IMPROVING COAL QUALITY FOR POWER PRODUCTION USING ELECTRONIC SORTING TECHNOLOGY

Michael Kiser[1], Gerald Luttrell[1] and Charles Roos[2]

[1]*Virginia Tech, Blacksburg, VA*
[2]*Mineral Separation Technologies, Inc. Coal Center, PA*

ABSTRACT

Electronic ore sorters were first introduced to the minerals processing industry in the late 1940s. Since that time, faster microprocessors, improved sensors, and lower equipment costs have allowed this unique technology to evolve and become commercially attractive for a variety of applications. Recent estimates indicate that nearly 300 industrial-scale sorters are now used worldwide for ore concentration. One of the most advanced sorting technologies is the DriJet™ separator, which has been designed specifically for coal cleaning applications. This technology offers many benefits for the upgrading of coarse coal fractions such as low cost, lessened environmental impact, mechanical simplicity, and high capacity. This paper describes the working features of the DriJet technology and provides data from recent tests conducted with run-of-mine coals.

INTRODUCTION

Coal preparation facilities use physical cleaning processes to remove noncombustible impurities from run-of-mine (ROM) coals purchased by coal-fired power stations. As the first step in the power generation cycle (Figure 1), these industrial facilities improve fuel affordability by lowering freight charges, improving boiler efficiency, and minimizing ash disposal costs Akers, 1996). These facilities also improve the environmental acceptability of coal by removing impurities that may be transformed into harmful gaseous or particulate pollutants when burned. These pollutants typically include particulates (fly ash) and sulfur dioxide (SO2), as well as air toxins such as mercury (Couch, 1995).

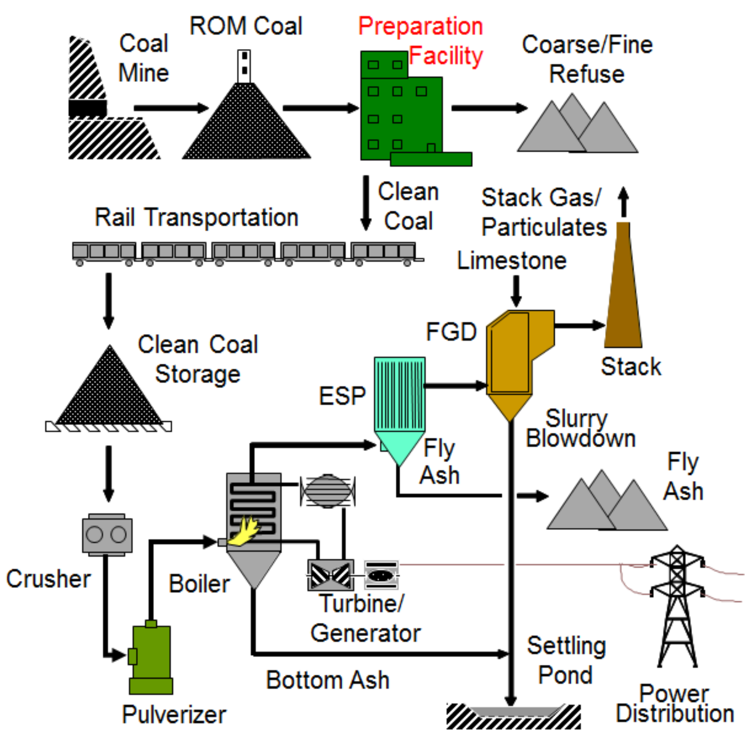


Figure 1. Coal preparation facilities serve as the first step in controlling fuel quality in the power generation cycle.

Unfortunately, the coal preparation industry faces challenges associated with increased solid waste disposal requirements and higher demands for process water (Meenan, 2005, Couch, 2000; Ore, 2002; Gardner et al., 2003). To address these issues, several groups have begun to actively develop new technologies that are capable of upgrading run-of-mine coals without any water (Luttrell, 2008). One particularly promising process is electronic sorting. Electronic ore sorters were first introduced to the minerals processing industry in the late 1940s. Since that time, faster microprocessors, improved sensors and lower equipment costs have allowed this unique technology to evolve and become commercially attractive for a variety of applications.

Electronic sorters utilize specially-designed sensors, such as x-ray analyzers, to interrogate the quality of feed particles that are spread across the surface of a moving conveyor belt. High-speed microprocessors use the sensor data to control pneumatic actuators located at the end of the conveyor. The pneumatic actuators are sequenced so that particles meeting the target quality are diverted into the product stream. This system offers many benefits for coarse coal upgrading including mechanical simplicity, high capacity, low cost and minimal environmental impacts. Moreover, the compact size and low unit cost of sorter technology improves the viability of separating rock from run-of-mine coal at many different locations within the fuel production cycle including surface mines, underground mines, intermediate blending facilities, train loadouts, shipyard loadouts, or power stations stockpiles.

One of the newest and most highly advanced coal sorting technologies is the DriJet™ separator, which is marketed commercially by Mineral Separation Technologies, Inc. The essential working features of this innovative technology are illustrated in Figure 2. During operation, coal is fed onto a conveyor belt as a thin layer. The bed of material passes through a proprietary dual-energy X-ray analyzer that subjects the particles to hundreds of sequential X-ray scans. The X-rays transmit through the bed of solids in proportion to the atomic number of the components present in each particle. As shown in Figure 3, this phenomenon makes it possible to distinguish coal (organic matter composed mostly of carbon with a low atomic number) from rock (inorganic mineral matter composed of various elements such as Si and

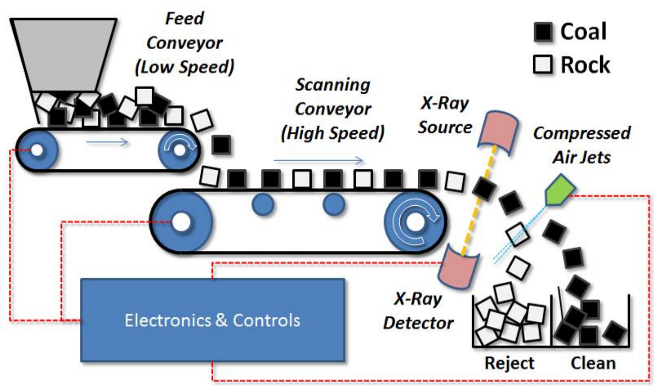


Figure 2. Schematic of the X-ray sorting process.

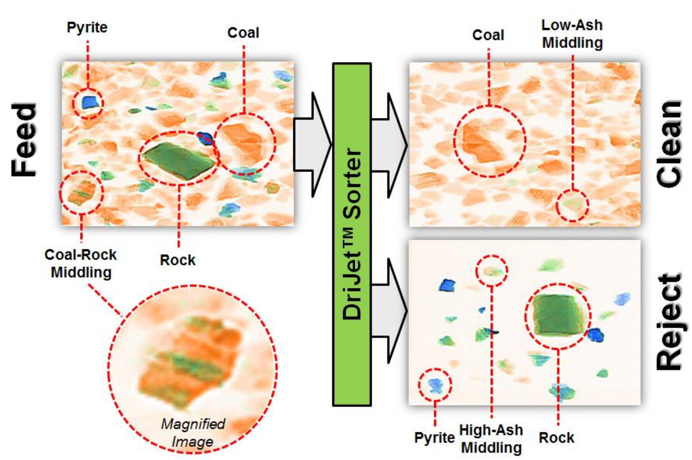


Figure 3. X-ray images of feed, reject and clean coal.

Al with higher atomic numbers). The resolution and speed of the scanner and associated electronics is of sufficient quality so that a compositional profile of each particle can be reconstructed in fractions of a second. Once identified, controlled microbursts of compressed air from a horizontal array of pneumatically actuated jets divert unwanted particles of rock into the reject stream, while coal particles follow their normal trajectory into the clean coal product stream.

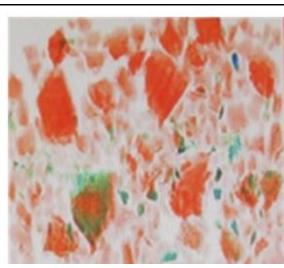
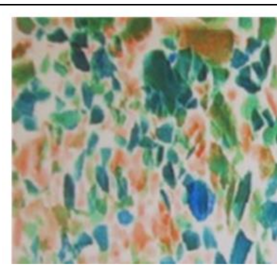
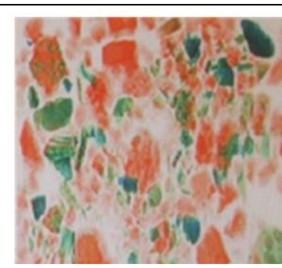
PILOT-SCALE TESTNG

Several series of dry coal cleaning tests were conducted using a prototype pilot-scale version of the DriJet technology. These exploratory experiments were performed using coal samples from three different coal producing regions in the eastern United States (i.e., Pennsylvania, Alabama and West Virginia).

Coal Fuel Upgrading

The first sample treated by the DriJet technology was a run-of-mine (ROM) coal obtained from a major coal producing region in Pennsylvania. The ROM sample contained 24.74% ash and 10,325 Btu/lb. As shown in Table 1, the DriJet process reduced the ash content of the Pennsylvania coal sample down to 12.53% and increased the heating value up to 12,874 Btu/lb. The material rejected by the DriJet system contained a high ash content of 58.6% and a low heat value of only 3,553 Btu/lb. Based on the heating values of the resultant products, the DriJet process recovered 90.8% of the coal heating value in the clean coal stream.

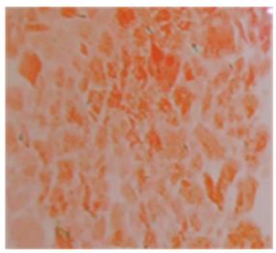
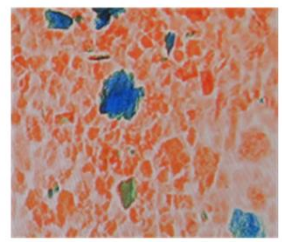
Table 1. Test data from treatment of ROM coal from Pennsylvania.

	Clean	Reject	Feed
Weight (%)	72.65	27.35	100.00
Ash (%)	12.53	58.60	24.74
Heat (Btu/lb)	12874	3553	10325
Recovery (%)	90.76	9.24	100.00
Image from X-Ray			

Coal Desulfurization

The second coal sample treated by the pilot-scale DriJet system was obtained as a clean coal product from a mine site located in the coalfields of Alabama. The purpose of this test run was to determine whether the DriJet technology could further reduce the sulfur content of the coal sample prior to shipment to utility customers. As shown in Table 2, the feed coal introduced to the DriJet system had ash and sulfur contents of 7.11% and 1.30%, respectively. After treatment, the sulfur content was reduced to 0.74% by rejecting material containing 4.68% sulfur. The process also cut the ash content by about half (i.e., from 7.10% ash down to 3.37%. ash). Although heat values were not measured in this case, estimates based on a DAF (dry, ash free) basis indicate that the DriJet process recovered more than 89.2% of the coal heating value while producing a clean product with less than 1.2 lbs SO2/MM Btu.

Table 2. Test data from desulfurization tests conducted an Alabama coal.

	Clean	**Reject**	**Feed**
Weight (%)	85.78	14.22	100.00
Ash (%)	3.37	29.65	7.11
Sulfur (%)	0.74	4.68	1.30
Recovery (%)	89.26	10.74	100.00
Image from X-Ray			

Effect of Particle Size

Sorters such as the Dri-Jet technology are designed for the upgrading of relatively coarse (>¼ inch) particles. To illustrate the effect of particle size on sorter performance, a series of test runs were conducted in which the resultant products from the DriJet technology were subjected to size analysis after two stages of sorting. The tests were conducted using a ROM coal sample from an industrial facility located in southern West Virginia. In the first series of tests, the sorter was specifically tuned to treat coarser particles. The resultant test data, which is plotted in Figure 4, shows that the sorter tuned to this condition performed well in upgrading plus ½ inch particles. For the 2 x ¾ inch material, the sorter reduced the feed ash from 44.8% down to below 20.0% after the first stage of cleaning and down to 17.2% after two stages of cleaning. The ash content of the reject material was exceptionally high (81.0% ash) after the first stage of processing, which demonstrates that very little carbonaceous material was being lost after the first stage. Very little reject material remained in the 2 x ¾ inch size class after the first stage of processing, as indicated by the significantly lower reject ash (42% ash) obtained after a second stage of processing. In contrast, the finer material contained in the ¾ x ½ inch size class continued to benefit from the additional stage of cleaning. After one stage, the sorter reduced the ash content in this size fraction from 38.2% ash down to 28.8% after one stage of processing and down to 16.9% ash after two stages. The corresponding reject ash values after the first and second stages were 73.0% and 67.6%, respectively. The rather small difference between the two reject ash values suggests that the single-stage sorter was not ideally configured for upgrading ¾ x ½ inch solids and that two stages of cleaning was able to minimize this problem.

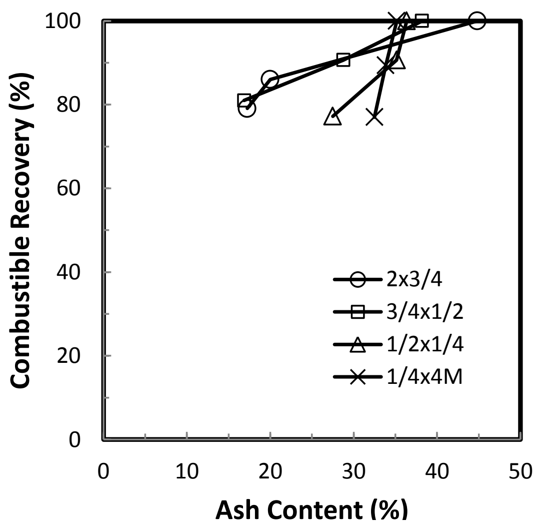


Figure 4. Size-by-size combustible recovery and clean coal ash obtained while the sorter was configured for coarse coal cleaning.

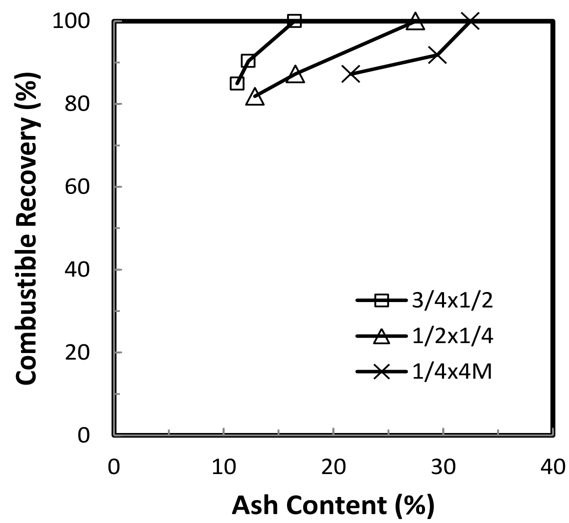


Figure 5. Size-by-size combustible recovery and clean coal ash obtained while the sorter was configured for fine coal cleaning.

The next set of DriJet tests were conducted after re-tuning the sorter to perform better with finer particles. The feed for these experiments were prepared by screening the clean coal product from the first round of testing at ¾ inch. The plus ¾ inch material was collected and set aside, while the minus ¾ inch was then passed through two additional stages of sorting using the new set of operating conditions. The resultant test data, which is shown in Figure 5, shows that the separation of both of the finest size fractions (i.e., ½ x ¼ inch and ¼ inch x 4 mesh) improved dramatically by reconfiguring the sorter electronic setting to conditions more suitable for treating finer solids. After the first stage of cleaning, the feed ash content for the ½ x ¼ inch fraction was reduced from 27.5% down to 16.6%. A second stage of cleaning further reduced the ash down to 12.9%. As expected, the ¼ inch x 4 mesh size did not respond as well, achieving clean coal ash values of 29.5% and 21.6%, respectively, after two stages of cleaning a feed stream containing 32.5% ash. Nevertheless, this level of performance was still considered to be good given that the sorter technology was primarily designed for upgrading plus ¼ inch solids.

Impact on Utilization Properties

The test data provided in the previous section illustrates the performance capabilities of the DriJet technology in applications involving the upgrading of run-of-mine (ROM) coals prior to shipment to utility sites. However, this low-cost technology may also have considerable promise in upgrading feed coals just prior to combustion at coal-fired power stations. To assess this possibility, feedstocks containing less than 10% ash from several coal-fired power stations were subjected to DriJet processing to evaluate potential on-site improvements in fuel utilization properties. The resultant test data, which is summarized in Table 3, shows the percentage change in coal quality relative to the feed quality obtained after one stage of DriJet sorting. As expected, the test data show that the levels of performance achieved using the dry cleaning technology were coal/site specific. The most notable improvements were in the percentage reductions in pyritic sulfur in the clean coal products, which ranged from a low of 5.1% for Coal B up to

77.7% for Coal A. The changes in ash contents were also impressive with percentage reductions of 20.4%, 17.7%, 24.0% and 14.9% for the clean coal products produced from these tests. Emission reductions for elements of environmental concern were also very good. For example, the percentage reduction in arsenic in the cleaned products for Coals A and C were very impressive at 81.2% and 87.5%, respectively. The preliminary test data suggest a strong correlation between reductions in pyritic sulfur and arsenic, as illustrated in Figure 6. Similar reductions in emission levels of other important elements of environmental concern, such as mercury, would be expected to follow a similar trend based on reports published in the literature (Luttrell et al., 1998). On the other hand, some elements may have a strong organic association that precludes removal by physical cleaning. Antimony may fit into this category since the DriJet process was not able to reduce concentrations of this element in the final cleaned product.

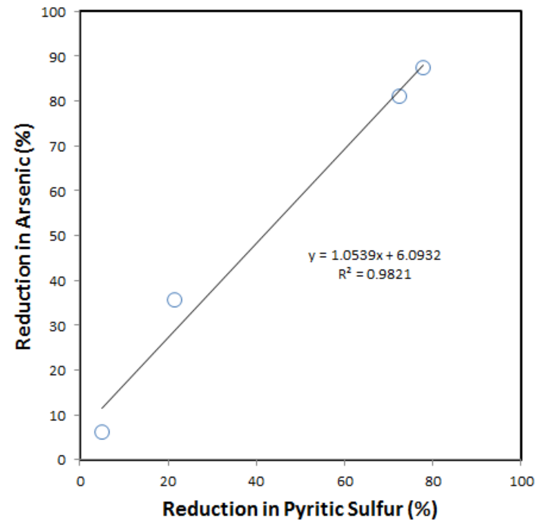


Figure 6. Correlation between pyritic sulfur an arsenic reductions.

Table 3. Effect of DriJet process on clean coal utilization properties.

	Coal A		Coal B		Coal C		Coal D	
% Change in…	Clean	Reject	Clean	Reject	Clean	Reject	Clean	Reject
… Moisture	1.4	-44.8	0.4	-3.3	-0.3	6.5	-0.5	4.7
… Ash	-20.4	643.6	-17.7	140.4	-24.0	473.8	-14.9	140.8
… Volatiles	0.5	-16.4	1.9	-15.5	1.0	-19.5	0.2	-2.3
… Fixed Carbon	0.5	-16.4	2.9	-23.3	1.1	-22.2	2.2	-20.8
… Iron	-45.3	1430.6	-5.3	42.3	-52.9	1042.9	-22.9	216.7
… Arsenic	-81.2	2563.1	-6.1	48.1	-87.5	1724.1	-35.8	338.5
… Antimony	0.8	-26.7	1.1	-8.8	-0.7	13.5	-0.9	8.7
… Sulfur	-12.9	406.5	0.1	-0.8	-18.3	361.3	-2.9	27.8
… Pyritic Sulfur	-72.4	2283.5	-5.1	40.2	-77.7	1531.5	-21.5	203.1
… FSI	0.0	0.0	3.5	-27.6	1.0	-19.2	1.3	-12.1
… HGI	0.0	0.0	2.6	-20.4	0.3	-5.2	-0.8	7.1

DISCUSSION

The pilot-scale test program provided some important information regarding the operational characteristics of the dry sorter technology for coal cleaning applications. The most important finding is that the DriJet technology effectively improved the qualities of coal samples obtained from a wide variety of sources including both run-of-mine coals and power station feedstocks. The test data also indicate that the technology performs best when the unit has been configured to treat a specific narrow particle size fraction. The data suggest that high levels of

Figure 7. Full-scale DriJet coal cleaning system.

separation performance may be realized by prescreening the feed coal into different size classes then treating each size using a sort optimized for that particular particle size class. This upfront preprocessing step is not considered to be a serious issue; however, since coal sizing is a normal occurrence in all coal processing operations. Also, this type of size-by-size circuitry would allow each sorter to be optimized for a given size class so that maximum throughput capacity could be attained for the lowest overall investment in capital equipment. Another interesting observation obtained from the test data is that the performance begins to deteriorate significantly below a critical particle size. This finding supports the manufacturer's recommendations that only particles coarser than approximately ¼ inch are best suited for upgrading using the current configuration of the coal sorter technology. From an engineering perspective, the particle size constraint is not surprising considering the requirement that a single layer of particles needs to be presented to the X-ray scanner. In order to more effectively evaluate these impacts and assess the cost-benefit of the process, a full-scale DriJet demonstration unit has now been constructed and is currently operational (Figure 7). This system is being used to conduct trial runs for potential customers and to development operational guidelines for industrial applications.

SUMMARY

Several series of experimental test runs were conducted to evaluate the potential of the DriJet electronic coal sorter for upgrading of coal samples from eastern U.S. mining operations and power stations. The test data indicate that this novel sorting technology can effectively remove unwanted mineral matter impurities contained in coarse (2 x ¼ inch) coal feeds. Due to inherently low capital and operating costs, this unique technology has the potential to serve as a viable coal cleaning alternative for sites that are water constrained or that have too low tonnage to justify a full-scale coal preparation facility. Moreover, as a dry process, this method of separation avoids issues related to water usage and waste disposal that typically occur using traditional water-based separation processes. The compact footprint of this process may also allow the technology to be integrated into the flowsheet of power stations to improve boiler efficiencies and reduce emission levels. Full-scale equipment is now operational and is being evaluated for industrial applications.

REFERENCES

Akers, D. J., 1996. "Coal Cleaning Controls HAP Emissions," Power Engineering, June.

Couch, G.R., 1995. Power From Coal — Where To Remove Impurities?, IEA Coal Research, London IEACR/82, 87 pp..

Couch, G.R., 2000. "Opportunities for Coal Preparation to Lower Emissions," International Energy Agency (IEA), CCCr30, London, 46 pp.

Gardner, JS, Houston, KE and Campoli, A (2003) Alternatives analysis for coal slurry impoundments. SME Annual Meeting, Feb. 24–26, Cincinnati, OH, Preprint 03-032, 1-5.

Luttrell, G.H., Kohmuench, J.N., and Yoon, R.-H., 1998. "The Role of Coal Preparation in Controlling Trace Element Emissions," Preprint, Air Quality: Mercury, Trace Elements and Particulate Matter Conference, Tysons Corner, Virginia, December 1-4, 1998, 6 pp.

Luttrell, G.H., 2008. "Coal Preparation," Chapter 4, in Meeting Projected Coal Production Demands in the USA: Upstream Issues, Challenges, and Strategies, M. Karmis (Chair), National Commission on Energy Policy, Published by Virginia Center for Coal and Energy Research (VCCER) of Virginia Tech, December, 2008, pp. 106-143.

Meenan, G., 2005. "Implications of New Dewatering Technologies for the Coal Industry," Invited Lecture, Center for Advanced Separation Technologies (CAST) Workshop, July 26-28, 2005, Virginia Tech, Blacksburg, Virginia, 14 pp.