

INJECTION OF COAL COMBUSTION BYPRODUCTS INTO THE OMEGA MINE FOR THE REDUCTION OF ACID MINE DRAINAGE¹

by

Thomas A. Gray, Terence C. Moran, David W. Broschart, and Gregory A. Smith

Abstract: The Omega Mine Complex is located outside of Morgantown, West Virginia. The mine is in the Upper Freeport Coal, an acid-producing coal seam. The coal was mined in a manner that has resulted in acid mine drainage (AMD) discharges at multiple points. During the 1990's, the West Virginia Division of Environmental Protection (WVDEP) assumed responsibility for operating a collection and treatment system for the AMD. Collection and treatment costs are approximately \$300,000 per year. An innovative procedure of injecting grout into the mine workings to reduce AMD and the resulting treatment costs is proposed. The procedure involves injecting grout mixes composed primarily of coal combustion byproducts (CCB's) and water, with a small quantity of cement. The intention of the injection program is to fill the mine voids in the north lobe of the Omega Mine (an area where most of the acidity is believed to be generated) with the grout, thus reducing the contact of air and water with potentially acidic material. The grout mix design consists of an approximate 1: 1 ratio of fly ash to byproducts from fluidized bed combustion. Approximately 100 gallons of water per cubic yard of grout is used to help achieve flowability. Observation of the mine workings via subsurface borings and downhole video camera operation confirmed that first-mined areas were generally open while second-mined areas were generally partially collapsed. Closer injection hole spacing was used in second-mined areas to account for collapsed workings. The construction documents have been prepared with the project being bid in late 1997. The engineer's cost estimate was approximately \$2,500,000, with the low bid of approximately \$2,200,000 being submitted by Howard Concrete Pumping of Bridgeville, Pa.

Administration of a construction contract for the project is on-going through WVDEP's Abandoned Mine Lands (AML) program. Funding for the project is coming from the WVDEP; Allegheny Power; Consol, Inc.; United States Office of Surface Mining Reclamation and Enforcement (OSMRE); Anker Energy Corporation; and the Electric Power Research Institute.

Key Words: Coal Combustion Byproducts (CCB's), Grout, West Virginia

Introduction

The intention of the Omega Mine Complex project is to reduce the generation of AMD in the north

lobe of the Omega Mine Complex and to minimize potential mine subsidence via injection of grout materials. Some residences and a primary state highway exist above the area to be grouted.

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²Thomas A. Gray is Manager of Special Projects, GAI Consultants, Inc., 570 Beatty Road, Monroeville, Pennsylvania, 15146; Terence C. Moran is Lead Engineer, GAI Consultants, Inc., 114 West Lee Street, Charleston, West Virginia, 25302; David W. Broschart is District Engineer and Gregory A. Smith is Project Manager for the West Virginia Division of Environmental Protection, 105 South Railroad Street, Philippi, West Virginia 26416.

The Omega Mine Complex project site is located 6 miles south of the City of Morgantown, Monongalia County, West Virginia (Figure 1). The project area is located along U.S. Route 119 near its intersection with Owl Creek Road (County Road 119/7) and Phillips Road (County Route 119/8). The project area is underlain by the Upper Freeport Coal, which is approximately 4.5 feet thick, at depths varying from approximately 70 to 160 feet. The dip of the seam is to the northwest at approximately 11% (Omega Mining Company Mine Map, 1985). The seam was mined by Omega Mining Company, Inc. in the 1980's/early 1990's, in an operation called Omega Mine No. 100 (Omega Mine).

Acid mine drainage was noted to be discharging from the Omega Mine site and impacting Owl Creek and other watersheds located geologically down-dip of the mine during operation of the mine. (The Owl Creek watershed and these other watersheds lie generally to the west of U.S. Route 119 [See Figure 1]). These watersheds were already impacted by AMD from older mine operations in the area. Accumulation of water in the mine after closure resulted in additional AMD discharges into the Cobun Creek watershed east of the mine. (The Cobun Creek watershed lies generally east of U.S. Route 119.) After discovering the AMD discharges east of the mine, horizontal relief drains were installed to lower the water level in the mine in order to reduce the discharges into the Cobun Creek watershed. Collection points were then established to direct the AMD discharge to a central treatment facility. In early 1995, the WVDEP took over treating the AMD from the site. Treatment costs (labor and materials) are approximately \$300,000 per year.

Concurrent with other activity at the site in the early 1990's, public and private entities completed investigations of the feasibility of utilizing injection of grout materials to reduce AMD. Eventually, an agreement was reached between WVDEP, Monongahela Power Company, a subsidiary of Allegheny Power (formerly Allegheny Power Systems, APS); Anker Energy Corporation (Anker); Consol, Inc. (Consol); United States Office of Surface Mining Reclamation and Enforcement (OSMRE); and the Electric Power Research Institute (EPRI) to contribute funds for the project. The agreement dictated that only the north lobe of the mine would be grouted with coal combustion by-products (CCB). Existing water quality data indicated that the majority of the acidity at the site came from the north lobe (GAI Acidity Estimate, 1995). The north lobe encompasses approximately 26 acres of the 170 acre Omega Mine. The agreement provided that CCB's from APS (fly ash) and Anker (hauler of fluidized bed combustion [FBC] ash from the Morgantown Energy Associates [MEA] power station) would be evaluated for use in the grout mixes.

Although the Omega Mine was a post-1977 deep mine, the WVDEP Abandoned Mine Lands (AML) Section took over administration of the design and construction contract. This was due to AML's expertise with subsurface grouting projects (having completed 100 plus subsurface grout projects to prevent mine subsidence), and disproportionate financial interest in the project. GAI Consultants, Inc. (GAI) was selected as the design contractor. A borehole video camera and crew

were provided by the OSMRE, at the request of the WVDEP.

Field Investigations

An inventory of existing site discharges was deemed a prudent initial step in the field investigation. Many seeps on or adjacent to the site were being monitored by the United States Bureau of Mines (USBM) and the WVDEP. Many of the seeps have been monitored on a regular basis since the late 1980's. A report on the pre-construction water quality will be submitted prior to construction. This data base will allow for comparison of pre-construction water quality data with post-construction water quality data. There are some punch mines (small local mines, possibly used by individuals for home heating) discharging AMD in the area that were not included in the scope of work for the project. These mines are not associated with the Omega mine.

A subsurface investigation of the project area was completed by drilling 17 borings: 14 air rotary drill holes and 3 core holes. The borings were drilled to obtain information on soil and rock conditions above the Upper Freeport Coal, mine voids, and coal thicknesses. The borings provide geological information such as rock type, occurrence of voids and their location, and broken rock thicknesses. The exploratory borings were cased into rock and left open for future use or closure during the grouting operation.

Mine mapping of the Omega Mine indicated that approximately 40% of the north lobe was first-mined (development mining only), while approximately 60% of the north lobe was second-mined (commonly known as retreat mining). In borings that encountered mine voids, borehole camera work was performed by the OSMRE to document existing mine conditions (OSMRE Memo and Videotapes, 1996). Mine workings generally appeared open in first-mined areas, while workings in second-mined areas appeared partially collapsed, thus partially confirming the accuracy of the mine maps. Extraction rates in the workings (based upon area measurements from the mine map) are approximately 50 and 75 percent in the first-mined and second-mined areas, respectively.

Also included in the field investigations was surveying. Base mapping for the project was produced in early 1996, and was provided by the WVDEP. Surveying was utilized to:

- locate noteworthy features not picked up by the aerial mapping, such as seeps, punch mines, old foundations, etc.;

- confirm the structural contouring presented on the mine map, in conjunction with other data; and
- locate the borings relative to the mine map (by tying-in to the mine map control system) prior to aerial mapping development to allow for drilling into selected portions of the mine, and to locate "as constructed" borings which were adjusted from originally proposed locations due to field conditions.

Laboratory Investigations

Project Goals

The goals of the grouting program, as identified in discussions between WVDEP and GAI, were as follows:

- The primary requirement of the grout is to fill the mine voids of the north lobe of the Omega Mine to reduce contact of water and air with acidic material, with a secondary requirement that the grout have some alkaline leaching potential to help treat AMD.
- The set-up grout mix must have sufficient strength to allow it to prevent mine subsidence.
- Use of a mixture of fly ash and FBC material is preferred so that the project will demonstrate the synergistic attributes of the combined materials.

To meet these goals in an economical manner requires utilizing as few injection holes as possible. To accomplish this the grout must be fluid, have stability and develop reasonable strength and dimensional stability.

Project Approach

In response to the various project goals outlined above, GAI developed a two-part approach. The first part involved site reconnaissance and subsurface investigation to characterize the mine and provide information used in selection of appropriate grout performance, design of the grouting program, and assessing the generation of AMD. The subsurface investigation was to characterize voids in first and

second mined areas to estimate grout quantities, assess the magnitude and areal extent of roof falls and estimate their effect on grout flow, and evaluate the ability to fill the mine with grout. This investigation is described in more detail in the preceding section.

Simultaneously, the second part of the approach involved a laboratory testing program designed to evaluate potential grout components and to select and evaluate a grout mix(es) of suitable character for the injection program. Data from the subsurface investigation were utilized to develop material parameters and the laboratory program to facilitate the selection of the grout mix(es) that would best meet the requirements of the overall project goals.

The laboratory testing program was initiated with the objective of identifying a grout mixture(s) within 60 days of GAI commencing work. This time frame was selected so the preferred grout(s) could then be further tested prior to beginning the injection program. This required the application of prior knowledge and experience to achieve the objective and precluded an extensive test program that evaluated small, incremental changes in mixture components.

Laboratory Methods

The laboratory testing was conducted in two phases. The first phase was a preliminary material screening. The second phase involved mix design and product evaluation.

The laboratory test program evaluated the various grout mixtures by using the following principal criteria:

- Flowability, determined by flow cone measurements of approximately 60 seconds, indicating that the grout would flow in the mine without separating into solid and liquid portions, and could be expected to flow into small voids.
- Set time, determined to be approximately 2 days for final set, indicating that the grout would remain in place and not flow to other portions of the mine, causing loss of roof contact, when injection at that location ceased.
- Dimensional stability indicating that, after placement and final set involving approximately ± 1 percent shrink/swell, the

- grout mix would have no tendencies to shrink or swell in the long term.
- **Unconfined compressive strength** indicating the grout has the integrity to resist overburden pressures; strength development under simulated mine conditions was used to determine what degree of cementing of the grout product was occurring and to compare the various grout mixtures. Strength was, in this case, a secondary consideration in the grout selection process and, therefore, no specific strength criterion was established for the grout.
- Dimensional stability throughout the test period;
- Low permeability;
- Little potential to leach metals to groundwater;
- Relatively insensitive to variations in mix components.

An additional consideration in the design of the grout(s) was that the contractor might not have refined mixture control devices. It was therefore important that the mix be readily achievable with unsophisticated equipment, be easily monitored by the engineer, and be relatively insensitive to minor variations in mix components.

A portion of the testing program evaluated the grout mixtures in simulated mine conditions. That is, the grout was cured at 50°F in air and in mine water so that set time, dimensional stability, and strength could be evaluated and predicted for field conditions.

Permeability testing was conducted to determine if the grout would reduce the potential for water and air to contact acidic material. TCLP leaching analysis was conducted to evaluate possible leachate production from the grout.

The test program indicates that by blending the candidate materials an acceptable grout mix can be provided. The FBC material ash has the potential to provide strength to the grout while the coal combustion fly ash enhances the fluidity of the grout. The addition of 2 percent cement provides dimensional stability to the hardened grout product. Therefore, it was suggested that a grout blend of 49 percent FBC material ash + 49 percent coal combustion fly ash + 2 percent cement with enough water added to produce a grout having a flow cone value of 60 seconds be used.

The suggested grout mix demonstrated the following characteristics in the laboratory:

- Flow without separating into solid and liquid portions;
- A set time of approximately 2 days (so that it will remain in place following injection);

These characteristics meet the primary project goal because the grout will fill mine voids in the north lobe of the Omega Mine to reduce AMD generation and will have sufficient strength to prevent mine subsidence. In addition, the grout will have some alkaline leaching potential and will utilize a mixture of fly ash and FBC material. Furthermore, the grout will be easy to mix in the field with typical construction equipment and be easy to monitor by the engineer. (GAI Laboratory Test Program, 1996.)

Acid/base accounting tests were performed on coal samples from the exploratory borings, as well as on rock samples from the overburden (from the first two distinct strata over the mine: a sandstone and a silty sandstone) and mine floor to help evaluate the acid generating potential of the strata in the area of the mine. Laboratory procedures used were in accordance with published procedures (Sobek, 1978). Samples were taken for discrete intervals of strata from two core borings. The percent total sulfur and neutralization potential (NP) were measured for each sample. The maximum potential acidity (MPA) and net neutralization potential (NNP) were then estimated for each sample. All were expressed in equivalent tons of CaCO_3 per one thousand tons of material. The MPA was calculated by multiplying the percent total sulfur by 31.25, a conversion factor that assumes all sulfur contributes to acidity (this possibly overestimates the MPA). The NNP was then estimated by subtracting the MPA from the NP. In all samples except one, the MPA was greater than the NP. Review of the NNP values listed in Table 1 indicates that the AMD potential of the Upper-Freeport Coal is much greater than surrounding strata as indicated by the coal's NNP values of approximately 10 to 100 hundred times the associated strata NNP values.

Thus, based on estimated NNPs, the strata near the mine (where water may flow after injection is completed in the mine) has much less potential to contribute AMD than the mined Upper Freeport Coal.

Remediation Plan

A remediation plan was developed utilizing the subsurface injection of CCB grout to help reduce the generation of AMD from the north lobe of the Omega Mine. Vertical injection holes are proposed. The injection hole layout assumes injected material will flow 100 feet in more open mine entries (i.e. - generally areas of first-mining) and 50 feet in entries where broken material (i.e. - generally areas of second-mining) may reduce grout flow. The injection plan is shown in Figure 2.

Injection of materials is to commence with barrier injection holes at the south end of the project site. This will block the inflow of water from updip portions of the mine. The injection program will then proceed downdip, beginning with the second-mined areas. The

next area to be grouted will be the first-mined area to the east of U.S. Route 119. The final area to be grouted will be the area west of U.S. Route 119 in the vicinity of the horizontal drains. The sequence of injection is intended to allow water to drain from the mine during construction, probably through the existing horizontal drains. The WVDEP will have the flexibility of adjusting the grouting sequence depending on the flow of grout. Grout flow may be such that some injection holes can be eliminated by the WVDEP. If water is encountered, the specifications direct the Contractor to add it (via potential pumping to other locations in the mine or to the existing collection system) to the flows being treated by the WVDEP.

A barrier is not proposed for the downdip portions of the mine workings. This decision was based on the lower probability of completely filling the mine voids

Table 1. Acid/Base Accounting Results

Sample ID	Strata	Neutralization Potential (NP) tons CaCO ₃ equiv/thousand tons material	Total Sulfur %	Maximum Potential Acidity (MPA) tons CaCO ₃ equiv/thousand tons material (calculated from % total sulfur)	Net Neutralization Potential (NNP) tons CaCO ₃ equiv/thousand tons material
CB-2 1	Sandstone	3.5	0.13	4.1	-0.6
CB-2 2	Silty Sandstone	1.0	0.39	12.2	-11.2
CB-2 3	Upper Freeport Coal	<1	12.19	380	-380
CB-2 4	Shale (underclay)	2.5	1.29	40.3	-37.8
CB-3 1	Sandstone	7.0	0.09	2.8	4.2
CB-3 2	Silty Sandstone	2.0	0.63	19.7	-17.7
CB-3 3	Upper Freeport Coal	<1	5.32	170	-170
CB-3 4	Shale (underclay)	3.8	0.16	5.0	-1.2

with a stiffer mix, along with the increased construction cost of the additional holes that would be required. Seeps (existing or new) adjacent to the site will need to be monitored on a regular basis for indications of grout leaking from the mine. The cleanup of any blowouts is currently specified to be an incidental cost to the Contractor. The grout plan minimizes the effects of blowouts by requiring the monitoring and giving the WVDEP the ability to alter the grout sequence if blowouts occur.

Construction documents include technical specifications with appended survey notes, boring logs, and an eight sheet drawing package that depicts existing features, mine map including structural contouring, existing borings, proposed injection holes, construction limits, tax mapping, and details.

Cost and Construction Duration

GAI estimates that the remediation plan will require drilling approximately 200 injection holes for a total of approximately 26,000 lineal feet of drilling. All holes may not have to be drilled depending on actual mine conditions and on the flow of grout within the mine. Some of the existing exploratory holes will be utilized as injection and monitoring points, while others will only be closed. Approximately 118,500 cubic yards of material are anticipated to be injected. The estimated grout quantity assumes that previous coal extraction and injection volumes are equivalent. The engineers estimated cost is \$2,500,000. A contract was awarded in late 1997 at a value of \$2,200,000 to Howard Concrete Pumping of Bridgeville, Pa. Construction will occur in the spring and summer of 1998.

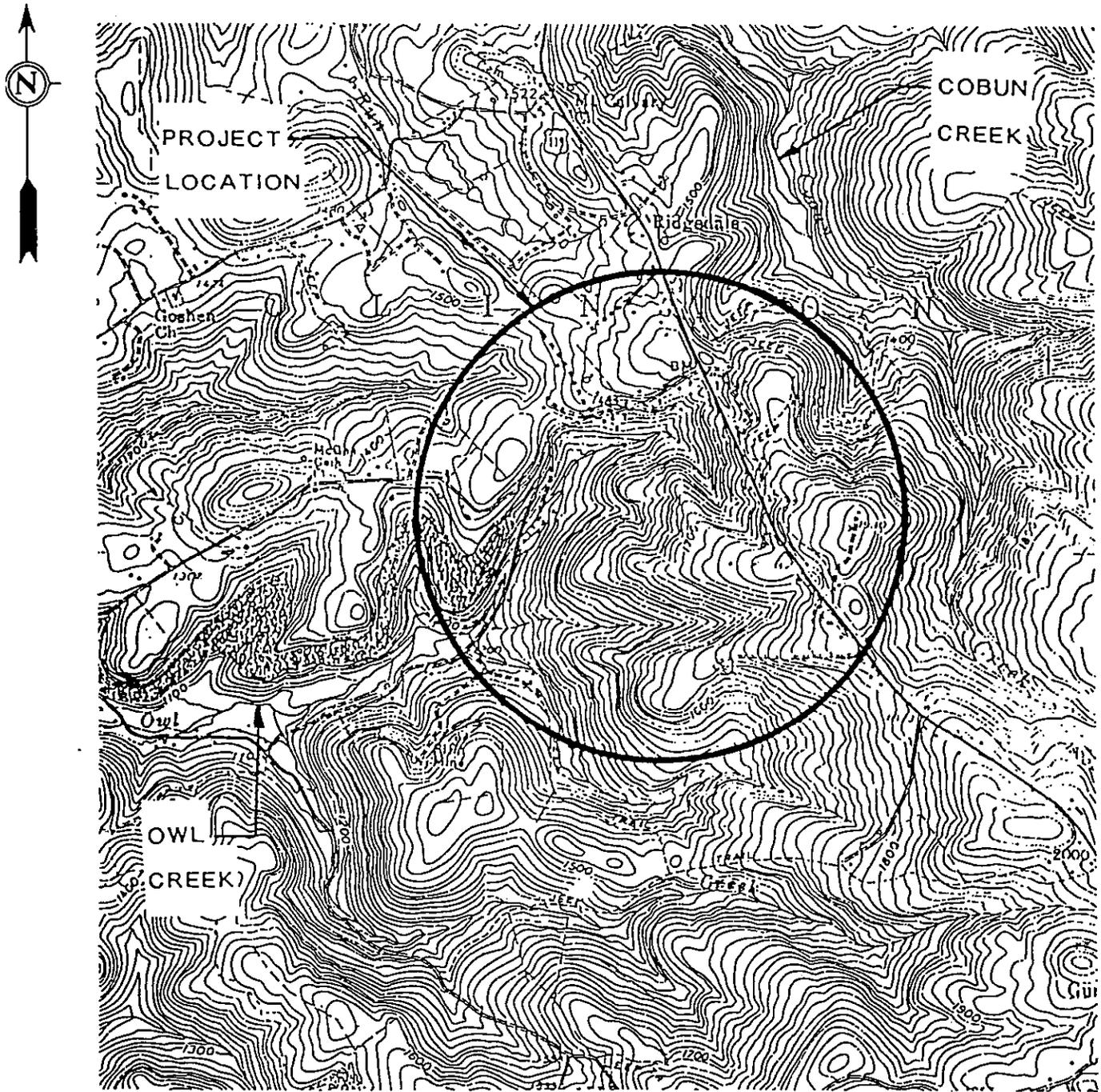
The injection period would be on the order of 30 weeks if 4,000 cubic yards were injected per 5-day paper work week, although the total construction period may be somewhat longer due to site preparation, demobilization, etc.

Summary

An innovative procedure of injecting grout into the mine workings to reduce AMD and the resulting treatment costs is proposed. The procedure involves injecting grout mixes composed primarily of coal combustion byproducts (CCB's) and water, with a small quantity of cement. The intention of the injection program is to fill the mine voids in the north lobe of the Omega Mine (an area where most of the acidity is believed to be generated) with the grout, thus reducing the contact of air and water with potentially acidic material. The preliminary grout mix design consists of an approximate 1:1 ratio of fly ash to byproducts from fluidized bed combustion. Approximately 100 gallons of water per cubic yard of grout is used to help achieve flowability. The construction documents have been prepared, and the project was bid in late 1997. The engineer's cost estimate was approximately \$2,500,000, with a contract valued at \$2,200,000 being awarded to Howard Concrete Pumping of Bridgeville, Pa. Construction will occur in the spring and summer 1998.

Literature Cited

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MAPPING REFERENCE:
MORGANTOWN SOUTH, WEST VIRGINIA
U.S.G.S. 7.5 MINUTE QUADRANGLE
1957 (PHOTOREVISED 1976)

Figure 1
Site Location

OMEGA MINE COMPLEX

INJECTION PLAN

Figure 2

NORTH LUBE

