U. S. DEPARTMENT OF ENERGY PROJECTS INVOLVING THE USE OF COAL COMBUSTION BYPRODUCTS IN MINING APPLICATIONS[1]

by

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Abstract. The onset of utility deregulation now makes it apparent that coal combustion by-product (CCB) utilization is one key area that may help utilities better manage their available resources. Because current utilization rates of CCB's are relatively low, the United States Department of Energy is actively co-sponsoring a variety of CCB utilization projects, along with projects that seek to characterize the by-products resulting from newly-developed technologies for coal combustion, gasification, or flue gas cleanup. Mining applications represent a potential high-volume market for CCB's, with beneficial uses that include the prevention or control of acid mine drainage, surface subsidence over underground mines, and reclamation of acidic surface mine spoils. Future applications may include the development of CCB-based construction materials for use in mining and the selective backfilling of CCB's to increase underground coal mine extraction rates. The goal of these projects is to demonstrate that CCB's are of significant value when used in mining applications, and that CCB utilization in mines represents more than just a cheaper alternative to landfill disposal.

Additional Key Words: fly ash, flue gas desulfurization, fluidized bed combustion, low-NO_x burners

Introduction

Although world-wide coal consumption has increased only about 10% the past 15 years, U. S. coal consumption has increased by 25%. The U. S. produced approximately 1 billion short tons of coal in 1996 and possesses over 200 years of coal reserves based on current production estimates. Electric utilities consume about 90% of the coal produced annually in the United States. Additionally, electricity generated from coal accounts for almost 60% of the annual U. S. production with oil, natural gas, and hydro power producing less than 10% each. These statistics indicate that coal should continue to be a key fuel source for at least several decades to come (Energy Information Administration, 1996).

As a result of coal's dominance of the U. S. electricity market, a necessary residual has been and will continue to be the production of large amounts of solid coal combustion byproducts (CCB's). As shown in Table 1, over 100 million tons of the four "conventional" CCB materials — fly ash, bottom ash, boiler slag, and flue gas desulfurization (FGD) material — were produced in the United States in 1997, but less than 30 percent were recycled for productive purposes (American Coal Ash Association, 1998). The remainder were disposed of in landfills or sluice ponds, representing both a significant cost to electric utilities (and ultimately to their customers) and the waste of raw materials that could potentially be of greater value if they were utilized rather than disposed.

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Table 1. 1997 Coal Combustion By-Product Production and Utilization (in short tons)

CCB Type	Production	Utilization	Percent Utilized
Fly ash	60,264,791	19,317,362	32.1%
Bottom ash	16,904,663	5,096,905	30.2
Boiler slag	2,741,614	2,578,851	94.1
FGD materials	25,163,394	2,183,363	8.7
TOTAL	**105,074,462**	**29,176,482**	27.8

Importance of Mining in CCB Utilization

Table 2 shows that over 1.6 million tons of "conventional" CCB's per year are being used for mining applications. This is only about 6 percent of the total amount of CCB's utilized in all applications, and less than 2 percent of the total production of CCB's. By contrast, in recent years, mining applications have played a very important role in the utilization of fluidized bed combustion (FBC) ash, a "non-conventional" type of CCB. Figure 1 shows that almost 60 percent of all the FBC ash generated during 1990 through 1995 was used in mining applications (Council of Industrial Boiler Operators, 1997). More than twice as much FBC ash was used at mine sites than was disposed, and the FBC utilization rate in mines was almost twice the overall 1997 utilization rate of conventional CCB's. It is reasonable to assume that the ability to use FBC ash in mining applications has improved the overall economic viability of FBC boilers, and has allowed the annual production of FBC ash to increase from about 1.6 million tons in 1990 to almost 6 million tons in 1995.

Table 2. Use of Coal Combustion By-Products (short tons)

Application	Fly Ash	Bottom Ash	Boiler Slag	FGD Material	Amount Utilized
Cement/concrete/grout	9,421,903	604,705	10,755	202,423	10,239,786
Structural fill	2,877,535	1,384,327	84,669	91	4,346,622
Waste stabilization/solidification	3,117,947	206,368		15,428	3,339,743
Road base/subbase	1,417,600	1,286,585	792	17,797	2,722,774
Blasting grit/roofing granules		159,749	2,288,581		2,448,330
Mining applications	1,413,567	162,638		104,690	1,680,895
Wallboard				1,603,762	1,603,762
Snow and ice control		723,615	56,057		779,672
Mineral filler	285,580	130,888	108,796		525,264
Flowable fill	386,158	15,260			401,418
Agriculture	34,571	8,197		55,644	98,412
Miscellaneous/Other	362,501	414,572	29,200	183,527	989,800

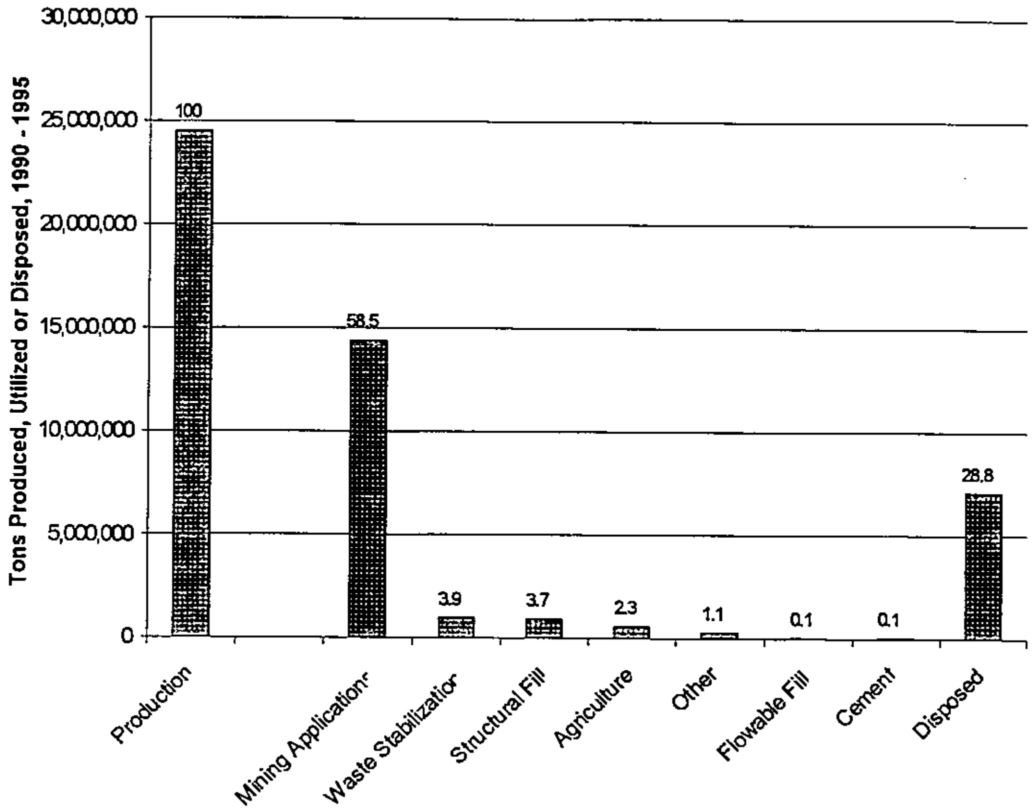

Figure 1. Production, Use, and Disposal of Fluidized Bed Combustion Ash, 1990-95

The relatively high utilization rate of FBC ashes in mining compared to conventional CCB's has resulted from several interrelated factors. Many FBC boilers burn coal refuse from an abandoned coal mining or preparation facilities that are already causing environmental or safety problems (acid mine drainage, erosion, unstable slopes, etc.). Since the FBC ash usually contains significant amounts of free lime, which helps neutralize acid-forming materials that are commonly found in the coal refuse, the haulback of the entire ash output of the FBC boiler to the mine site is often looked upon very favorably by environmental regulatory agencies. Regrading of unstable slopes and establishment of vegetation and erosion controls at the coal refuse site also occurs as a natural consequence of the ash haulback operation. The FBC operation is thus viewed as a means of achieving environmental remediation at no cost to the taxpayer, and the placement of the ash at the mine site is considered a beneficial re-use rather than a disposal method. Haulback of highly alkaline FBC ash to active surface mining operations in historically acid-producing coal seams has also been strongly encouraged by regulators; such haulback can even help companies obtain mining permits in such areas. (Hamric, 1995)

Coal refuse material has a very low heating value and high pyrite content compared to coal, and it cannot be used in standard pulverized coal (PC) boilers that are the source of conventional CCB's. Moreover, the source of coal to PC boilers is almost always an active mining site rather than an abandoned site that is already causing environmental problems. Therefore, the perceptual and regulatory advantages associated with an FBC ash haulback operation do not often accrue to the haulback of conventional CCB's. While most state regulatory agencies do allow conventional CCB's to be hauled back to mine sites, this practice is often viewed merely as an alternative method of waste disposal rather than a beneficial re-use of the CCB material. The transportation costs associated with 100% haulback to source mines are usually too high to allow the CCB producer to forego the construction and operation of a regulated disposal facility near the CCB production site. Therefore, in order for more conventional CCB's to be used in mining applications, it is first necessary to demonstrate that these applications can be of significant practical and economic value rather than just a convenient alternative to landfill disposal.

Summaries of Projects Sponsored by DOE-FETC

The U. S. Department of Energy's Federal Energy Technology Center (DOE-FETC) has co-sponsored several research, development and demonstration projects that have helped the utilization of FBC ash in mining applications to become a readily accepted practice. DOE-FETC is currently dedicating significant resources toward the development and demonstration of the practical and environmental benefits of large-scale utilization of conventional CCB's at mine sites. Table 3 lists the mining-related CCB utilization projects that have been co-sponsored by DOE-FETC since 1990.

Table 3. List of CCB Utilization Projects Sponsored by DOE-FETC

Project Title	Project Performer(s)	Co-funding Organization(s)	Mine Site Name; Location	Status
Land Application of Dry FGD Byproducts	Dravo Lime Co. Ohio State Univ. US Geol. Survey	OH Coal Dev't Office Elec. Power Research Inst. American Elec. Power Co. Ohio Edison Co.	Fleming AML; Tuscarawas Co., OH	Complete
Reclamation of Acid Coal Mine Spoils Using Wet FGD Byproducts	Ohio State Univ.	U.S. Bureau of Mines	Caldwell AML; Noble Co., OH	Complete
Abandoned Underground Mine Reclamation with Clean Coal Byproducts	West Virginia Univ.	Anker Energy Corp.	Fairfax mine; Longridge Mine; Preston Co., WV	Complete Active
Backfill of Abandoned Highwalls Using FGD-Derived Cements	Univ. of Kentucky	Addington, Inc.	Ivy Creek mine; Floyd Co., KY	Complete
Management of Dry FGD By-Products in Abandoned Underground Mines For Subsidence Control	Southern Illinois Univ.	Illinois Clean Coal Inst. Illinois Dept. of Commerce and Community Affairs	Peabody No. 10 mine; Pawnee, IL	Complete
Injection of FGD Grout to Abate Acid Mine Drainage in Underground Coal Mines	American Electric Power; Ohio State Univ.	OH Coal Dev't Office OH Dept. Natural Res. Ohio EPA US Ofc. of Surface Mining Amer. Coal Ash Assoc. Dravo Lime Company	Roberts-Dawson mine; Coshocton and Muskingum Co. OH	Active
Injection of CCB's into the Omega Mine for the Reduction of Acid Mine Drainage	West Virginia Div. of Environmental Protection	Anker Energy Inc. CONSOL, Inc. US Ofc. of Surface Mining Elec. Power Research Inst. Allegheny Power	Omega mine; Monongalia Co., WV	Active

In almost all cases, the projects have involved substantial levels of cost sharing among electric utilities, mining companies, universities, other State and Federal government agencies, and other private sector organizations. The remainder of this paper contains brief summaries of the projects listed above, along with descriptions of two potential new projects in mine-related CCB applications.

Land Application of Dry FGD Byproducts

Dry FGD byproducts were used in the reclamation of an abandoned, acid-producing surface coal mine site (Fleming site) in eastern Ohio (figure 2). Six 1-acre test "watersheds" were re-soiled with various mixtures of atmospheric fluidized bed combustion (AFBC) ashes and yard-waste compost and their performance was compared to that of standard cover soils (Stehouwer, et al., 1996). All test watersheds showed complete vegetative cover, improved runoff pH from less than 4 to greater than 7, and decreased soluble Al. The standard borrow soil provided greater biomass production, and lower concentrations of Ca and S in runoff water than the AFBC-amended plots. Boron was the only trace element whose concentration increased in the AFBC-amended spoil and water, but this increase was not enough to cause any negative effects on vegetation. Concentrations of other trace elements in all water sampled remained very low and showed almost no treatment effects.

The test watersheds were surrounded by an additional 7-acre area of mine spoil that was reclaimed by applying a mixture of pressurized fluidized bed combustion (PFBC) ash at 125 t/acre and yard waste compost at 50 t/acre. An intensive monitoring program consisting of on-site precipitation measurement, ground water monitoring wells upgradient and downgradient of the PFBC-amended area, lysimeters in the unsaturated zone beneath the reclaimed area, and surface water flow and quality measurements was conducted before and after reclamation (Dick, et al., 1999). Interstitial waters in the FGD application area had higher pH and specific conductance values than waters collected in the resoiled area, along with higher concentrations of SO_4, Mg, B, Cl, and F. This indicated some dissolution of the FGD byproduct in the unsaturated zone.

Ground water flow and solute transport modeling studies (figure 3)indicated that the time required for a dissolved constituent to travel through the groundwater flow system at the site (from entry at the water table beneath the reclaimed to discharge at a ground water spring) would range from 228 days to 26.9 years. Based on chemical and sulfur isotope data, ground water at the site had not yet been affected 16 months after the initial application of the PFBC material. Longer term monitoring at this site is being conducted to determine whether any ground water effects of the PFBC application can be detected.

As part of this project, an economic model to estimate the social benefits of strip mine reclamation via FGD byproduct reclamation was developed. One lake impacted by mining (and targeted for reclamation via FGD byproducts) and one unimpacted lake were chosen for analysis. The results showed that a potential annual net benefit of \$4,390 to lakeside property values and an upper bound estimate of over \$250,000 of potential annual recreation benefits could result from future reclamation of strip mines in the watershed of the impacted lake.

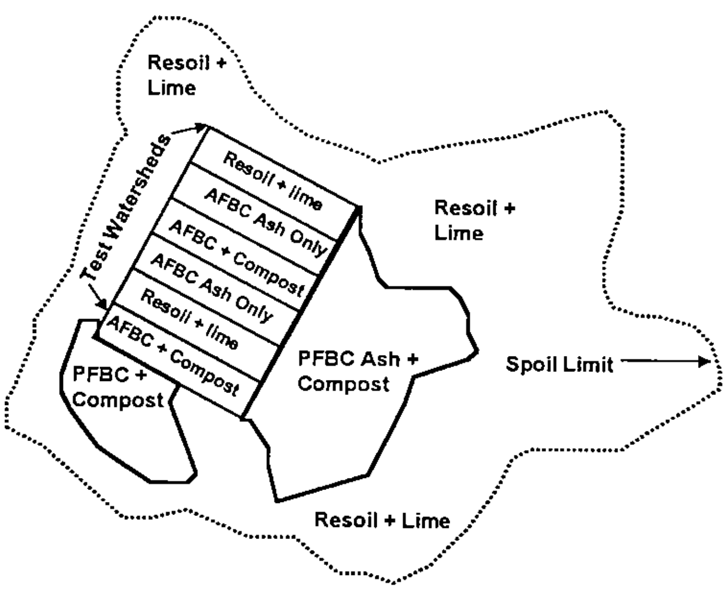

Figure 2. Layout of FBC Reclamation Area at Fleming Abandoned Mine Site

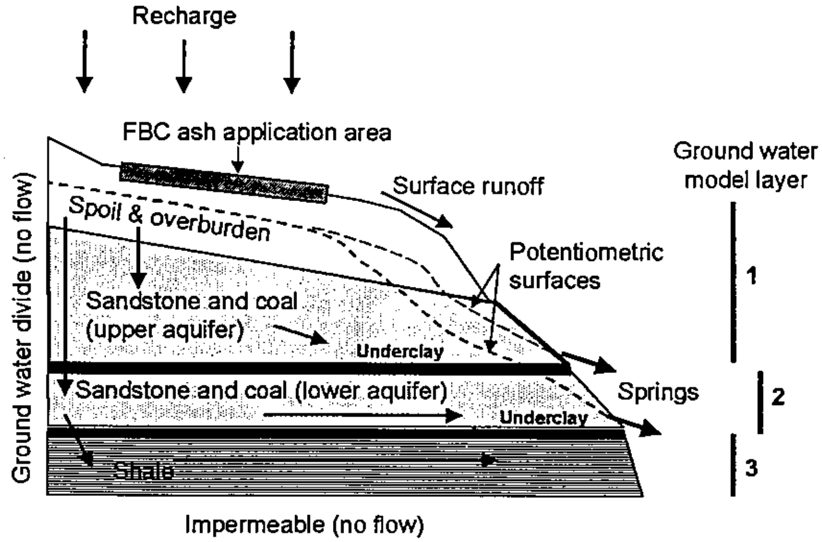

Figure 3. Conceptual Ground Water Flow Model, Fleming AML Site

Reclamation of Acid Coal Mine Spoils Using Wet FGD Byproducts

The objective of this project (Kost, et al., 1998) was to evaluate two types of wet FGD by-products for effects on vegetation establishment on acid minesoils and concurrent effects on surface and ground water quality. One FGD by-product was a calcium sulfite sludge that had been stabilized with fly ash at a ratio of approximately 1:1. The other FGD material was a calcium sulfate (gypsum) by-product with about 4% magnesium hydroxide [$Mg(OH)_2$]. Six soil amendment types were evaluated at an acidic mine spoil site (Caldwell site) in Noble County, OH that was devoid of natural vegetation. Each FGD by-product was used as a soil amendment by itself; each by-product was also mixed with sewage sludge and used as an amendment. Local topsoil and sewage sludge were used as control amendments. Plant growth, plant tissue composition, soil composition, and surface and subsurface water quality were monitored for two years.

All treatments resulted in a complete herbaceous cover, with the sewage sludge and FGD-amended plots resulting in plant cover that equaled or exceeded that of the control (local topsoil) plot. . Elevated concentrations of boron were found in the soil, vadose water, runoff water, and plant tissue associated with the FGD-amended plots, but there was no evidence of plant toxicity or reduced growth due to the elevated boron levels. With the exception of Ca, SO_4, B, and Mg (for the Mg-gypsum plots only), there were little or no significant differences between the concentrations of dissolved constituents in vadose or runoff water of the FGD-amended plots compared to those of the control plots. In runoff water, no significant differences in the concentrations of trace metals of environmental concern were found between the control and FGD-amended plots.

Abandoned Underground Mine Reclamation with Clean Coal Byproducts - Fairfax Mine

Underground injection of alkaline fluidized bed combustion (FBC) ash was pursued as a means of preventing and controlling both surface subsidence and acid mine drainage. By filling the mine voids, the ash keeps air out of the workings and helps prevent pyrite oxidation from starting. The alkalinity of the ash also reduces the oxidation rates in areas where air may remain, and neutralizes any acidity already generated.

Underground injection of FBC ash was first demonstrated at the Fairfax mine using a grout recipe that included 5% bentonite to provide greater flowability at high solids content with decreased risk of solids settling during the pumping process. In this pilot-scale test (1000 yd^3 of grout) the grout filled the void to within 10 in. of the roof at the injection point and flowed 600 feet laterally from the injection borehole (figure 4) After hardening, the grout reached compressive strengths typically in excess of 600 psi, which was more than sufficient for subsidence control at this site (Ziemkiewicz, et al., 1998).

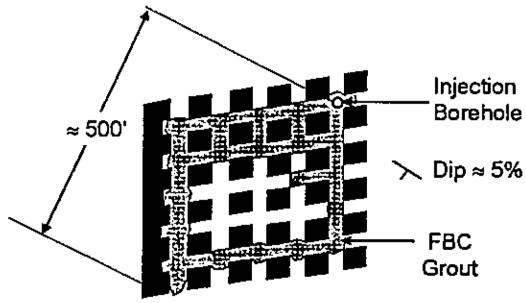

Figure 4. FBC Grout Flow at Fairfax Mine

Abandoned Underground Mine Reclamation with Clean Coal Byproducts - Longridge Mine

The Longridge site was originally intended to be a scale-up of the Fairfax mine project, using FBC grout to control an existing AMD discharge (36 gpm) at the field scale. However, because the FBC ash source near the mine site was in such great demand as an AMD ameliorant at active surface mines, the supply of FBC ash needed to perform the Longridge injection project was not available. Instead, a set of alternative mixtures consisting of varying proportions of Class F fly ash, cement kiln dust, and crushed limestone (3/4" x 0) was developed for injection to the mine.

In order to maximize the potential for AMD control, the injection plan is based on the results of the hydrologic investigation at the Longridge site. The mine discharge emanates from an auger hole that had been drilled through the coal barrier to intercept the mine pool at the down-dip end of the mine workings (figure 5). The plan is designed to cut off the recharge coming from the up-dip sections of the mine. In order to do this, the mine is being divided into three separate "cells." A cell in the farthest up-dip area of the mine is being created first, with the subsequent two cells progressing in the down-dip direction. The down-dip end of each cell consists of a dry barrier of limestone gravel that is injected pneumatically across selected mine entries. Next, a thick grout consisting of 44% cement kiln dust, 28% fly ash, and 28% limestone gravel is injected immediately behind the gravel barriers to strengthen the seal. Finally, a more fluid grout mix consisting of 60% fly ash and 40% cement kiln dust is being injected to completely fill the remainder of the cell. This procedure is expected to result in more roof contact and less chance of AMD blowouts due to ungrouted mine voids.

An estimated 50,000 cubic yards of grout will be used in the Longridge project. Since AMD control was the primary concern rather than subsidence, a water:solids ratio of 1:1 (by weight) and a design strength of 250 psi was chosen for the fluid grout. The make-up water for the grout is taken from an AMD-impacted stream adjacent to the Longridge mine.

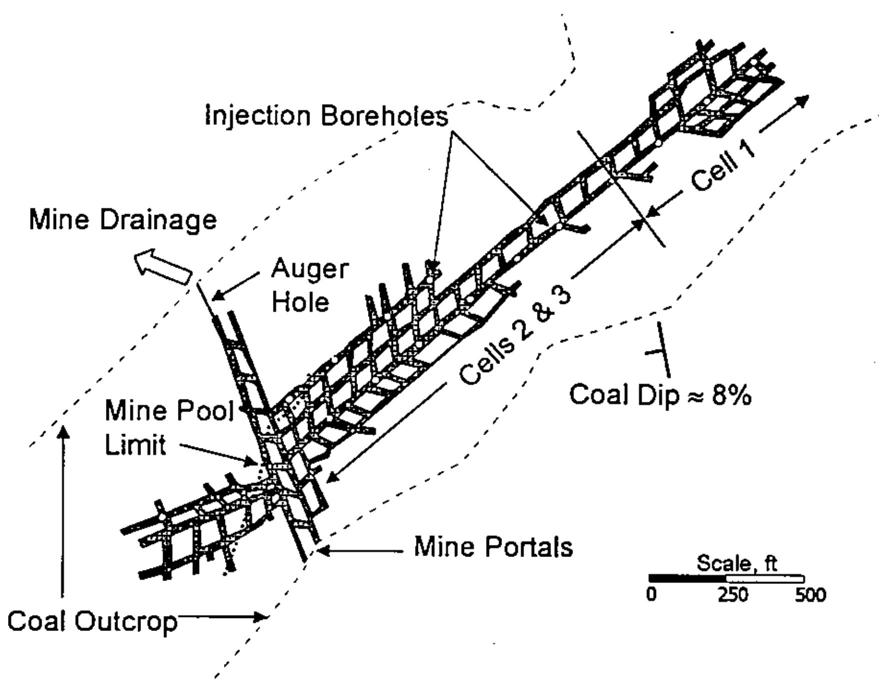

Figure 5 - Longridge Mine CCB injection Plan

Backfill of Abandoned Highwalls Using FGD-Derived Cements

There are an estimated 5,000 miles of abandoned highwalls in the Appalachian coal fields which were auger-mined prior to abandonment. Auger mining makes the highwall too unstable to allow the recovery of the coal, even with modern, remote-controlled highwall mining equipment. This "stranded" coal represents billions of tons of America's best coal. At the same time, the augered highwalls present a serious risk of landslides, slumps, and acid drainage.

This project investigated the use of dry flue gas desulfurization (FGD) materials as a low cost grout to fill auger holes in abandoned highwalls, thereby strengthening the face so that the residual coal web can be recovered. Most dry FGD materials form an expansive cement when mixed with water. Optimizing these cements creates a material that completely fills the highwall voids and becomes a self-stressing roof support. Construction procedures for FGD materials were found to be similar to those used for concrete. The FGD material was wetted to minimize dust and to meet EPA air quality standards. Additional mix water was added at the loadout facility to bring the FGD-mix to its desired slump of 10 inches prior to its loading into standard cement trucks. Continued moisture loss associated with hydration reactions of the FGD material while in transit required that additional mix water be added at the site prior to emplacement to optimize the slump for pumping.

The optimized FGD mixture was placed in the auger holes using a high capacity concrete pump. A sandbag bulkhead was constructed to keep the FGD material in the auger hole, and the pump discharge was extended approximately 40 feet into the hole so that the entire void is filled. These placement procedures have been documented with a low-light video camera mounted on a robot.

Management of Dry FGD By-Products in Abandoned Underground Mines For Subsidence Control

In the State of Illinois, high-sulfur coals are mined by underground methods at depths of 200 to 400 feet below the ground surface. Prime agriculture lands and shallow ground water resources can be damaged by surface subsidence that is related to such mines. The placement of large volumes of FGD by-products into underground mines for the purpose of controlling surface subsidence represents a significant beneficial use of these materials. Since the geologic strata surrounding the mines generally have very low permeabilities, the volume of leachate from FGD by-products placed in the mines is likely to be very small. Furthermore, the ground water in these deeper strata is already non-potable due to extremely high concentrations of dissolved natural salts (primarily sodium and chloride), so the leachate, if it occurs, is very unlikely to cause appreciable environmental degradation (Chugh, et al., 1997a). The objectives of this project were to develop and demonstrate hydraulic and pneumatic backfilling technologies that could be used to inject FGD by-products in abandoned underground mines in Illinois, and to determine their effectiveness in subsidence mitigation. (Chugh, et al., 1997b).

For hydraulic injection, the optimum procedure was to use a front-end loader to blend a mixture of fly ash and bottom ash (mixture obtained from a disposal pond at a power plant) with FGD scrubber sludge on the surface at the field site. The resulting mix (52% fly ash/bottom ash, 48% FGD sludge) was conditioned with 2-3% lime, mixed with water in a pug mill to produce a slurry with 71-75% solids (8-10 inch slump), and pumped into the injection borehole with a 750 psi concrete pump. Over 5,600 yd^3 of grout were injected into an abandoned section of the Peabody #10 mine through two boreholes at average pumping rates of 105 tons/hr. The 28-day compressive strength of grout samples exceeded 300 psi. Borehole camera observations indicated that the grout completely filled the open voids (6.75 ft entry height) available in the test section. No significant problems occurred with the grout materials or injection equipment. Additional borehole camera work and coring will be conducted to determine the amount of long-term shrinkage, strength, and stiffness of the injected grout. Subsidence measurements will be made to determine the effect of the grouting on the previously-measured subsidence patterns at the field site.

For pneumatic injection, FBC fly ash was delivered to the test site in pneumatic tank trucks. The trucks discharged the FBC ash directly into a covered hopper, which alternately supplied material to two feed tanks which were fitted with internal ribbon screws. As one tank emptied its contents into the compressed air line and thence to the injection borehole, the other tank filled with FBC ash from the hopper. Water required for conditioning and hardening of the injected FBC ash was introduced into the compressed air/FBC ash stream at the bottom of the injection borehole and allowed to disperse with the injected material. Over 2000 tons of FBC ash were injected at rates of about 55 tons/hr. Flow of ash through the mine voids during injection was significantly enhanced by periodic blasts of compressed air to disperse the solid material that built up at the bottom of the injection borehole. The primary operational problem was excessive abrasion of the ash delivery hose at the 90-degree bend at the top of the injection borehole.

Injection of FGD Grout to Abate Acid Mine Drainage in Underground Coal Mines

The objective of this project was to demonstrate the technical feasibility of injecting fixated, sulfite-rich FGD sludge into a small, abandoned underground coal mine (Roberts-Dawson mine, figure 6) for the purpose of mitigating AMD from this mine (Whitlatch, et al., 1998). The FGD material was provided from a wet scrubber at American Electric Power' s (AEP) Conesville Plant, which is located about 5 miles north of the mine.

Two general types of FGD grouts were injected into the mine. The first type was a "mine seal" grout mix consisting of a fly ash:FGD sludge ratio of 1.25:1, with 5% added lime and enough water to create a grout with a 4 to 6-inch slump. Design strength of the mine seal grout was a minimum of 145 psi after 91 days of curing. By filling the lower, down-dip areas of the mine completely with this grout, it was expected that the remainder of the mine workings would become inundated with water, which would in turn reduce the rate of pyrite oxidation that is the source of AMD. Clay seals were constructed at all four mine openings in order to retain the injected grout within the mine while allowing water to escape via pipes placed at the bottom of the seals. The second grout type, a more fluid, "infill" grout mix, was injected into the up-dip portion of the mine workings in order to neutralize the acid water that would be stored in the mine after sealing, and to cover pyritic surfaces that could generate additional acidity. The infill grout had a fly ash:FGD ratio of 1:1, with 5% added lime and enough water to create an 8 to 10-inch slump. Strength of the infill grout was not a primary concern, but values of about 75 psi at 91 days curing were expected.

A total of 318 vertical grout holes were used to inject over 23,000 yd^3 of grout (combined mine seal and infill grout) into the Roberts-Dawson Mine. Despite the extensive mine seal grouting, water continued to flow from the drain pipes at two of the clay seals. In an effort to complete the sealing, the drain pipes were grouted shut, and pressure grouting was performed in a set of 20 closely-spaced holes behind one of the clay seals. This temporarily halted the flow of water from the mine, but

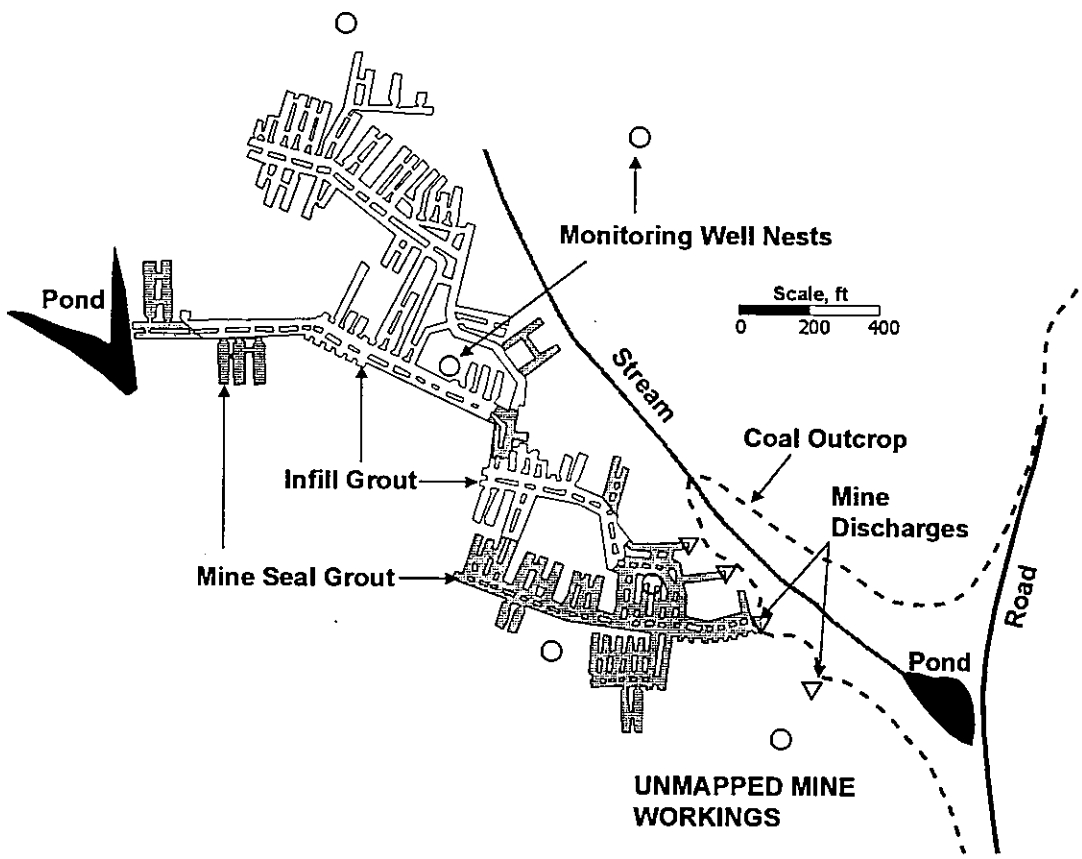

Figure 6. Injection of Fixated FGD Grout at Roberts-Dawson Mine Site

flow re- emerged a few weeks later from above the top of the clay seal at the mine opening with the lowest topographic elevation. This mine opening is connected to an unmapped set of mine workings whose overall size and degree of interconnection to the Roberts-Dawson mine was uncertain prior to the start of grouting. It is believed that flow from this mine opening consists of flow from the unmapped (and ungrouted) workings along with water that has been diverted into these workings from the grouted Roberts-Dawson mine.

Twelve surface water quality monitoring points around the periphery of the Roberts- Dawson mine have been sampled monthly to determine the flow rates and quality of the mine drainage and to assess the impact of this drainage on existing surface streams. Although total flow from the mine appears to be significantly lower than before grouting, further study is needed to determine whether the changes have resulted from seasonal effects or grouting. Nests of ground water monitoring wells were installed upgradient and downgradient of the Roberts-Dawson mine. Work is now being focused on determining the long-term surface and ground water quality changes at the mine site, evaluating the long-term integrity of the injected grout, and developing a comprehensive ground water flow and solute transport model to describe the hydrogeologic changes resulting from the grouting.

Injection of CCB's into the Omega Mine for the Reduction of Acid Mine Drainage

The Omega underground mine (figure 7), located approximately 8 km south of the city of Morgantown, WV, was operated during the early to mid-1980's but has since been abandoned. Depending on the season of the year and the amount of precipitation in the mine area, four to ten discrete acidic mine discharges emanate from the down-dip outcrop of the mined coal seam. Two of the discharges came from horizontal boreholes which were drilled through the coal outcrop into the mine workings to prevent the uncontrolled buildup of water pressure within the mine (which could subsequently cause a catastrophic blowout of mine water). The other discharges flow from small "punch mines" into the down-dip outcrop; these mines are believed to be hydrologically connected to the larger Omega mine. All discharges are routed to a chemical treatment system consisting of anhydrous ammonia for pH elevation, liquid hydrogen peroxide to promote iron oxidation, and a series of settling ponds for metal hydroxide sludge precipitation and storage. The treatment system is operated by the West Virginia Division of Environmental Protection (WVDEP) at a cost of approximately $300,000 per year.

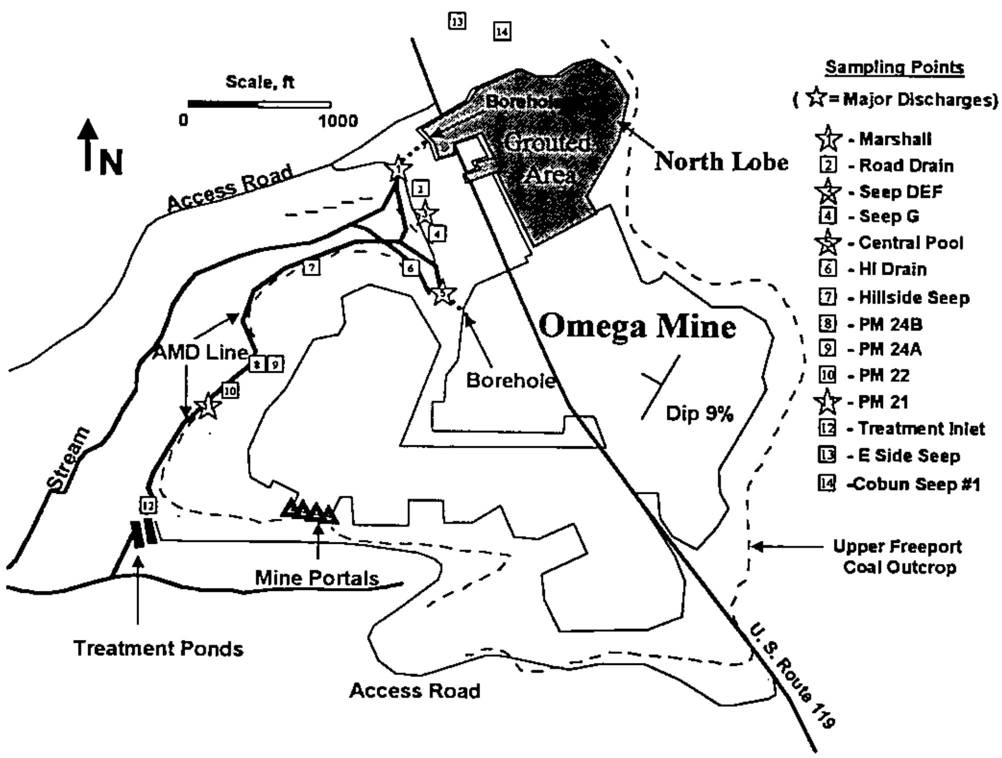

Figure 7. Layout of Omega Mine CCB Grout Injection/AMD Remediation Project

The objective of this project was to reduce the severity of the AMD from the Omega mine by completely filling a 23-acre portion of the mine with a grout composed primarily of CCB's (Gray, et al., 1997). Baseline hydrologic and water quality data from the mine, which had been collected since 1993, showed that the discharges from the targeted area (North Lobe) of the mine comprised 70 to 90 percent of the total AMD load from the mine complex. It was anticipated that filling the North Lobe with CCB grout would divert ground water away from important acid-producing zones, thereby significantly reducing the total AMD load and lowering the long-term AMD treatment costs incurred by the State of West Virginia.

Grouting operations began in May 1998 and were completed in November 1998. The grout mix consisted of 49% pulverized coal fly ash from Allegheny Energy's Fort Martin Power Station, 49% fluidized bed combustion (FBC) ash from Anker Energy/Morgantown Energy Associates FBC plant, 2% Portland cement, and water at about 100 gal per cubic yard of grout. Water for grout mixing was obtained by upgrading the local township water supply line and tapping into the line. Approximately 80,000 cubic yards of grout were needed to fill the target area through 227 injection boreholes. Lateral flow around each vertical injection borehole was approximately 50 ft in areas where roof collapse had occurred, and up to 500 ft in open entries where roof collapse had not occurred. Compressive strength of the solidified grout (28-day value) was 600 to 1000 psi. In the areas of the mine closest to the coal outcrop, where it was critical to create as tight a seal as possible, grout penetration into collapsed areas was maximized by using pressure grouting with a more fluid mix consisting of only fly ash and cement.

By the end of the grouting period, flow from the North lobe discharges had decreased to levels that were as low as any that had been measured previously. However, the mine area had experienced extremely dry conditions throughout the final three months of injection, so it was uncertain whether the decreased flow rates resulted solely from grouting. Monthly sampling and analysis of all discharges emanating from the Omega mine will be performed for at least three additional years to determine the long-term effectiveness of the CCB grouting procedure in reducing the AMD load.

Future Projects

In addition to the completed and ongoing projects described above, DOE-FETC is currently evaluating the possibility of providing cost sharing in the development of two different types of " value-added" CCB use at active underground mining operations.

Underground Placement of Coal Waste and Combustion By-Products Based Paste Backfill for Mining Economics

At many underground mines in Southern Illinois, surface subsidence must be prevented because of the damage it could cause to prime farmland. Subsidence can be prevented by leaving large coal pillars within the mine, but this harms the economic viability of the coal mining operation. The proposed project will involve the selective backfilling of mixtures of CCB's and coal refuse into room-and-pillar mining sections almost immediately after completion of mining in those sections. The extra roof support provided by the paste backfill will allow smaller pillars to be left behind (30' x 30' vs. 40' x 40'), allowing approximately 15 percent more coal to be extracted per unit of surface area. The overall economics of the mining operation may also be enhanced by reducing both subsidence mitigation costs and the cost of coal refuse management.

For this specific project, the objectives are to: 1) develop an approach to management of coarse coal refuse (gob) with combustion ashes, and 2) demonstrate placement of the developed paste-like mixes from the surface in a panel section of an active underground mine. The project will also study the flow characteristics of paste backfill during pumping, evaluate the shrinkage, durability, and strength/deformation properties of the pumped backfill as curing progresses, and assess operational, environmental and health and safety impacts of the backfilling operation.

Manufacture of Lightweight Roof Supports and Mine Ventilation Blocks Using Coal Combustion Byproducts

Over the years, there has been a sustained interest in developing technologies for using CCB's as a raw material in the manufacture of lightweight concrete-like products for construction applications. The use of CCB-based materials in underground mine roof supports (posts and crib blocks) is particularly attractive because these applications typically require large volumes of wood, which is becoming increasingly expensive in some areas of the U. S. Mine ventilation stopping blocks made from CCB-based materials are also desirable because they can be made to be lighter and less expensive than standard masonry blocks. Since the primary purpose of these blocks is to divert airflow rather than support a load, and the blocks do not experience severe temperature and weather fluctuations, the lighter weight does not compromise the blocks' functionality.

During the mid 1990's, CCB-based mine roof supports and ventilation blocks were produced in a batch mode using both Class F fly ash (Chugh, 1995) and FBC ash. The project being evaluated by DOE will demonstrate the technology in a commercial-scale facility (20 tons of CCB's per day). The manufacturing process involves the dry mixing of CCB's, Portland cement, and other admixtures, water addition in a pug mill, pumping into mold assemblies, and several stages of curing. Specific modifications to the mix designs and curing techniques will be made as necessary to optimize the performance and cost requirements of specific applications. Performance of these products in actual underground mine applications will be monitored and documented.

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