DRY MAGNETIC SEPARATION OF ASH, SULFUR, AND MERCURY FROM A SOUTHWESTERN WYOMING COAL

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ABSTRACT

This paper presents results of earlier laboratory scale (200 lb/hr) dry magnetic separation tests of an Adaville series bituminous/sub-bituminous rank coal from southwestern Wyoming. A two stage ParaMag™ dry magnetic separator was employed. The first stage is a belt magnetic separator suitable for separation of strongly magnetic minerals which contribute predominantly to the ash in coal. The second stage is an open gradient, free flow ParaTrap™ separator capable of separating very weakly magnetic minerals, such as iron pyrites, which contribute to the sulfur and trace metals such as mercury and arsenic in some coals. The raw coal is diamagnetic. It has feebly paramagnetic mineral inclusions. The first stage belt separator was ineffective in mineral separation for this coal. The results presented here were achieved in two passes through the second stage ParaTrap™ separator. Reductions of ash of 28%, pyritic sulfur of 78%, arsenic of 31%, and mercury of 72% on a pounds per million Btu basis were achieved with Btu recoveries of 95% for this coal. The clean coal product had a sulfur content of 1.17 $LbSO_2$/MBtu. A practical method of achieving these levels of performance in which the separators are retrofitted to treat the internal circulation of a pulverizer at the coal-fired power plant (the MagMill™) will be described. Very effective separations can be achieved because of the synergism between the pulverizer and the dry magnetic separator.

INTRODUCTION

In the last 30 to 40 years great strides have been made in developing innovative magnetic separation technology. This has resulted from advances in materials and in the understanding of the nature of magnetic forces. The time is now for wide ranging applications of magnetic separation to processing industrial minerals including coal.

Conventional wet technologies now used in cleaning Eastern US bituminous rank coals are based on gravimetric and surface methods because, at least in part, of their effectiveness and because wet methods are used in large scale underground mining. Water-based cleaning, however, is self limiting because of the very broad size distribution in which contaminants occur in coal and because of the high cost of dewatering fine coal which must be cleaned and recovered to achieve an economical heat recovery. Dry methods, which reached their maximum usage in cleaning coal in the mid 1960's, are now being reconsidered for application to both Eastern and arid Western US coals because of their simplicity and low cost. New amongst the dry cleaning technologies is magnetic separation which has been slow to achieve acceptance because of the common misperception that it is restricted to handling strongly, i.e., ferromagnetic, materials. However, it is now possible to separate magnetic minerals from coal which are five or more orders of magnitude less magnetic than iron, such as iron pyrite and alumino-silicate minerals which have surface stains of iron deposited by ground water percolation. This paper will illustrate use of very powerful dry magnetic separation technology employing electromagnets to remove ash forming minerals, sulfur, and trace metals from an Adaville Series A Seam sample from Pittsburg & Midway's Kemmerer mine in Southwestern Wyoming. A separate paper in this symposium will illustrate the use of belt-type magnetic separators for recovery of carbon values in dry cleaning of lignite.[1]

DRY MAGNETIC SEPARATION

Figure 1. ParaMag™ Separator.

Figure 1 is a photograph of EXPORTech Company's (ETCi) pilot scale two stage ParaMag™ magnetic separator. Coal dependent, this unit is capable of processing nominally one ton-per-hour (TPH) of minus 8 mesh topsize Eastern US bituminous rank coal. The unit consumes 10-12 kW-Hr/T. The first stage (patent pending), which can be operated alone, is a one foot wide belt magnetic separator employing rare earth permanent magnets. It consumes 1-2 kW-Hr/T and produces a surface magnetic force which is about 40 times the weight of a particle whose magnetism is 1 part in 2300 of that of iron. The first stage is used to scalp strongly magnetic minerals from the feed to the second stage which is a transverse access free-fall electromagnet separator [US Patent 5,017,283 (May 21, 1991)] The second stage deflects feebly diamagnetic coal particles out of the falling stream of coal and collects them separately from the refuse fraction. It is capable of separating 75 micron liberated iron pyrite from minus 8 mesh coal at the rate of nominally one TPH.

RAW COAL CHARACTERISTICS

The coal employed in the work reported here is an Adaville Series coal whose rank is between bituminous and sub-bituminous. It was taken from the A seam at the Pittsburg & Midway Kemmerer mine in Southwestern Wyoming. The characteristics of the raw, untreated coal are listed in Table I.

Table I. Characteristics of the raw, untreated coal.

Ultimate Analysis		Proximate Analysis		Ash Fusion Temperatures	
Substance	**Wt.% dry**	**Substance**	**Wt.% dry**		**°F**
Carbon	68.87	Ash	6.22	Initial Deformation	1918
Hydrogen	4.58	Volatile	50.97	Softening	2064
Nitrogen	1.49	Fixed Carbon	42.81	Hemispherical	2140
Sulfur	1.33			Fusion	2276
Ash	6.22				
Oxygen (diff)	17.52				

Forms of Sulfur		Other Analyses	
Sulfur	**Wt.% dry**	Heat Content (dry)	11,925 Btu/Lb
Total	1.33	HGI	53
Pyritic	0.62	Chlorine	0.01 Wt.% dry
Sulfatic	0.03	$LbSO_2$/MBtu	2.23
Organic (diff)	0.68		

Mineral Ash Analysis		Trace Element Analysis	
Oxide	**Wt.% in Ash**	**Element**	**ppm**
Silicon	42.16	Antimony	0.26
Aluminum	10.74	Arsenic	0.41
Titanium	0.57	Beryllium	0.29
Calcium	10.85	Cadmium	0.04
Potassium	0.96	Chromium	5.30
Magnesium	3.06	Cobalt	0.40
Sodium	0.05	Copper	4.80
Iron	12.26	Lead	4.20
Phosphorous	0.24	Manganese	78.00
Sulfur	17.60	Mercury	0.028
		Molybdenum	0.46
		Nickel	1.90
		Selenium	0.66
		Vanadium	3.30
		Zinc	7.90

TEST RESULTS

A 200 lb/hr bench top ParaMag™ separator was used for the work reported here. Although it is smaller than the unit shown in Figure 1, the results achieved with the two units correlate closely.

Splits of the raw Kemmerer coal were ground to minus16 mesh, dried to nominal 3% surface moisture and processed through ETCi's dry ParaMag™ separator. Reductions in weight percent of sulfur, ash, mercury, etc., are plotted in Figure 2 as a function of Btu recovery. Mercury and pyritic sulfur reductions are similar. Routine analyses were performed by commercial sources in the Pittsburgh, PA area. Trace metal measurements were made by

Frontier Laboratories of Seattle, WA, and confirming measurements by the Fuels Laboratory at Detroit Edison.

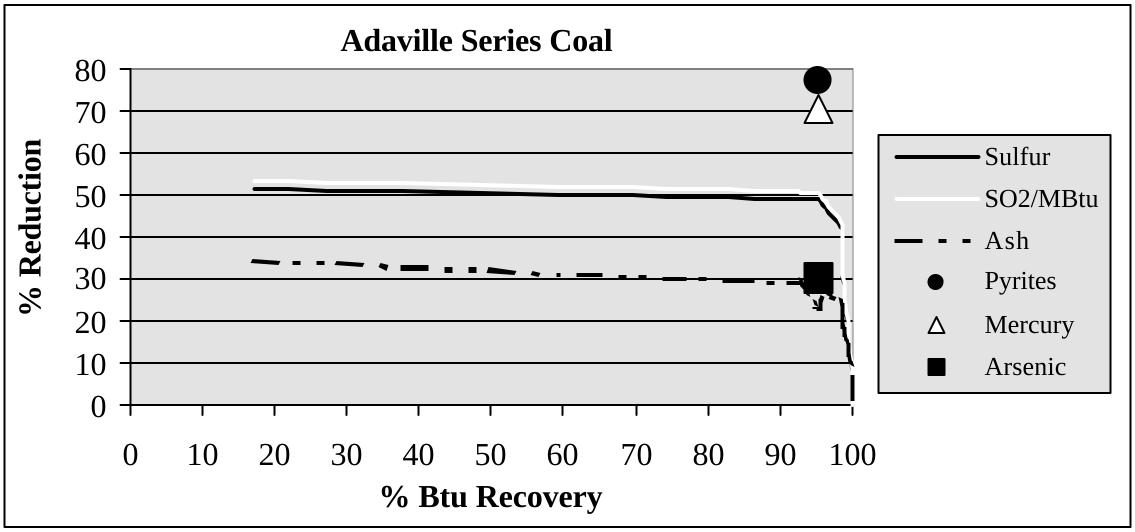

Figure 2. Grade and Recovery Curve, Adaville Series Coal.

Table II compares the cleaned coal characteristics to those of the feed coal on a weight basis at 95% Btu recovery. The treated coal has 1.17 pounds SO_2/MBtu, a 47.5% reduction from that of the feed coal. The lost heat value consists of the heat content of useful carbon which has been lost in the separation process and the heat contents of sulfur and of less reactive forms of carbon which are closely associated with the mineral matter and which do not burn well. The loss of "Useful Btu's" is unknown at this time but is expected to be significantly less than implied by the measured Btu recovery. The carbon recovery is 95.6 %.

Table II. Cleaned and raw Adaville series coal compared on a weight basis, 95% Btu recovery.

	Feed Coal	**Cleaned Coal**	**Reject**	**Reduction, %**	**Recovery, %**
Weight Recovery (%)	100.00	93.62	6.38		93.6
Heat Content	11,925	12,128	8,947		95.2
Carbon, Wt.%	68.87	70.29	48.01		95.6
Ash, Wt.%	6.22	4.57	30.37	26.48	68.8
Sulfur, Wt.%	1.33	0.71	10.41	46.57	50.0
Pyritic Sulfur, Wt.%	0.62	0.14	7.62	77.32	21.1
LbSO_2/MBtu	2.23	1.17	23.27	47.5	49.1
Mercury, ppm	0.028	0.008	0.318	70.45	26.7
Arsenic, ppm	0.411	0.288	2.22	29.97	65.6

POTENTIAL APPLICATION

The ParaMag™ separator can be used as a component of the MagMill™, a new power plant technology for improving the quality of coal fed to the burner. The MagMill™ consists of a

ParaMag™ separator retrofitted to a coal pulverizer as illustrated in Figure 3. A concentrated stream of minerals is removed from the pulverizer and processed by the separator. The minerals, especially hard minerals such as iron pyrite and their associated trace metals, are rejected by the separator and are disposed. Cleaned coal is returned to the mill for grinding to specification. This has the effect of reducing the amount of minerals fed to the burner while also changing their ash chemistry in a beneficial way. The amounts of iron pyrites and associated hazardous air pollutant precursors, especially mercury, fed to the burner are greatly reduced.

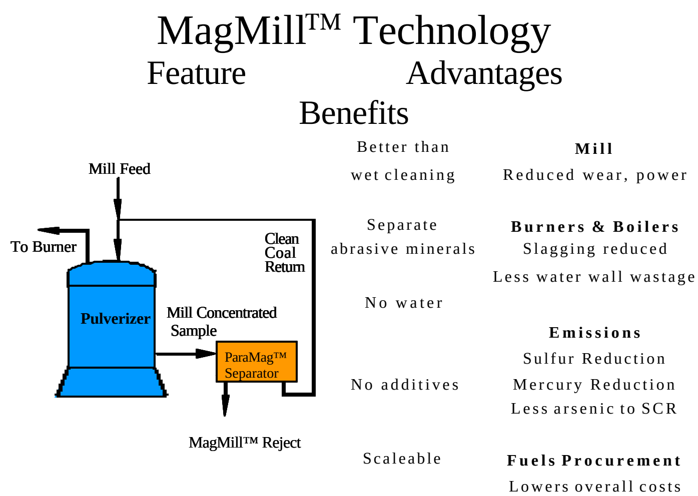

Figure 3. MagMill™ Technology.

ETCi has built and operated a 200 lb/hr alpha prototype and a 1½ ton per hour beta prototype MagMill™ and has extracted and tested material from a variety of operating pulverizers including CE Raymond bowl mills and B&W roller mills. The work reported here was part of a larger project to determine the effects of dry magnetic separation for removal of hazardous air pollutant precursors in which several of the coals tested were extracted from pulverizers. The ParaMag™ separator is designed to process a mill concentrated stream of minerals. No such concentrated stream was available to us from a power plant that was grinding the Kemmerer coal. However, the separation tests on the raw coal have demonstrated that:

- Expressed on a pounds per million Btu basis at 95% Btu recovery, the magnetically separated coal has

  - ♦ 48% fewer pounds of SO_2 per million Btu than the raw coal
  - ♦ 78% less pyritic sulfur than the raw coal
  - ♦ 72% less mercury than the raw coal
  - ♦ 28% less ash than the raw coal.

ACKNOWLEDGEMENTS

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REFERENCES

[1] R. Weinstein, R. Snoby, and R. Oder, "Combining technologies to make lignite into a premium fuel; using an integrated air and magnetic separation process," *18th International Low-Rank Fuels Symposium*, Billings, MT (June 24-26, 2003).