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Concentration of Trace Metals Inside Coal Pulverizers

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INTRODUCTION

Extensive work has now been completed which establishes the potential for separation of Hazardous Air Pollutant Precursors (HAPPS) from coal using magnetic methods. [1] This paper will stress measurements made on coals from North Central Pennsylvania. Results for other coals will be published later.

Figure 1 shows the statistical relationship between sulfur, ash, and magnetic susceptibility for diamagnetic fractions separated from an Upper Freeport raw coal using magnetic methods. This type of relationship has been observed for many coals from throughout the United States of America. It shows that magnetic methods can be used to separate mineral rich paramagnetic coal components from diamagnetic hydrocarbon particles. Iron pyrite is one such paramagnetic mineral.

Others have reported a relationship between trace metals such as mercury with sulfide minerals, especially iron pyrite.[2] The implication is that removal of iron pyrite from coal can have the concomitant benefit of removing many HAPPS as well. Iron pyrite and most minerals found in coal are at least feebly paramagnetic while the hydrocarbon component of coal is primarily diamagnetic. Magnetic methods can be used to separate iron pyrite and most ash forming minerals and hence to reduce the burden of pollutants to the burner.

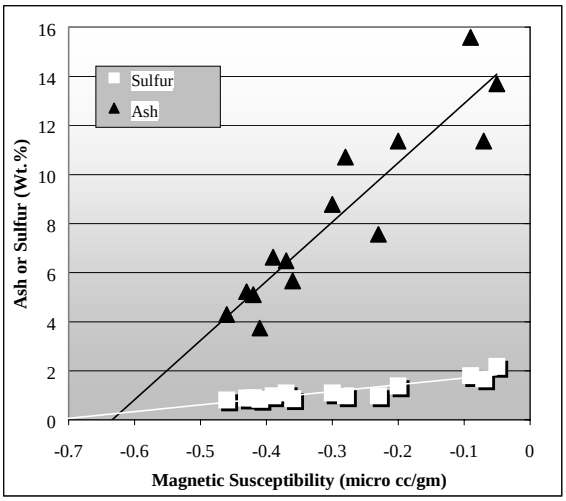

Figure 1. Ash and Sulfur vs. Magnetic Susceptibility, Upper Freeport Coal

MAGMILL™ TECHNOLOGY

Coal is pulverized at pc-fired power plants to improve combustion characteristics. In the process of reducing the coal particle size from nominal inches to 70%-80% smaller than 74 microns, minerals, which cannot be removed economically at the mine where wet methods are used for coal cleaning, are liberated from the coal matrix. It has been found that these minerals concentrate inside coal pulverizers because of differences in particle density and particle grindability when compared to the light and soft hydrocarbon components of coal. Hard and often abrasive minerals such as quartz and especially iron pyrite have been observed to increase in concentration inside of coal pulverizers as much as 30 times that in the pulverizer feed.

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[1] E. D. Brandner, R. R. Oder, and R. E. Jamison, "Removal of Selected Hazardous Air Pollutant Precursors by Dry Magnetic Separation," Proceedings of the 25th International Technical Conference on Coal Utilization and Fuel Systems, Clearwater, FL (March 6-9, 2000), pp. 187-194.

[2] Brown et al., "Mercury Measurement and Its Control: What We Know, Have Learned, and Need to Further Investigate," J. of the Air & Waste Management Association. (June, 1999); U.S. Department of Energy Program Research and Development Announcement DE-RA26-98FT97098, "Solid Fuels and Feedstocks Grand Challenge." pp. 45; Finkelman, Robert, *Workshop on the Environmental Aspects of Trace Elements in Coal.* The Energy Institute, Pennsylvania State University. May 22-24, 2000. Section 9; Swaine, Dalway and Goodarzi, Fari, *Environmental Aspects of Trace Elements in Coal.* Kluwer Academic Publishers. Dordrecht. 1995. p. 25.

Selective concentration of iron pyrite has the consequence of also increasing the concentrations of trace metals such as mercury and arsenic which are associated with the pyrite in coal.

Figure 2 outlines the features, advantages and, benefits of a novel new method for pre-combustion dry cleaning of coal at the power plant.[3] A ParaMag™ Separator employing electric and magnetic methods is attached to the pulverizer. A stream is withdrawn from the internal circulation of the pulverizer which is concentrated in mineral refuse and processed through the separator. Non-hazardous mineral refuse is discarded and cleaned coal is returned to the pulverizer for grinding to power plant specification.

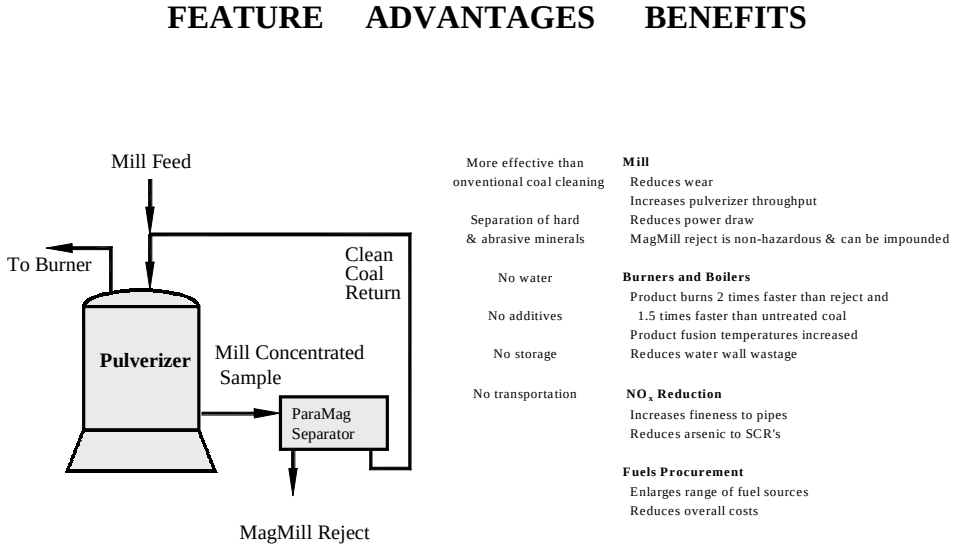

Figure 2. MagMill™ Technology

There are many benefits to the power plant operator which justify the investment in new equipment. Use of this novel technology can improve plant efficiency and reliability resulting in significant reductions in hazardous emissions and savings in the bus bar cost of electricity.

RESULTS

Beta Prototype MagMill™

A 3000 Lb/Hr Hercules air swept ring/roller mill was retrofitted with a ParaMag™ separator to make a beta prototype MagMill™ which has been described elsewhere.[4] Ten tons each of raw Lower Kittanning and Upper Freeport coals from North Central Pennsylvania were processed. Reductions in the concentrations of ash and forms of sulfur are given in Table I for the two coals. All concentrations are measured; recoveries are calculated by dividing the product concentration by the feed concentration.

[3] R. R. Oder, E. D. Brandner, and R. E. Jamison, "MagMill™ Prototype Testing," Proceedings of the 25th International Technical Conference on Coal Utilization and Fuel Systems, Clearwater, FL (March 6-9, 2000), pp. 51-59.

[4] Oder, R.R. "Dry Coal Cleaning with a MagMill™," Preprint 00-053, 2000 SME Annual Meeting and Exhibit. Salt Lake City, UT. February 28-March 1, 2000. To be published in Mining Engineering.

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Table I
Summary Results for Ash and Sulfur Reductions
Lb/MBtu Basis, Beta Prototype MagMill™

	Upper Freeport				Lower Kittanning			
	Concentration			Recovery	Concentration			Recovery
Quantity	MagMill™ Product	MagMill™ Reject	Feed	MagMill™ Product	MagMill™ Product	MagMill™ Reject	Feed	MagMill™ Product
Ash	7.2	17.0	16.3	44	10.4	12.9	17.3	60
Sulfur	0.9	2.6	2.2	39	2.7	3.7	4.6	58
Pyritic	0.2	1.9	1.2	20	1.8	2.7	3.2	56
Sulfate	0.0	0.0	0.0		0.0	0.0	0.0	
Organic	0.6	0.7	1.0	61	0.9	1.0	1.4	62
(Btu/Lb)	13528	5908	12135		2904	5599	11934	

Recoveries of trace metals, expressed as pounds per trillion Btu, are quantified in Table II. Trillion = 10^{12}. Six metals were reduced by 50% or more for the Upper Freeport coal. One metal was reduced by more than 50% for the Lower Kittanning coal. The materials balance is to within 10% for pyritic sulfur and mercury for both coals. The materials balance for arsenic is 10% for the Upper Freeport coal and 31% for the Lower Kittanning coal. The average materials balance for all trace elements is 8% for the Upper Freeport coal and 35% for the Lower Kittanning coal. The largest errors are expected for the trace elements with the lowest concentrations due to the difficulty in measuring them.

Table II
Trace Metal Concentrations in MagMill™ Feed, Reject and Product

Upper Freeport					Lower Kittanning				
	Concentration			Recovery		Concentration			Recovery
	MagMill™ Product	MagMill™ Reject	Feed	MagMill™ Product		MagMill™ Product	MagMill™ Reject	Feed	MagMill™ Product
	Lb/Trillion Btu			%		Lb/Trillion Btu			%
Arsenic	1331	32160	4532	29	Thallium	32	679	68	47
Thallium	35	965	115	30	Mercury	17	286	32	54
Lead	340	6770	989	34	Lead	550	5358	838	66
Mercury	13	237	30	44	Manganese	930	8930	1257	74
Manganese	1257	14387	2719	46	Arsenic	356	4644	478	75
Selenium	96	1168	198	49	Selenium	364	2858	486	75
Copper	710	7617	1236	57	Molybdenum	155	929	201	77
Cobalt	200	1862	338	59	Cobalt	194	947	218	89
Nickel	687	8632	1071	64	Copper	930	4108	1006	92
Molybdenum	133	914	190	70	Nickel	558	6787	603	92
Chromium	1331	5755	1566	85	Zinc	1162	8930	1173	99
Cadmium	16	25	18	86	Beryllium	63	177	63	100
Beryllium	89	203	99	90	Chromium	1317	5894	1257	105
Zinc	1404	5924	1566	90	Vanadium	1317	4822	1257	105
Vanadium	1700	4739	1813	94	Cadmium	9	50	6	159
Antimony	17	27	18	94	Antimony	15	23	5	308

Commercial Pulverizers

Figure 3 shows test ports used to sample the stream of particles circulating inside a CE Raymond 633 pulverizer on Unit #4 at the Shawville Generating Station in Shawville, PA. The plant was burning a blend of raw coals from North Central Pennsylvania. A large proprietary sampling port (not shown) was used to collect samples weighing several hundred pounds.

Figure 3. Sampling Ports

Coal pulverizers have ports for withdrawing tramp iron and other hard materials which might damage the pulverizer. Frequently, small amounts of hard minerals exit these ports also. Table III summarizes measurements made on the feed and mill concentrated samples and compares the quality of coal withdrawn from the internal circulation of the mill to that taken from the tramp iron chute. Their qualities are similar except that the rate of withdrawal from the sampling ports is orders of magnitude greater than that characteristic of the tramp iron chutes. Additionally, significant concentrations of pyritic sulfur, mercury, arsenic, and selenium occur in the samples withdrawn from the mill's internal stream.

Table III
Comparison of Mill Concentrated Samples with
Feed and Pyrite Trap Samples, Shawville

Port	Ash	Sulfur	Pyritic Sulfur	Hg	As	Se
	(Wt.%)			(ppm)		
Tramp Iron Chute	66.2	24.06	—	—	—	—
Sample Port	58.13	33.58	28.66	10.7	799	44.3
Feed	14.39	1.98	0.98	0.46	26.5	3.8

Figure 4 shows the statistical relationship between mercury and pyritic sulfur for fractions separated by dry magnetic methods from the blend of the North Central Pennsylvania coals sampled at Shawville. The concentration of mercury in the mill concentrated samples and separator reject samples is many times that found in the feed to the mill. Separation of minerals from coal at the pulverizer offers a unique opportunity to improve coal quality and power plant operation and reliability.

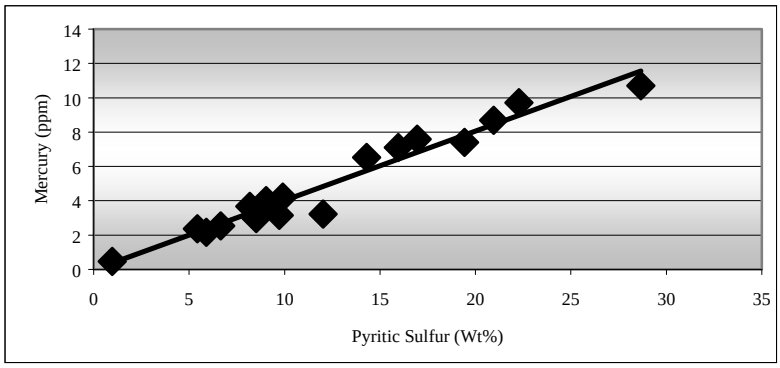

Figure 4. Relationship Between
Mercury and Pyritic Sulfur. Shawville

CONCLUSIONS

The measurements presented here show the relationship between trace metals, especially mercury, and iron pyrite for the bituminous rank coal of North Central Pennsylvania and illustrate the capability of the MagMill™, a novel new method for preparing clean coals for combustion. Results of magnetic separation of Eastern US and Western US raw coal and mill concentrated samples collected from pulverizers grinding products of conventional coal cleaning will be presented in a future publication.