Dam due to malfunc. of site rain gauge  
**samples 88 to 91 not utilized for averages**  
NA = not applicable

(1) data questionable-not used  
(2) samples 88 to 91 not utilized for averages
<table>
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<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Temp (C)</td>
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<tr>
<td>Precip. (in) *</td>
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<td>689</td>
</tr>
<tr>
<td>Acid. (mg/L)</td>
<td>&lt;1.0</td>
<td>&lt;1.0</td>
<td>&lt;1.0</td>
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</tr>
<tr>
<td>Alkalinity (mg/L)</td>
<td>150</td>
<td>153</td>
<td>160</td>
<td>154</td>
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<tr>
<td>Fe (mg/L)</td>
<td>1.24</td>
<td>1.11</td>
<td>0.497</td>
<td>0.949</td>
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<tr>
<td>Mn (mg/L)</td>
<td>0.329</td>
<td>0.281</td>
<td>0.158</td>
<td>0.256</td>
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<tr>
<td>Al (mg/L)</td>
<td>0.816</td>
<td>0.741</td>
<td>0.571</td>
<td>0.709</td>
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<tr>
<td>Ca (mg/L)</td>
<td>81.3</td>
<td>76.5</td>
<td>78.9</td>
<td>78.9</td>
</tr>
<tr>
<td>Mg (mg/L)</td>
<td>18.8</td>
<td>17.9</td>
<td>18</td>
<td>18.2</td>
</tr>
<tr>
<td>SO4 (mg/L)</td>
<td>225</td>
<td>219</td>
<td>225</td>
<td>223</td>
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<tr>
<td>As (mg/L)</td>
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<td>&lt;.175</td>
<td>&lt;.175</td>
<td>NA</td>
</tr>
<tr>
<td>Se (mg/L)</td>
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<td>&lt;.139</td>
<td>NA</td>
</tr>
<tr>
<td>Pb (mg/L)</td>
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<td>&lt;.040</td>
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<td>NA</td>
</tr>
<tr>
<td>Ba (mg/L)</td>
<td>0.094</td>
<td>0.091</td>
<td>0.095</td>
<td>0.093</td>
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<tr>
<td>Cd (mg/L)</td>
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<td>NA</td>
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<tr>
<td>B (mg/L)</td>
<td>&lt;.030</td>
<td>&lt;.030</td>
<td>&lt;.030</td>
<td>NA</td>
</tr>
</tbody>
</table>

*precip. data taken from Morgantown Lock & Dam due to malfunc. of site rain gauge
NA = not available
Figure 1. Flow vs Sample Number

Flow (gpm)

Sample Number

Flow (gpm)
Figure 2. Flow vs. Sulfate, Acidity & Iron.

Flow (gpm)

mg/L Sulfate, Acidity & Iron

Linear (Fe (mg/L))
Linear (Acid (mg/L))
Linear (SO4 (mg/L))
SO4 (mg/L)
Fe (mg/L)
Acid (mg/L)
Figure 3. Flow vs Acidity (mg/L & lbs/D)

Flow (gpm)

Acidity (mg/L & lbs/D)

- Acid. (mg/L)
- Acid. (lbs/d)
- Linear (Acid. (lbs/d))
- Linear (Acid. (mg/L))
Figure 5. Average Acidity & Iron vs Flow—Total Project Period

- Acid. mg/L
- Fe (mg/L)
- Linear (Acid. mg/L)
- Linear (Fe (mg/L))

Flow (gpm) vs Acidity (mg/L) & Fe (mg/L)
D. Subsidence Control and Contaminant Transport

1.0 Task Description

Task 5.0 Subsidence Control

Determine grout strength requirements needed to ensure subsidence control. Also development of borehole drilling pattern for the Phase II and Phase III mine sites.

Task 6.0 Contaminant Transport

Determine how contaminants will migrate from the grout (if any) and determine how the water that was filling the void will interact with the impermeable plug filling the void after injection.

2.0 Summary of Quarters Accomplishments and Significant Events

2.1 The grout strength requirements were established to account for possible stress concentrations around mine cavities.

2.2 The Longridge Mine was idealized to perform contaminant transport studies and some example flow problems were solved.

3.0 To Date Accomplishments

3.1 Started work on the final report for the grout strength requirements part of the project.

3.2 Continued work on finding the factor of safety to be used as a theoretical strength requirements of the grout to account for stress concentrations around mine cavities.

3.3 The Longridge Mine was idealized for the task on modeling the contaminant transport.

3.4 A finite element difference grid for the idealized Longridge mine was constructed and some example groundwater flow problems were solved using the existing computer software.

4.0 Technical Progress Report

A technical progress report is being prepared and will be included in the Phase II Topical Report due at the end of the Phase II contract period.
5.0 Plans for Next Quarter

To continue the analysis of fluid flow and contaminant transport problems at the Longridge Mine.