INJECTING ALKALINE LIME SLUDGE AND FGD MATERIAL INTO UNDERGROUND MINES FOR ACID ABATEMENT

James C. Ashby, Manager Environmental Affairs, Mettiki Coal LLC.

Abstract

Electric utility response to certain amendments of the Clean Air Act has resulted in a production of several types of alkaline coal combustion byproducts (CCB). Alkaline combustion byproducts are gaining increased usage for acid mine drainage (AMD) mitigation and abatement as research leads to a better understanding of their beneficial applications.

Since January of 1997, Mettiki Coal, LLC. (Mettiki) has been injecting alkaline flue gas desulfurization byproducts from Virginia Electric's Mt. Storm Unit #3 wet limestone scrubber into abandoned portions of the active Mettiki mine. This paper provides an overview of the key design, transportation, regulatory, and environmental issues faced in the project.

Background

Electricity constitutes a critical input in sustaining the Nation's economic growth and development. Coal combustion has historically accounted for the bulk of electrical energy production in the United States, accounting for over 50% of the total net generation of electricity in 1999.[1] One of the concerns of fossil-fueled combustion is the emission of sulfur dioxide (SO_2) during the combustion process. Title IV of the Clean Air Act Amendments of 1990 was enacted to reduce the emissions of SO_2 in two phases. Phase I, running from 1995 through 1999, affected approximately 435 generating units in the United States while Phase II, which is more stringent than Phase I, began in the year 2000 and affects more than 2000 generating units. Although fuel switching was the Phase I compliance method chosen by most utilities to meet their reduction requirements, as of 1999, flue gas scrubber systems have been installed on 192 units representing 89,666 megawatts of generating capacity[2].

All scrubbing units utilize a chemical reaction with a sorbant material to remove SO_2 from combustion gases and are classified as either "wet" or "dry". In the most widely used wet scrubber systems, combustion gases are contacted with a sorbent liquid which results in the formation of a wet solid byproduct. Most scrubber systems utilize an alkaline limestone sorbent, resulting in an alkaline calcium sulfite and / or calcium sulfate sludge byproduct. Over 24 million tons of these flue gas desulfurization (FGD) byproducts are being produced per year in the United States.[3] As increased cost of disposal and heightened environmental regulations make disposal less desirable, alternatives to disposal are being investigated. Alkaline FGD byproducts are finding increased uses in environmental applications as extensive research provides a more comprehensive understanding of their benefits and behavior.

In November of 1994, Mettiki made application to the State of Maryland Department of the Environment (MDE) for a permit modification to combine FGD material with the alkaline

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[1]Energy Information Administration/Annual Energy Review 1999
[2] Energy Information Administration/Electric Power Annual 1999 Volume II
[3]American Coal Ash Association, "1999 Coal Combustion Product (CCP) Production and Use".

metal hydroxide water treatment sludge it was currently injecting into abandoned sections of its underground mining operation in southwestern Garrett County. FGD material for injection was available from Virginia Power's Mt. Storm Power Station Unit #3 wet limestone scrubber located approximately 17 miles away in Mt. Storm, West Virginia.

Mt. Storm Unit #3 Scrubber

The Mt. Storm Unit #3 forced oxidation wet limestone scrubber is a General Electric Environmental Systems unit placed in operation in October 1994. The SO_2 laden flue gas from Unit #3 enters an absorber vessel down stream of the precipitators and flows up through a spray of limestone ($CaCO_3$) slurry. The SO_2 is contacted by the spray and falls into a reaction tank below. The initial collection of SO_2 is primarily with water, but once the slurry falls into the reaction tank, the SO_2 reacts with excess calcium to produce calcium sulfite. Additional oxygen is provided to the reaction tank by oxidation air blowers resulting in a conversion of calcium sulfite to calcium sulfate (gypsum) (Figure 1). The reaction tank provides suction for the recycle slurry pumps, which continually pump slurry to the spray headers in the absorber vessel. For Mt. Storm Unit 3, approximately 100 gallons of slurry is sprayed into the absorber vessel for every 1000 ACFM of flue gas. As the larger gypsum particles settle in the reaction tank, they are pumped by the absorber bleed pumps to the waste dewatering system which consists of a bank of hydroclones and a drum vacuum filter. The hydroclones separate the gypsum slurry into two streams. The overflow stream, containing less than 5% solids flows into a filtrate tank for recirculation back into the scrubber. The underflow stream, containing approximately 50% solids, is fed to the drum vacuum filters. The vacuum filters further concentrate the solids to approximately 80% solids with the resultant water also being recycled back into the scrubber. The byproduct solids are then temporally stored in an enclosed building sized to hold a 3-day supply of product where it is loaded into trucks for transportation to Mettiki for injection. Production averages approximately 400 tons per day.

Figure 1

$$SO_2(l) + CaCO_3(l) + 1/2H_2O \rightarrow CaSO_3 \bullet 1/2H_2O(s) = CO_2(g)$$

$$SO_2(l) + 1/2O_2(g) + CaCO_3(l) + 2H_2O \rightarrow CaSO_4 \bullet 2H_2O(s) = CO_2(g)$$

"l" = liquid, "s" = solid, and "g" = gas.

Regulatory Issues

In 1993, the U.S. Environmental Protection Agency (EPA) issued its "final" regulatory determination on FGD residues. EPA at that time deemed the material to be non-hazardous and therefore, regulated under Subtitle D of the Resource Conservation and Recovery Act (RCRA). This determination gave individual States regulatory authority - which can vary widely from state to state. EPA has since conducted additional studies on combustion wastes from fossil fuels and submitted its report to Congress on March 31, 1999. Again, the material was deemed non-hazardous.

Based on available data, it is felt that alkaline solids addition will assist Mettiki in maintaining an alkaline environment in its underground mine pool at closure and assist in preventing acid generation. Since 1987, Mettiki has been injecting alkaline metal hydroxide sludge from its mine drainage treatment facility along with thickener underflow from its coal preparation plant into inactive portions of its underground mine under an Underground Injection Control (UIC) permit. Though permitted under the UIC program, compliance monitoring and environmental impact assessment is handled through a National Pollution Discharge Elimination Systems (NPDES) permit.

Being the first permittee in the state to request a permit to inject FGD material - coupled with the fact that the material is not being generated anywhere in the State of Maryland - added a level of complexity to permitting. Part of the problem faced by Mettiki was that coal combustion byproducts are not covered under any one regulatory unit in the State of Maryland.

In January of 1995, MDE requested a meeting of section heads from Solid Waste Management, Hazardous Waste, Underground Injection Control, and Mettiki to discuss which department would regulate the injection and maintain oversight. Coal combustion byproducts – including FGD - are not considered hazardous in Maryland. FDG has its own line item exclusion ((Code of Maryland Regulations 26.13.02.04-1.A(4)) and does not fail any of the required RCRA tests used to determine if a material is hazardous (Table 1). This fact excluded the material from MDE Hazardous Waste oversight.

Table 1.

TCLP Chemical Analysis - Mt. Storm #3 FGD (mg/L) [1]

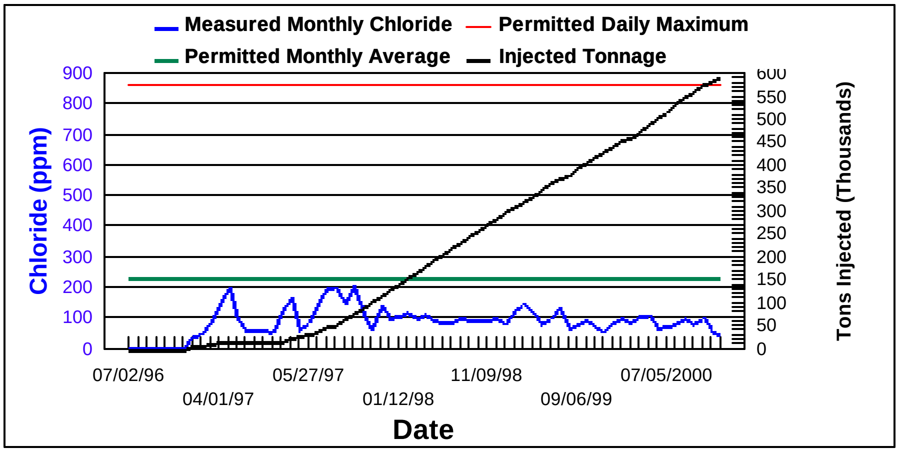
Arsenic	< 0.10	**Calcium**	186,000
Selenium	< 0.20	**Magnesium**	685
Barium	0.15	**Iron**	273
Cadmium	< 0.01	**Aluminum**	229
Chromium	< 0.03	**Potassium**	< 500
Lead	< 0.10	**Sodium**	<50
Silver	< 0.02	**Zinc**	<10
Mercury	< 0.002	**Chloride**	6000
pH	7.88	**Moisture**	39.7 %

1. Mean Analytical data. Multiple tests performed using standard TCLP extraction fluid, raw mine water, and dilute sulfuric acid

A similar concurrent and successful path of registering the material with the Maryland State Chemist (under the Department of Agriculture) as a soil amendment, excluded it from Solid Waste oversight.

Since the material was chemically and physically similar to Mettiki's historic injection materials, it was decided within MDE that oversight would be handled under Mettikis' Underground Injection Control permit. A modification of the existing NPDES permit was required to address what MDE felt was a potential for salt dissolution in the underground mine pool. Of particular concern to MDE were chloride levels in the FGD material and the potential for fisheries impacts. Accordingly, chloride discharge limits based upon U.S. Fish and Wildlife recommendations were set at 230 mg/L quarterly average and 850 mg/L quarterly maximum. Given Mettikis' cooperative trout rearing facility location and potential impacts to trout production, Mettiki agreed to the limitations. Injection effect on raw mine water chloride are shown in Figure 1.

Figure 1. Raw Water Chloride Content



The permitting process was fairly straightforward once the information, test results, and applications were submitted. MDE issued tentative determination in late January 1996 and scheduled a public hearing for March of that year. At the hearing, sixteen citizens attended as a group to voice concerns that injection of CCB's would cause subsidence and that all heavy metals in the material would leach out of the material and contaminate drinking water supplies, both surface and groundwater.

The public hearing lasted approximately two hours and no amount of technical information or explanation seemed to convince the public of the benign and potentially beneficial effects the injection should have. Final permit issuance occurred in May 1996, approximately 19 months after initial application.

UNDERGROUND INJECTION

To handle the additional injection material, Mettiki modified an injection system upgrade occurring at the time designed to carry Mettiki through the life of its mine reserves. To accommodate the delivery of the FGD material to the site, Mettiki constructed a truck unloading facility with slurry makeup water conveyed from existing deep well turbine pumps at the AMD plant.

Once slurried at the unloading facility to approximately 15% percent solids content - controlled by a Texas Nuclear nuclear densometer and Allen Bradley SLC 500 programmable logic controls - the material is pumped to the disposal surge tank located at the AMD plant. Disposal tank level controls cycle two Warmen 12 x 10 discharge pumps arranged in series. Line velocities and the potential to sand out the line over the 14,000 foot distance to our B mine injection points required the high pressure, high volume Warmen pumps. Design capacity is 2800 gallons per minute at 200 psi at the pumps. Figure 2 depicts the final integrated system. Vertical elevation difference between the pumps and the highest point in the disposal line is 250 feet with approximately 150 feet of elevation to work with in the mine voids. Ultimate placement is approximately 550 to 650 feet below surface elevations (Figure 3).

Figure 2. Integrated Facility

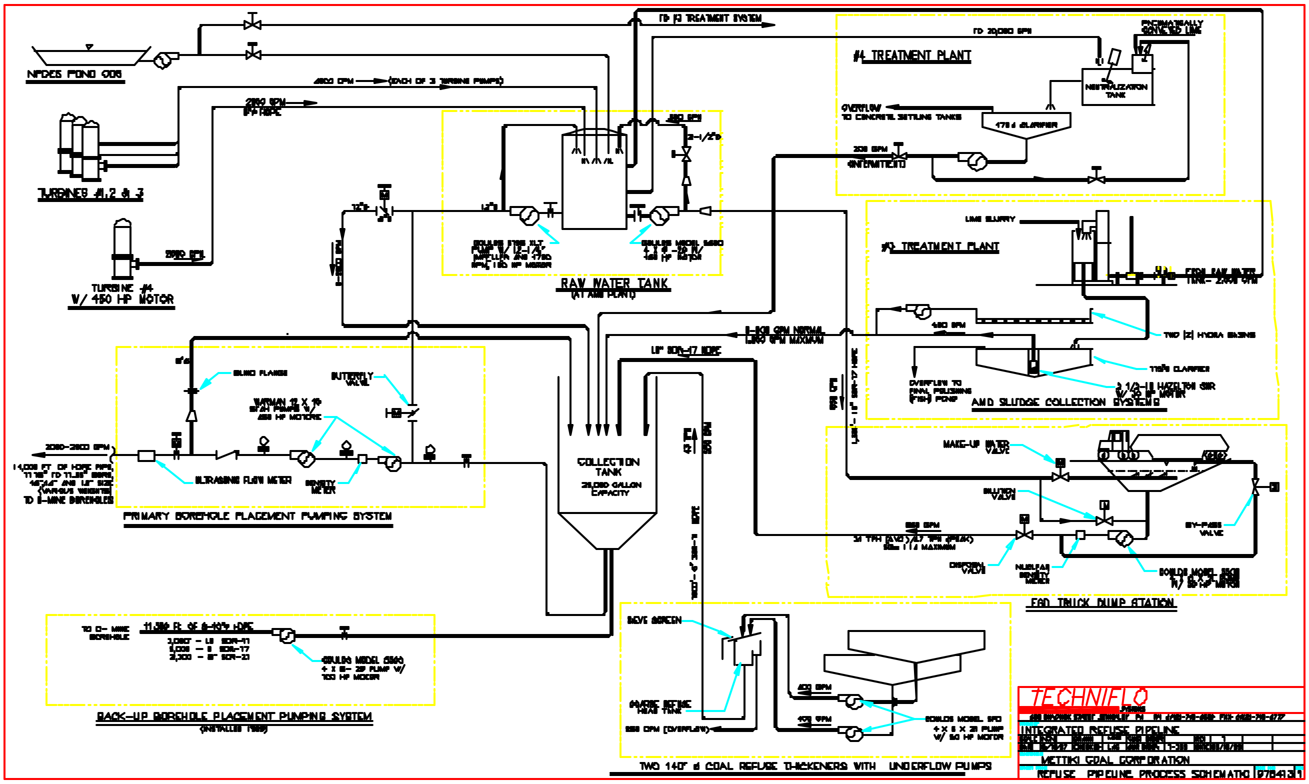
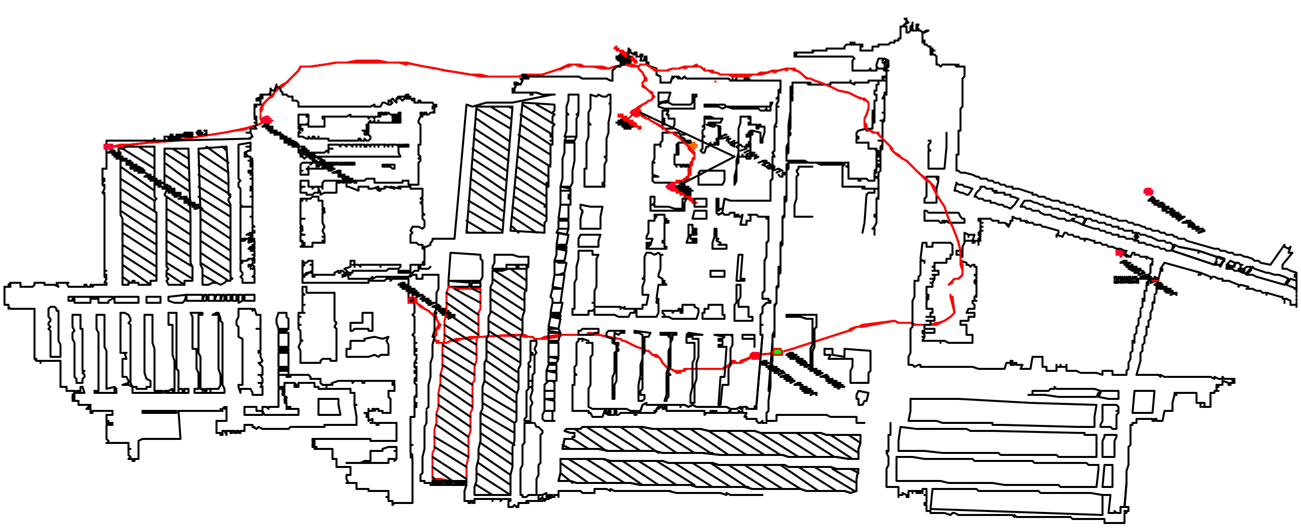


Figure 3. Injection Placement



Mine Pool Impacts

Water which pools underground is either stage pumped through the mine in Mettikis' active works or flows by gravity in the inactive portions (including the decant solution from the injection) to an underground sump located below the water treatment plant. The water is then conveyed to the surface by a combination of one 400 hp Layne, one 800 hp Goulds, or two Peabody Floway 800 hp deep well turbine pumps and treated at the AMD plant. Under normal conditions, flow rates of from 2,000 to 14,000 gal/min are maintained depending upon what pump or combination of pumps is placed in operation. Treatment consists of a high-density sludge system capable of treating 22,000 gal/min. A Techniflo in line aeration system presently capable of treating 4,000 gal/min. is available for backup purposes.

Raw mine water enters the neutralization tank by gravity from the raw water storage tank. The pH of the neutralization tank is maintained at approximately 8.0 pH by a hydrated lime / metal hydroxide sludge slurry fed from the high-density sludge conditioning tank. Recycled metal hydroxide sludge reports to the conditioning tank from the clarifier centerwell pump. Lime addition is controlled by redundant Great Lakes pH probes located in the neutralization tank. Aeration is accomplished using two Roots blowers conveying air through two 6 inch steel pipes discharging through a manifold below a Lightning agitator. The treated water then discharges through a sluice-way where AKJ anionic polymer is added prior to entering the 170' Westech clarifier for precipitation of the hydroxide sludge.

The backup in-line aeration system differs from the above in the oxidization step. Oxidization is accomplished by an air inductor that entrains air by a venturi device which is powered solely by the pressure of the raw water pump feeding the unit. Post aeration treatment involves anionic polymer addition to aid flocculation of the metal hydroxides and clarification in a concrete 115 ft. by 14 ft. circular clarifier.

Metallic hydroxide accumulation in the bottom of the clarifier is raked to the centerwell and pumped either to the sludge-conditioning tank (under normal operations) or to the sludge disposal tank (when wasting) via a 25 hp. Goulds Model JCU centerwell pump. Final sludge disposal into old underground workings is accomplished by two Warmen 12 x 10, 400 hp disposal pumps and ancillary equipment.

Table 2. Chemical Analysis - Raw Mine Water (mg/L)

	06/13/96	10/25/96	04/14/97	07/10/97	05/13/99	04/18/2000
PH	5.98	5.58	6.15	6.20	6.4	6.61
Alkalinity	37			74.9		103
Al	0.4	1.06	0.194	1.32	na	0.81
Arsenic	<.025	<.025	<.025	<.025	<.10	.005
Antimony	<.05	<.05	<.05	<.05	na	.0084
Barium	0	0.035	0.033	0.033	<.10	0.0367
Beryllium	<.0025	<.0025	<.0025	<.0025	na	<.0011
Boron	0.065	0.073	0.47	0.937	na	na
Cadmium	<.0025	<.0025	<.0025	<.0025	<.010	<.00081
Calcium	224	267	421	541	na	533
Chromium	<.0075	<.0075	<.0075	<.0075	<.030	<.0075

Cobalt	0.1	0.146	0.133	0.137	na	0.0853
Copper	0	0.0431	<.0062	0.0095	na	<.0029
Iron	37.8	61.1	24.8	34.4	na	31.8
Magnesium	49.5	65.6	66.1	83.7	na	87.6
Manganese	2.72	3.87	4.28	4.8	na	2.95
Nickel	0.139	0.206	0.183	0.195	na	0.132
Potassium	7.43	11	10	10.2	na	8.97
Silver	<.0025	<.0025	<.0025	<.0025	<.02	<.0056
	06/13/96	**10/25/96**	**04/14/97**	**07/10/97**	**05/13/99**	**04/18/2000**
Vanadium	<.0050	<.0050	<.0050	<.0050	na	<.0050
Zinc	na	0.273	0.201	0.266	na	0.227
Thallium	<.13	<.13	<.13	<.13	na	na
Lead	<.025	<.025	<.025	<.025	<.10	<.0079
Sodium	77.2	86.4	75.3	79.2	na	85.2
Sulfate	830	1090	1240	1345.7	na	1710
Selenium	na	na	na	Na	na	0.0085
Mercury	na	na	na	Na	<0.0002	<.00010

na = not analyzed

Transportation Issues

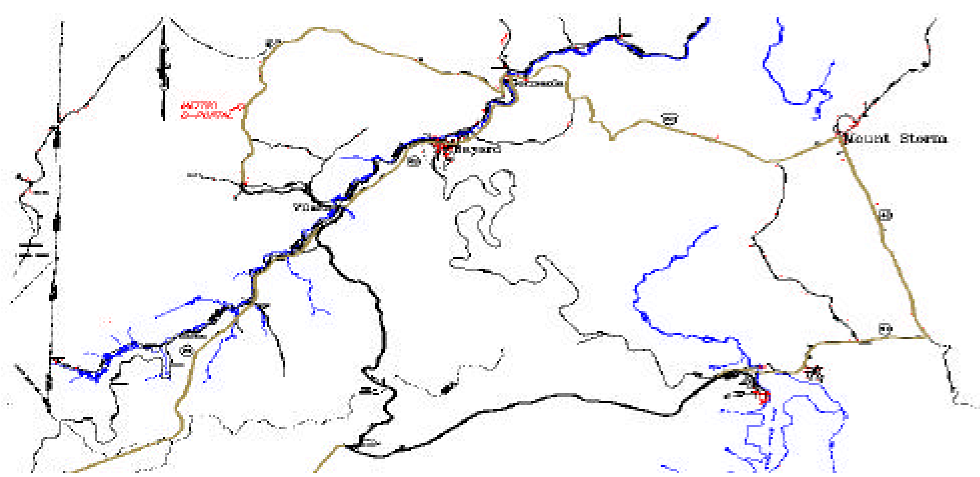
To make the project possible and to economically deliver the FGD material to the site, transportation had to be included as part of a haul back arrangement in a coal supply agreement. To move coal to the Mt. Storm plant and FGD material back to the mine, only two options were available - Rail or Truck. For economic reasons, trucking the materials was chosen but that choice presented its own unique problems. The two largest were infrastructure upgrades at the mine to convert from primarily rail shipments and route selection for the trucks.

Working with Savage Industries of Salt Lake City, Utah, a twin hopper aluminum trailer was chosen to convey the materials allowing for maximum payload potential.

To accommodate this new mode of transportation, route selection became an issue both publicly and economically. Three options were available: 1.West Virginia Route 90 to 93 - through the town of Thomas, West Virginia. 2. US Route 50 to West Virginia Route 93. 3.Upgrade 6.5 miles of private haul road to highway standards.

Option 3 was chosen because it shortened the route somewhat but more importantly, it isolated the trucks as much as possible from public roads and local communities (Figure 4).

Figure 4. Transportation



Conclusion

This project, though complex in implementation, is intended to quantify the benefits of CCB utilization and affords a unique opportunity to provide real-life data on CCB interactions with acid producing mine waters. The fact that there are no exits to the environment other than the deep well pumps and through Mettikis' treatment facility offers a controlled environment to observe those interactions and benefits.

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