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Dry Coal Cleaning In a MagMill

Y. Feng and R.R. Oder
EXPORTech Company, Inc., P.O. Box 588, New Kensington, PA 15068-0588
412-337-4415 / FAX 412-337-4470

R.W. DeSollar
Central Illinois Public Service Company, 607 E. Adams Street, Springfield, IL 62739
217-523-1792 / FAX 217-535-5003

E.A. Stephens, Jr.
Tennessee Valley Authority, 1101 Market Street, Chattanooga, TN 37402-2801
423-751-7474 / Fax 423-751-2463

G.F. Teacher and T.L. Banfield
Allegheny Power, 800 Cabin Drive, Greensburg, PA 15601
412-830-5668 / FAX 412-838-6888

ABSTRACT

Precombustion cleaning of coal is one of the most effective methods of removing unwanted minerals and pollutants. Coals are wet-cleaned at the mine to remove non-combustible minerals and to lower the concentration of pollutants such as sulfur. Because of the high cost of pulverizing, cleaning, dewatering, and shipping fine sized coal, wet cleaning is carried out at the coarsest size practicable which limits the effectiveness of the wet coal cleaning process. As an alternative to wet coal cleaning at the mine mouth, a practical and economically sound ***dry*** coal cleaning technology called the MagMill has been developed by EXPORTech Company, Inc. (ETCi). A portion of the development effort has been focused on sampling a variety of pulverizers. Three (3) different types of pulverizers (ball, roller, and bowl mill) which are commonly used by the utility industry have been tested in operation. Results of this testing and preliminary results of magnetic separation of the mill samples are reported in this paper.

INTRODUCTION

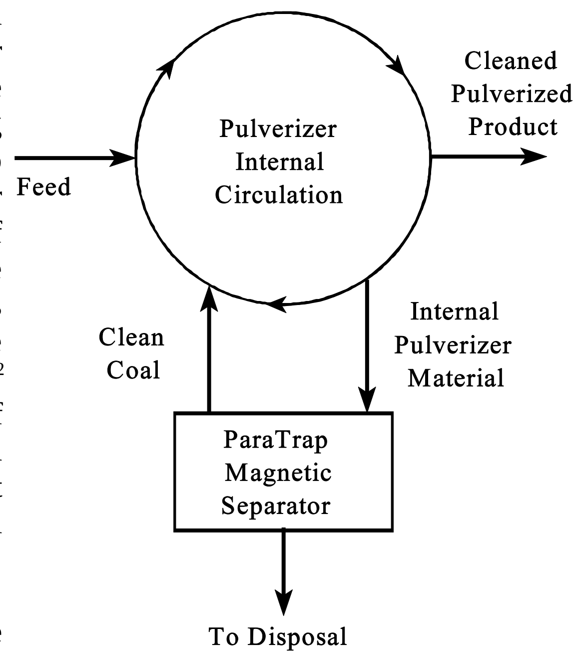
Technology Description

In pulverized-coal (pc) fired power plants, coal is pulverized to 70-80% passing 200 mesh to promote good combustion. Coincidentally, grinding to 200 mesh is also effective in liberating fine minerals encased in the feed-coal particles. The bulk of the hydrocarbon structure of bituminous coals is much softer than the minerals commonly found in coal. Hard and abrasive minerals such as silica and pyrites are more difficult to grind than coal itself and hence make several more passes through the grinding zone of the pulverizer than do the hydrocarbon particles. Because of this, the mineral concentration is greater in the internal circulation of the pulverizer than it is in the feed coal. Iron pyrite is the hardest and most abrasive mineral commonly found in coal. Removal of a small amount of the concentrated mineral reject from the pulverizer internal circulation can have a large effect on the ash and sulfur levels of pulverizer product and on the pulverizer throughput. The promising logical location for fine coal cleaning is in the pulverizer during the pulverization of the coal. However, other than tramp iron chutes for removal of very small amounts of pyrites, no means are currently employed in the pulverizers to separate the liberated minerals from the hydrocarbon.

The MagMill technology combines coal pulverization and dry beneficiation in one operation. The concept of the MagMill is shown in Figure 1.[1] In a MagMill, the pulverizer structure is modified to extract a stream which contains concentrated hard mineral components such as silicates and pyrites from the pulverizer **before they are overground**. This reject stream is then passed through a ParaTrap Magnetic Separator[2] to remove minerals and recover the clean coal. The clean coal product from the magnetic separator is returned to the grinding zone of the pulverizer and the mineral-rich material is discarded from the ParaTrap Separator. The quality of the pulverizer product is improved by the removal of sulfur and non-combustible minerals.

The MagMill technology introduces two unique innovations. First, the MagMill utilizes the existing pulverizer to grind the coal and make a preliminary separation of mineral matter (pulverizer reject) from the coal based on its grindability, particle size, and density. Secondly, continuously operating open-gradient dry magnetic separators are used to separate clean coal for return to the pulverizer grinding zone to minimize the Btu loss. The design of these magnetic separators is new and allows the separators to achieve magnetic forces and throughputs not previously possible in dry processing. The specific throughput for the novel design, 23 TPH/Ft^2 magnetized cross-section, is more than an order of magnitude greater than that achieved by the High Gradient Magnetic Separators now used in wet processing of kaolin clay in the southeastern United States.

Figure 1. MagMill Concept



This novel approach is effective in the separation of minerals which are liberated from the combustibles at the intermediate particle sizes found in the internal circulation of the pulverizer.

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[1] R.R. Oder, R.E. Jamison, T.W. Reichner, and J.R. Davis, "Coal Cleaning in a Mag_Mill," Proc., 12th Annual Pittsburgh Coal Conference -- Coal: Energy and the Environment, Sept. 11-15, 1995, Pittsburgh, PA, Ed., S-H Chiang, pp. 306-311 (1995)

[2] R.R. Oder, "Method of Magnetic Separation and Apparatus Therefore," U.S. Patent 5,176,260 (January 5, 1993).

Removal of the particles from the pulverizer during the grinding avoids overgrinding of coal and permits dry magnetic separation to treat the concentrated, intermediate size particles for which it is well suited.

Advantages of the MagMill

Use of the MagMill technology offers several potential advantages to the utility. First, purchasing raw coal and cleaning it in the MagMill will increase fuel procurement options and lower fuel cost by avoiding the cost of coal cleaning at the mine, about $3 per ton. Secondly, the MagMill technology can lessen the burden on flue gas scrubbers. With current (February, 1996) sulfur emission allowances selling at $100 per ton, reduction of the feed coal sulfur content by 1% is worth $2 per ton, thus providing a significant margin for saving at a large power plant with no flue gas scrubbers. Thirdly, maintenance costs ascribed to unscheduled outages caused by erosive boiler tube wear could be reduced because of selective separation of abrasive minerals. The throughput of the pulverizer can be increased because the hard minerals removed from the grinding zone are replaced with soft coal which grinds readily.

Development Program

The initial development of the MagMill technology, sponsored by the Pennsylvania Energy Development Authority and the Pennsylvania Power and Light Company, was carried out using a 1½ ton per hour (TPH) pilot ring/roller pulverizer located at Bradley Pulverizer Company in Allentown, PA, and ETCi's 20 Lb/Hr laboratory scale ParaTrap Magnetic Separator.[3,4] It demonstrated that material with high levels of ash and sulfur can be extracted/pulled from the internal circulation of an air swept ring/roller mill, and that the removal of this reject from the pulverizer can lower the ash and sulfur levels in the pulverizer product. It also demonstrated that dry magnetic separation is an efficient way to recover the clean coal from the pulverizer circulation reject for return to the pulverizer. An on-going research project[5] is focusing on testing the responsiveness of U.S. coals to magnetic separation,

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[3]R.R. Oder, and R.E. Jamison, "Magnetic Separation of Pyritic Sulfur at the Pulverizer at Coal-Fired Power Plants," Final Report, Pennsylvania Energy Development Authority Grant 9203-3012 (June, 1994).

[4]R.R. Oder, R.E. Jamison, and Y. Feng, "Coal Upgrading in a MagMill," Presented at The 21st International Technical Conference on Coal Utilization & Fuel Systems, Clearwater, Florida, U.S.A., (March 18 - 21, 1996).

[5]"Pulverizer Modification for Pyrite Separation at the Power Plant," U.S. Department of Energy SBIR Phase II Grant DE-FG05-94ER81764, (June, 1995); "Determination of the Magnetic Separation, Sulfur Removal, and Ash Removal Potentials for Selected TVA Coals," TVA Contract TV-95568V (September, 1995); "Pulverizer Sampling for EXPORTech's Dry Magnetic Separator," EPRI Agreement No. WO3852-01 (December, 1995); "MagMill Prototype," Ben Franklin Technology Center of Western PA through PA's Ben Franklin/ IRCPartnership Program Grant 96W.CR00303R-1 (September, 1996). The support of these agencies does not consitute their endorsement of the views expressed in this paper.

sampling the internal circulation of different types of pulverizers at power plants, scaling up ETCi's ParaTrap Magnetic Separator, and preparing site-specific conceptual engineering evaluations for two different pulverizers.

This paper presents the results of on-site sampling of a B&W MPS-89 roller mill and subsequent magnetic separation of these pulverizer samples. Overall MagMill performance has been projected by using ETCi's Pulverizer Internal Circulation Simulator.

INSTALLATION OF PULVERIZER SAMPLING PORTS

Pulverizers

A large portion of the development program has been focused on sampling a variety of different pulverizers at utility power plants. Three (3) different types of pulverizers (ball, roller, and bowl mills, commonly used by the utility industry) have been tested. The capacities of these pulverizers range from 15 to 58 TPH. Access ports for withdrawal of samples were installed in the casings of roller and bowl mill pulverizers and in the classifier at the output of the ball mill.

Sampling Ports

Two types of sampling ports were used to sample the internal circulation of the pulverizer, Particle Sampling Ports (PSP) and Kickout Doors (KOD). The PSP samplers were made from pipes with sampling holes along the length and at the ends and were inserted into the pulverizer at angles to the horizontal to sample particles in remote regions. The KOD was used for extracting large amounts of material for analysis and magnetic separation. It was installed on the existing access door on the side of the roller and bowl mills just above the level of the grinding zone. The location of the KOD was restricted by constraints of the test program and was not the optimum position.

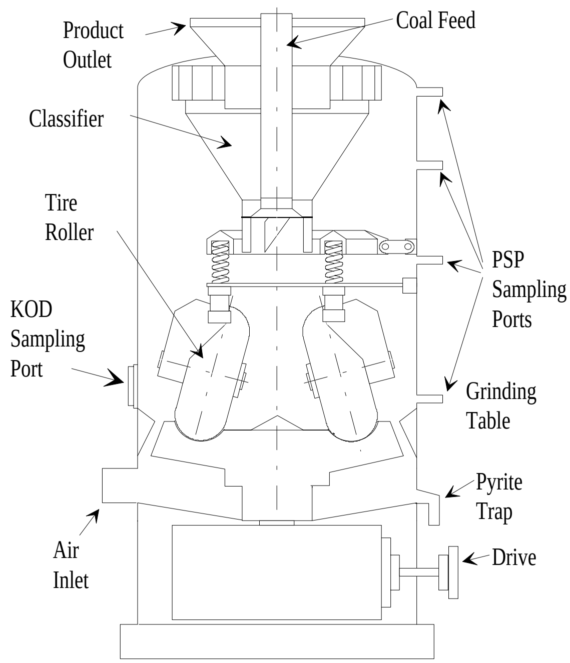
PULVERIZER SAMPLING TESTS

ETCi's earlier work at Bradley Pulverizer Company demonstrated that the rejects with high ash and sulfur concentrations can be extracted from an air swept ring/roller mill. In more recent work, three different types of pulverizers widely used at power plants were sampled to determine if high ash and high sulfur reject material can be extracted. The concentration ratio [(ash in the stream withdrawn from the pulverizer)/(ash in feed)] or [(sulfur in the stream withdrawn from the pulverizer)/(sulfur in feed)] is used as a measure of the degree of concentration in the pulverizer internal circulation.

The test data for four types of pulverizers, including the ring/roller mill, are summarized in Table 1. The results show that the concentration of ash-forming minerals and sulfur found in the samples withdrawn from the internal circulation of the pulverizer are much higher than those in the pulverizer feed for the ring/roller, bowl, and roller mills. The ash concentration ratio ranged from 1.2 to 2.6 and the sulfur concentration ratio ranged from 1.3 to 7.6.

Because the internal circulation of the ball mill could not be sampled due to the mill structure, the ball mill was sampled from the classifier. Samples withdrawn from the ball mill classifier had much lower concentration ratios than those from the internal circulation zone of the other three types of pulverizers. In addition, the particle size distribution of the ball mill classifier was much finer than those of other three types of the pulverizers making it a less attractive candidate for the MagMill technology than are the other mill types.

Figure 2. Schematic Drawing of a B&W MPS-89 Roller Mill



Roller Mill Sampling Test Data

One KOD and eight PSP sampling ports were installed on a 58 TPH Babcock & Wilcox MPS-89 roller mill located at a power plant in northern West Virginia. The KOD was installed to extract sufficient pulverizer reject material for sample analysis and magnetic separation at EXPORTech Company and to get a rough idea of the rate at which pulverizer reject can be withdrawn. The PSP's were installed at different locations on the pulverizer to investigate the effect of the sampling position on the quality of the pulverizer reject. A schematic drawing of the roller mill is shown in Figure 2.

The coal feed to the pulverizer consisted of a blend of raw and washed coals during this test. Samples of the feed were taken for subsequent magnetic separation tests at ETCi. Product samples were also taken and analyzed for ash and sulfur content. The product ash and sulfur levels were used to calculate the ash and sulfur concentration ratios. The characteristics of the pulverizer feed and product are presented in Table 2.

1. KOD Sampling Test Results

Five (5) KOD samples were taken at different sampling conditions during the course of the sampling program. Results of the KOD sampling test are summarized in Table 3. As can be seen from the data in the table, both sulfur and ash concentration ratios indicate that sulfur and ash-forming minerals were very concentrated in the internal circulation of the pulverizer and could be extracted from the pulverizer during the grinding. The average ash concentration ratio is about 2.16 and average sulfur concentration ratio is about 5.25. The average sulfur concentration ratio is about 2.4 times higher than that of the ash.

The data in Table 3 show that while the measurements of ash ratio showed very small variation under the test conditions employed, the pulverizer reject withdrawal rate changed significantly. The pulverizer reject withdrawal rates ranged from about 100 Lb/Hr to above 1,000 Lb/Hr.

2. PSP Sampling Test Results

Eighteen (18) PSP samples were taken under different sampling conditions during the course of the test; the results are presented in Table 4. As was seen in the KOD sampling, both sulfur and ash concentration ratios indicate that sulfur and ash-forming minerals were concentrated in the internal circulation of the pulverizer at all the locations sampled. The average ash concentration ratio was about 2.13 and the average sulfur concentration ratio was about 5.29. The average sulfur concentration ratio was about 2.5 times higher than that of the ash. Compared to the ash and sulfur concentration ratios obtained from the KOD sampling tests, the variation in both ash and sulfur concentration ratios obtained here was much larger due to the much larger changes in sampling conditions. No definite trend was observed in the variation of the ash and sulfur ratios.

Magnetic Separation Test Results

Representative samples of the pulverizer feed and pulverizer internal circulation reject material obtained from the sampling tests were subjected to the magnetic separation using ETCi's 200 Lb/Hr ParaTrap Magnetic Separator (PTMS). The magnetic separation results are shown in Table 5.

The pulverizer feed material was a blend of raw and washed coals, one inch to two inch topsize. It was crushed to 16 mesh top size and processed in a single pass through the ParaTrap magnetic separator as a whole coal sample. The pulverizer internal circulation reject samples were also crushed to 16 mesh topsize and processed through the PTMS.

The ash reduction for the pulverizer feed sample was about 16 percent; the sulfur reduction was about 8 percent at 90 percent Btu recovery. The ash and sulfur reductions achieved with the pulverizer reject samples averaged about 30 percent and 40 percent, respectively, at a similar Btu recovery.

Comparing the magnetic separation results for the pulverizer feed and reject samples, it is very clear that the pulverizer reject samples responded much better to magnetic separation than did the pulverizer feed sample. The average ash reduction for the pulverizer reject sample was about two times higher than that of the pulverizer feed. The average sulfur reduction for the pulverizer reject sample was about five times higher than that of the pulverizer feed. The reason may be because of two significant differences in these samples. First, the reject samples contained many fewer very fine particles than did the feed sample. Magnetic separation will perform better on samples containing few fine particles. Secondly, the composition of these samples were different. The reject sample contains fewer soft components than the feed sample because the soft components are easy to grind and report quickly to the pulverizer product while all coal components are present in the feed sample and are treated in the magnetic separator.

The high ash and sulfur concentration ratios and the much better response to the PTMS of the pulverizer reject sample indicate a very good potential for ash and sulfur reduction using the MagMill technology. In addition, the very different responses to the magnetic separation for the pulverizer feed and reject samples suggest that magnetic separation of whole coal samples should not be used to predict magnetic separation performance of pulverizer reject samples.

SIMULATED MagMill PERFORMANCE

Test program constraints limited sampling the pulverizers at very low withdrawal rates. In order to predict the performance of the MagMill, the quality of the pulverizer internal circulation reject material withdrawn at significantly higher rates needed to be determined. ETCi has developed a computer model of the internal circulation in the roller mill to simulate the quality of the pulverizer reject at different withdrawal rates. The computer model is based on the principle that hard minerals such as pyrites should take longer to reach product fineness and should make more passes through the grinding zone than do the soft components which grind readily. Therefore, the hard minerals will be selectively concentrated in the grinding zone.

Figure 3 shows typical calculated results of buildup in weight of the internal circulating stream and the increase in the concentrations of ash and sulfur as simulated by the computer model. High concentration ratios enhance the feasibility of the MagMill concept.

The computer simulation model was used to study the effect of the pulverizer reject withdrawal rate on the concentration ratios. Figure 4 shows the effect of the pulverizer reject withdrawal rate on the concentration ratios when the clean product from the PTMS is returned to the pulverizer. The pulverizer reject withdrawal rate is expressed as a percentage of the pulverizer feed rate. As can be seen from Figure 4, both the ash concentration and sulfur concentration ratios decrease as the reject withdrawal rate increases, but the effect is much smaller on the ash concentration ratio than on the sulfur concentration ratio.

The model was also used to study the effect of ash concentration ratio on the size of the PTMS. An example is shown in Figure 5. Using a feed coal ash of 20%, a 14% ash product can be produced with an internal circulation reject withdrawal rate of 40% at a concentration ratio of 1.6. If the concentration ratio is 2.0, then a 30% withdrawal rate will be sufficient.

Table 6 shows the projections of the quality of the pulverizer product that can be prepared with a MagMill employing the roller mill sampled. The ash and sulfur concentration ratios have been obtained from the measured values using the computer simulation model. The projections indicate that in this case the MagMill will be more effective in lowering sulfur than ash because of the much higher sulfur concentration ratio.

CONCLUSIONS

1. Power plant pulverizer sampling tests were conducted on three types of pulverizers (roller, bowl, and ball mill). Test results from the roller and bowl mill sampling confirmed that hard minerals were concentrated in the internal circulation of these pulverizers and that the significant amounts of concentrated minerals can be withdrawn from these two pulverizers.

2. The ash concentration ratio ranged from 1.2 to 2.6 and sulfur concentration ratio ranged from 1.3 to 7.6. For both roller and bowl mills, sulfur concentration ratios were much higher than those of ash.

3. As expected, the pulverizer reject sample responded to the magnetic separation significantly better than did the whole coal pulverizer feed sample.

4. A computer model was developed to simulate the internal circulation of the pulverizer based on the different grindability of the coal components and was used to project MagMill performance.