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EMISSIONS REDUCTION AND PLANT EFFICIENCY IMPROVEMENT USING THE MAGMILL™

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INTRODUCTION

This paper reports the first test results obtained with a commercial scale MagMill™[1] demonstration unit for on line dry coal cleaning. The demonstration unit, located at the Detroit Edison Energy Services (DTEES) Petcoke Grinding Facility in Vicksburg, MS, is jointly operated by MagMill LLC and DTEES and is available for testing coals.

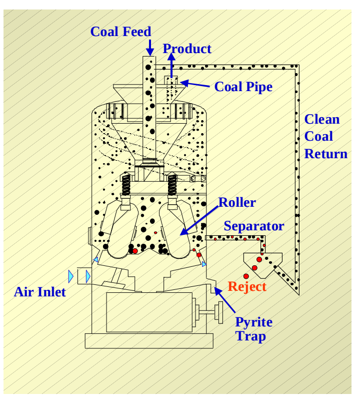

Figure 1. MagMill™ Configuration

A MagMill™ is a selective dry screening and magnetic separation process that is integrated into the existing coal pulverizers to remove unwanted coal constituents prior to combustion. The MagMill™ can be utilized to reduce emissions of mercury and/or sulfur, improve boiler performance by removing mineral components that contribute to slagging and/or erosion, and reduce coal costs by upgrading poor quality coals.

Within a pulverizer, coal falls down a central feed pipe or side feeder onto a rotating table in the bottom portion of the pulverizer. As the table rotates, the coal is slung radially outward and crushed as it passes underneath massive steel tires which roll in grooves on the table. Hot air blown from underneath the rotating table enters the grinding chamber through a gap at the outer circumference of the rotating table. This hot air both dries the coal and sweeps the fine particles released in the crushing upward to the classifier at the top of the mill. Oversize particles are returned for additional grinding and the fine particles are blown directly to the burners.

[1] R. R. Oder and R. E. Jamison, “Method and Apparatus for Separating Material,” U.S. Patents 6,820,829 (November 23, 2004) and 7,124,968 (October 24, 2006)

The mineral components in the coal become concentrated on the grinding table because they are denser than the hydrocarbon component of coal and because they are more difficult to grind. They require many more passes through the grinding zone to reach a size that allows to be lifted by air.

In the MagMill™ configuration a stream rich in these hard-to-grind minerals containing iron pyrite is withdrawn through the wall of the pulverizer and carried to the separators. Outside the pulverizer the material is processed through mechanical and magnetic separators to reject the minerals and to recover the carbon which is returned to the mill for final grinding.

The MagMill™ system has the advantage of reducing grinding energy, increasing pulverizer output, and reducing abrasive wear in the pulverizer and in all downstream parts of the plant touched by coal. In addition, it removes pyritic sulfur and associated trace metals such as mercury as well as lowering the ash level of the clean coal product. The overall effect is to improve plant performance by reducing wear, slagging, and fouling while simultaneously reducing pollutants to the burner.

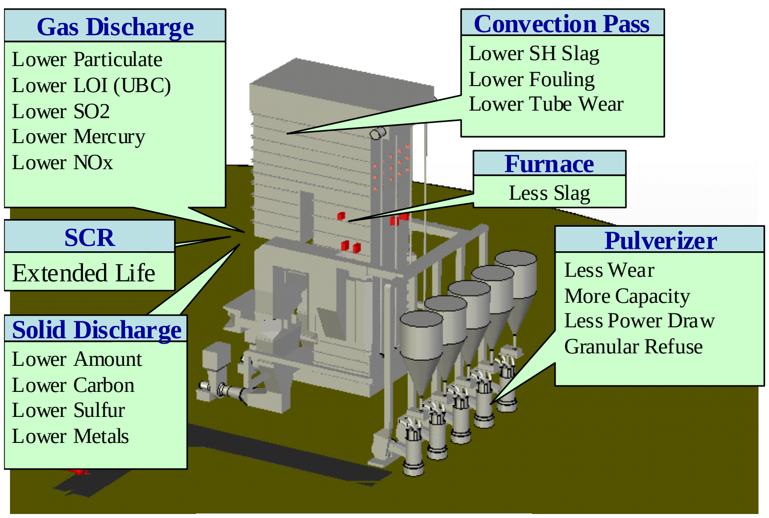

Figure 2. Impact on Plant

TEST RESULTS

The MagMill™ commercial demonstration unit is shown in Figure 3. The pulverizer is a CE Raymond bowl mill capable of grinding nominal 50 HGI coal at the rate of 3 TPH. The separators are contained within the orange framework. The MagMill™ commercial demonstration unit can be configured to operate with the full range of available coals. Operational parameters include; feed rate, withdrawal rate, and screening fractions as well as separator operating conditions such as belt separator configuration and throughput, splitter locations, and magnetic field operating parameters.

Figure 3. MagMill™ Demo Unit

Coal Analysis

The sample processed through the separators in this work was 8 × 100 mesh in size. The +8 mesh and -100 mesh fractions were recycled to the pulverizer. Table I shows an analysis of the composite of the MagMill product and the reject streams. It represents an analysis of the Upper Freeport seam raw coal feed to the pulverizer in the testing at Vicksburg.

Table I. Analysis of Upper Freeport Raw Coal Used in the Testing at Vicksburg

Ash, Wt.%	27.75
Sulfur, Wt.%	2.01
Btu/Lb	10,810
Mercury, µg/g	0.3
Carbon, Wt.%	60.72
Hydrogen, Wt.%	3.94
Nitrogen, Wt.%	1.1
Sulfur, Wt.%	2.01
Ash, Wt.%	27.75
Oxygen, Wt.%	4.47
Sulfate, Wt.%	0.01
Pyritic, Wt.%	1.46
Organic, Wt.%	0.54

Mill Concentrated Sample (MCS)

Mill sampling ports are located on the wall of the grinding chamber of the pulverizer. Two sampling ports can be seen in the photograph of Figure 5. The white horizontal tubes carry the mill concentrated sample to the separators.

Figure 5. Mill Sampling Ports

The sampling ports are independently controlled to adjust withdrawal rates ranging up to 88% of the rate of raw coal feed to the mill. The sampling port configuration can also be controlled to adjust the ash, sulfur, mercury, and screen fractions in the MCS. The rate dependence of the MCS sample is given in Table II.

Table II. Quality of MCS Withdrawn from the Pulverizer

Mill Withdrawal Rate as % of Mill Feed Rate	88	80	48	37		Base Coal
Mill Concentrated Sample, Dry Basis:						
Ash, Wt.%	63	59	58	57		28
Sulfur, Wt.%	5.6	7.8	4.9	5.5		2
HGI		49				63

The MCS values for ash and sulfur illustrate the ability of the mill to pre-concentrate hard minerals which enhances the effectiveness of the MagMill™ separators. The concentrating action of the pulverizer is a key part of the MagMill™ process. The purpose of the downstream separators is to reject the desired minerals and to recover the carbon for return to the pulverizer for grinding to specification.

MagMill™ Separators

The MCS sample is fed to a sequential train of separators which for the demonstration unit consist of a screen deck, a permanent magnet belt separator, and a ParaTrap[2] magnetic separator that are specifically adjusted for each coal type and separation requirement.

MCS Screen Fractions

For this example, the MCS sample was screened at 8 and 100 mesh. The hard and abrasive material in the +8 mesh fraction can be routed to refuse, removed, or sent back to the pulverizer as appropriate. This material in each of the screen fractions is the source of the abrasive wear damage done in the pulverizer and along the coal transport piping. The 8 × 100 mesh fraction is fed to the magnetic separators and the minus 100 mesh fraction can be discarded or routed to mill depending on quality. The analysis of the screen fractions for the initial run of the demonstration unit is given in Table III. The data illustrate the effects of the withdrawal rate on the quality of coal withdrawn from the mill.

[2] R. R. Oder, U.S. Patents 4,830,634 (May 16, 1989); 5,017,283 (May 21, 1991); 5,127,586 (July 7, 1992).

Table III. Size and Constituent Distribution of Mill Extraction Samples

Withdrawal Rate	**88%**				**80%**			
	Percent of Total	Wt.%		μg/g Mercury	Percent of Total	Wt.%		μg/g Mercury
		Ash	Sulfur			Ash	Sulfur	
Larger than 8 Mesh	11	53	10	0.9	9	49	4	0.8
Below 8 mesh and above 100 Mesh	74	67	5	1.4	70	62	7	1.4
Below 100 Mesh	15	50	4	2.1	20	54	13	2.4
Total Percent	100				99			
Composite		63	6	1.4		59	8	1.5

Withdrawal Rate	**48%**				**37%**			
	Percent of Total	Wt.%		μg/g Mercury	Percent of Total	Wt.%		μg/g Mercury
		Ash	Sulfur			Ash	Sulfur	
Larger than 8 Mesh	14	51	10	0.9	17	52	11	0.8
Below 8 mesh and above 100 Mesh	72	60	4	1.0	72	61	4	0.9
Below 100 Mesh	14	50	4	1.9	10	45	4	1.6
Total Percent	100				99			
Composite		58	5	1.1		57	6	1.0

Magnetic Separation

Samples of the product and magnetic separator reject were collected over 10 minute intervals for runs of up to typically 70 to 80 minutes per run. The product coal, collected at the underflow from the cyclone separator, along with the MCS and the reject from the belt and electromagnet separators were each analyzed for weight recovery, ash, forms of sulfur, mercury and Btu. This information is then used to prepare a "cumulative" sample representing the feed coal for each time interval. Using the values for the cumulative sample, the Btu recovery, or yield, is then calculated. Table IV presents the averaged values for the time intervals for one entire run which was made at a withdrawal rate of nominally 36% of the feed rate to the mill. The product coal was 70% finer than 200 mesh.

Table IV. Average Values Measured at a Withdrawal Rate of Nominally 36% of that of the Feed to the Mill

	Rate Lb/Hr	Wt% of Feed	Btu Recovery %	Ash Wt.%	Sulfur Wt.%	Pyritic Sulfur Wt.%	Mercury µg/g	Btu /Lb	Ash Lb/MBtu	Sulfur Lb/MBtu	Pyritic Sulfur Wt.%	Mercury Lb/TBtu
Pulverizer Feed	2,905	100	100	28	2.0	1.5	0.3	10,810	26	1.9	1.4	27
MCS	1,051	36	20.4	56	5.5	5.1	0.7	6,091	91	9.0	8.4	121
First stage Reject	283	9.8	2.9	73	2.3	2.0	0.5	3,206	228	7.1	6.3	140
Second Stage Reject	270	9.3	5.4	54	6.8	6.0	1.1	6,302	86	11	9.5	167
MagMill Product	2,352	80.9	91.7	19	1.4	0.9	0.2	12,244	16	1.2	0.7	16

Figure 6 shows the relationship between mercury and pyritic sulfur for the magnetic fractions separated from the high ash coal and shown in Table IV. The data are fitted by the regression given in Eq (1).

$$\text{Mercury} = -0.0135 \times Sp + 0.2623 \times Sp - 0.0373, \quad rSq = 0.998. \qquad \text{Eq. (1)}$$

The parameters of the regression suggest that if 90% removal if the pyritic sulfur can be achieved, then 100% of the mercury will have been removed also

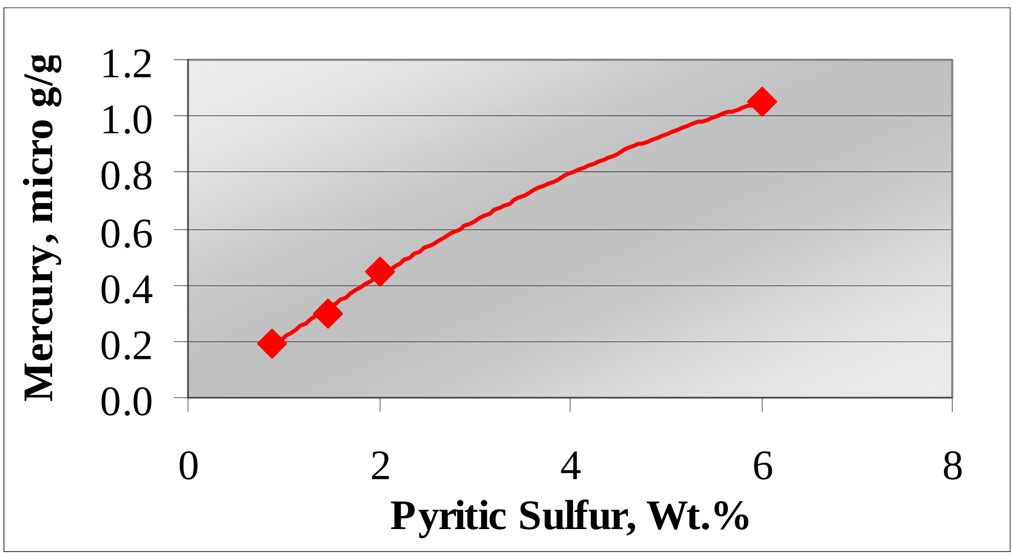

Figure 6. Mercury vs. Pyritic Sulfur
MagMill Feed and Products
Upper Freeport Seam Raw Coal

The percent reductions in ash, sulfur and mercury expressed as pounds per Million or Tera Btu achieved for five different runs at different MCS withdrawal rates are plotted in Figure 7. Trend lines for the ash and sulfur and mercury reductions are shown as solid lines. We believe the Btu recovery in actual power plant operation will be even higher because the MagMill™ system preferentially removes the hard to grind elements that contribute to loss of plant efficiency through unscheduled outages caused by pressure part wear in the pulverizer and boiler and coal transport piping as well as by unburned carbon.

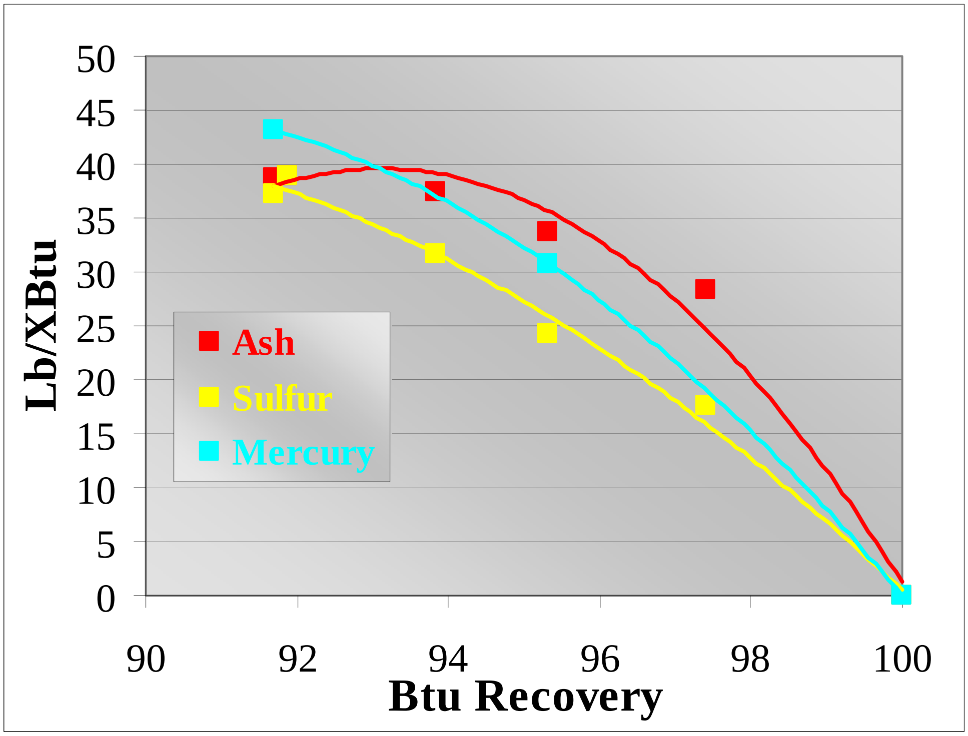

Figure 7. Reductions, Upper Freeport Raw Coal

CONCLUSIONS

A commercial scale demonstration unit for dry cleaning of coal employing the MagMill process is now on-line at the DTE Energy Services Petcoke Grinding Facility in Vicksburg, Mississippi, and is available for testing coals. It has successfully removed heavy, hard to grind, and abrasive minerals from coal before the coal is burned. This reduces abrasive and erosive wear throughout the power plant, lowers grinding energy and simultaneously removes minerals with hazardous components such as sulfur and mercury before the coal goes to the combustor.