COMBINING TECHNOLOGIES TO MAKE LIGNITE INTO A PREMIUM FUEL: USING INTEGRATED AIR AND MAGNETIC SEPARATION

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ABSTRACT

Combined air and magnetic separation technologies show promise to yield a high energy recovery and the removal of a significant amount of the undesirable materials contained in North Dakota Lignite. This improvement is made possible by taking advantage of the natural differences in the densities of coal and waste material combined with the higher magnetic susceptibility of the waste materials. By combining the strengths of each technology, there emerges a combined process that exceeds the potential of each technology taken on its own. This technology has the potential to recover additional lignite and/or to enhance the quality of coals utilized by power plants.

Using an allmineral Llc Allair® Jig plant in combination with a EXPORTech ElectriMag™ Belt Separator results in an ash, SO_2, and mercury reduction in excess of 10 percent, while yielding 95% energy recovery. The combination of an Allair® Jig Plant processing -2 inch lignite with a ElectriMag™ belt Separator handling the -1/4 inch fine reject is an ideal combination of processes that takes advantages of the strength of each technology.

The objective Falkirk Mining Company and Great River Energy, owner of the Coal Creek Power Station located 7 miles South of Underwood North Dakota, was to find a dry cleaning process that would improve the overall efficiency and economics of the mine and power plant.

Introduction

Lignite is faced with major challenges in the form of market forces in the electric generation industry, and mounting pressures in complying with clean air standards. Due to inexpensive mining costs and less restrictive environmental issues in the past, most lignite cleaning has been limited to very crude in–the-pit cleanup before shipment. To do this, the mining company has discarded or avoided low heating value coal and minimized dilution with waste material that lowered the heating content. Enough cleaning was done to fit the contractual commitments or to a point that allowed unrestricted power output with respect to the heating value of the coal. This has resulted in coal or energy losses that can typically run up to 20% or higher for some of the coal seams at Falkirk.

Today the coal miner and power plant operator must focus more on the overall mine plus power plant (bus-bar) cost of energy to thrive and survive in the long run. Just meeting contractual tonnage and quality limits for a miner may result in lower coal demand if the power plant suffers from increased maintenance outages, reduced performance, and/or reduced operation due to environmental compliance.

A simple solution to these vexing problems is to economically recover more of the resource while eliminating the contaminants that cause problems for the power plant. North Dakota lignite crushed to a 2 inch size results in the generation of a very high percentage of fine material. It is not unusual to see the -1/4 inch material represent nearly 50% of the lignite. The fine material also has a high clay content. While water is readily available at Falkirk, many western locations have a shortage of available water for wet processing. The high surface area of fines and wet processing moisture gain would be very detrimental to the heating value of Falkirk Lignite. The combination of a high percentage of fines, clay content, and water related issues steered Falkirk to investigate dry processing.

Experimental

Tests utilizing air and magnetic separation technologies were conducted in 2002 to evaluate the potential of dry cleaning methods for a typical high ash coal from the Falkirk mine. For the tests, coal was taken from a seam that had an in place thickness of approximately 4 feet. Mining conditions were dry and visibility good so one could conclude that the coal was typical of normal deliveries. On September 17, 2002 the coal was mined (see Figure 1) and reduced to -3 ½ inch size and then stockpiled at the Coal Creek Station.

Figure 1. Mining four foot thick seam for dry cleaning: September 17, 2003

The coal was stockpiled as shown in Figure 2. Note the clear distinction between the coal and associated contamination incidentally added during the loading operation. Inspection of the coal seam in the pit indicated that the light color material was probably waste material from below the seam. Several samples were taken by drilling the seam before mining and after the coal was stockpiled. Analysis of these samples indicated that the quality of the coal was typical of normal deliveries.

Figure 2. Falkirk Coal after crushing September 2002: Coal Creek Station

The shortfall of dry cleaning using Air separation is that the losses in fines can be quite high and the misplacement of coal and waste material can be high. The Allair® Jig (see Figure 3) has shown good separation and low energy loss on the coarse product circuit however, there were a substantial amount of fine rejects that had higher ash content than the feed.

Figure 3. allmineral Llc Allair® Jig: October 2002

The Lignite was shipped to a commercial Allair® Jig. At this site the lignite was reduced from -3 ½ inch to -2 inch. Typically this unit would operate on either a coarse or a fine stream of coal. Since only 24 tons of coal was shipped it was decided to run the Falkirk Coal in a single batch with no size separation. Theoretically the Allair® Jig operates more efficiently when a tighter particle distribution is processed. The system was purged and the Falkirk coal was run through as a batch with samples taken of the feed, coarse product, baghouse fines, and reject material throughout the test. The test took approximately 20 minutes. Figure 2 below shows the three project streams. From left to right they are; reject into truck, fines conveyor center, and product stream to the right.

Figure 4. allmineral Llc Allair® Jig: October 2002

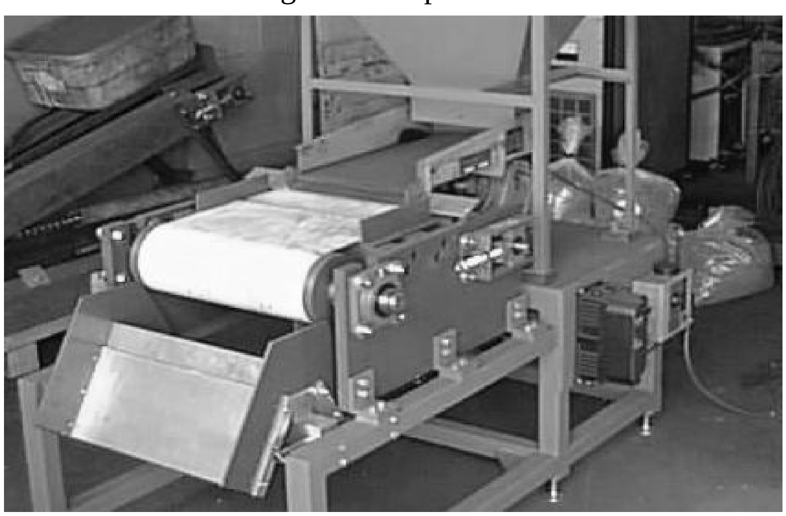
A positive feature of the Allair® Jig is the ability to produce a coarse waste reject material containing very little lignite. At the same time the clean product stream had a significant amount of the waste removed.

A negative feature of the Allair® Jig is that the baghouse captured fines turned out to be a high percentage of the initial feed. The main purpose of the baghouse is to control particle emission from the jig and in some cases to assist in the cleaning. Nearly all the material captured by the baghouse was -1/4 inch in size, and had little or no surface moisture. The fines had a ash level higher than the feed coal, and a BTU level lower than the feed coal. In some cases it might just warrant to throw the fines away and sell only the coarse cleaned material.

The next issue is what to do with the fines and its impact on economics. A representative sample of the baghouse fines reject from the Allair® Jig was then run through a bench scale model of the ElectriMagTM belt Separator shown below (see Figure 3). Lab results showed that the waste materials had a much higher magnetic susceptibility than the coal, and a distinct separation was achieved

Magnetic separators function effectively when the particle size is small, the material has little surface moisture and the feed has both magnetic waste and non magnetic coal. Air is used in the Allair® Jig to fluidize and stratify the bed of coal. This has the effect of removing most of the surface moisture in the fines. The size and moisture of the baghouse material is suitable for magnetic separation without further processing. It is quite possible that both surface and inherent moisture content of the product coal and the fines was lowered measurably by the air. The fines need no further size reduction or drying to make effective use of a magnetic separator. Thus fine coal reject material from the Allair® Jig is a very good feed for the ElectriMagTM belt Separator.

Figure 3. EXPORTech ElectriMag™ belt Separator



The laboratory model ElectriMagTM belt Separator has multiple splitters on the discharge end. The coal was passed through the device and the individual splits were sampled and analyzed. These splits can then used to determine an optimal setting for making a single separation cut.

Results and Discussion

The results from the Allair® Jig and the ElectriMagTM belt Separator are shown below in Tables 1.

Table 1. Quality and Energy Recovery Allair® and ElectriMag™

	% Moisture	% Ash	BTU/Lb	% Sulfur	% Sodium In Ash	Pounds SO2 /MMBTU	%Energy Recovery
Feed (Allair®)	30.65	19.72	5,956	0.92	3.34	3.10	100.00
Product (Allair®)	32.40	12.73	6,663	0.88	4.80	2.64	76.70
Fines (Allair®)	24.61	27.32	5,635	1.03	2.27	3.67	20.30
Cleaned Fines (ElectriMag™)	26.59	19.50	6,477	1.07	2.96	3.29	18.70
Reject (Allair® & ElectriMag™)	18.69	59.04	2,072	1.43	1.37	13.76	4.60

Looking at the Allair® Jig (Table 2) results we see that improvement in heating value and reductions in ash and sulfur dioxide (SO2) have very positive implications for a power plant. However the 76.7% energy recovery for the coarse product is not very good. The fines segregated by the Jig are of very marginal quality from a power plant operational standpoint.

Table 2. Allair® Jig: Change in Fuel Quality and Energy Recovery

	Moisture	Ash	Sulfur	BTU	SO2	Sodium	Hg (ppm)	#Hg/ TBTU	Energy Recovery
Falkirk raw coal	30.56	19.72	0.92	5,955	3.09	3.34	*	*	100.00%
Air Jig Product	32.40	12.73	0.88	6,663	2.64	4.80	*	*	76.70%
Change	6%	-35%	-4%	12%	-15%	44%	*	*	-23.30%

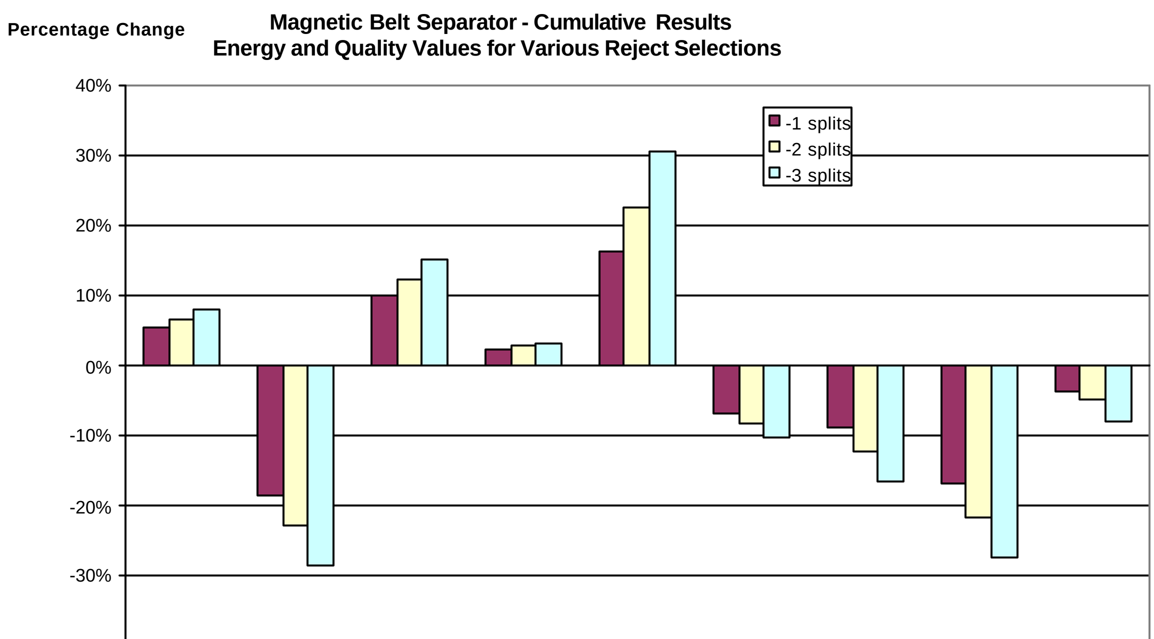
If the fines were to be recombined with the coarse product we would have a product better than we started with as shown below in Table 3. The improvement is still substantial and the Energy Recovery reached 97.05%. Mercury measurements were not available for the Jig test.

Table 3. Allair® Jig: Change in Fuel Quality and Energy Recovery

	Moisture	Ash	Sulfur	BTU	SO2	Sodium	Hg (ppm)	#Hg/ TBTU	Energy Rec
Falkirk raw coal	30.56	19.72	0.92	5,955	3.09	3.34	*	*	100.00%
Jig prod + Raw Fines	30.92	16.20	0.88	6,392	2.75	3.78	*	*	97.05%
Change	1%	-18%	-4%	7%	-11%	13%	*	*	-2.95%

The next step involved treating a representative sample of fines with the ElectriMag™ belt separator. As stated previously the fines were essentially all -1/4 inch in size and had very little surface moisture after discharge from the baghouse. The samples were run through the ElectriMag™ Belt Separator without any pretreatment. The lab bench size ElectriMag™ Belt separator is fitted with a series of cutters that make multiple segregations based on magnetic field response of the material and other physical handling characteristics. Each sample generated 5 to 6 splits. The improvement in quality and change in energy recovery is shown in the Figure 4 and Table 5 as shown below. The results show the cumulative change as additional material is removed by each successive segregation. The most magnetic material is removed first and each subsequent split had less response to magnetic separation.

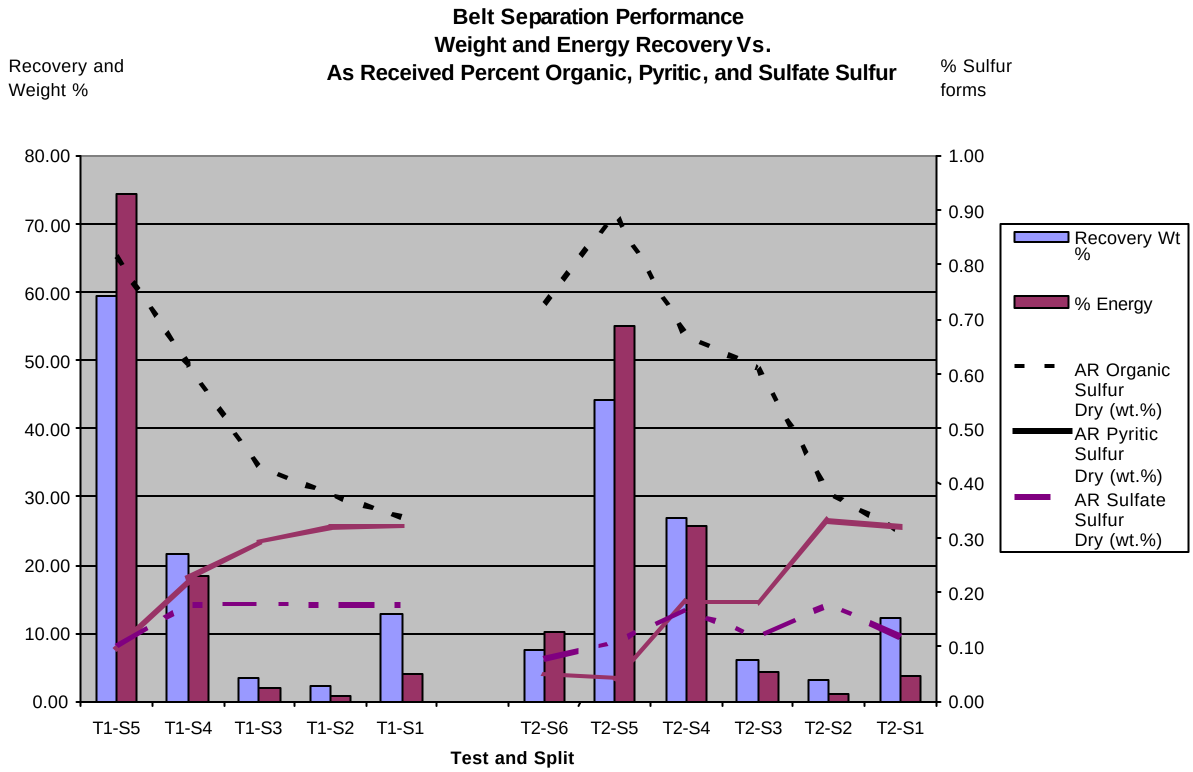
Figure 4. EXPORTech ElectriMag™ belt – Cumulative Separator Energy and Quality Changes



	Moist	Ash	BTU	Sul	Na	SO2	Hg (ug/g)	Lb HG/TBTU	Energy Recovery
-1 splits	5.2%	-18.7%	9.8%	2.3%	16.3%	-6.9%	-8.9%	-17.0%	-3.9%
-2 splits	6.5%	-23.0%	12.1%	2.7%	22.5%	-8.4%	-12.3%	-21.7%	-5.0%
-3 splits	8.0%	-28.6%	14.9%	3.0%	30.5%	-10.4%	-16.7%	-27.5%	-8.1%

The results show a high recovery of energy from the fines and a resulting large decrease in ash, SO2, and pounds of mercury per trillion BTU. Note that the sulfur percentage increased suggesting little magnetic susceptibility of the minerals containing sulfur. This is graphically presented in the analysis of sulfur forms shown in Figure 5. There is a definite removal of pyritic sulfur and, to a lesser extent, for sulfate sulfur. Most distinct is the high level of reported organic sulfur that is bound to the nonmagnetic coal and minerals.

Figure 5.Distribution of Sulfur forms in Splits by ElectriMag^{TM} Belt separator



Early in 2002, magnetic separation tests were done on daily coal samples obtained by Great River Energy at the Coal Creek Station. These earlier tests showed similar reductions in contaminants and improvements in heat content. A very interesting result of the earlier "lower ash coals" tested was seen in the ash fusion and sodium results. The ash fusion temperatures for both oxidizing and reducing environments showed a general increase of around 50 degrees Farenheight while experiencing a significant increase in sodium. In the October 2002 test we also observed an increase in Sodium in the coal. It is possible that this test would also show no degradation in the ash fusion temperatures because total mineral ash analysis showed similar changes.

Table 4. EXPORTech ElectriMagTM belt Separator Energy and Quality Values

	Moist	Ash	Sul	BTU	Na	SO2	Hg (ug/g)	Lb HG/TBTU	Energy Recovery
Feed	24.61	27.32	1.03	5,635	2.27	3.67	0.093	16.583	100.00%
-1 splits	25.89	22.21	1.06	6,189	2.64	3.42	0.085	13.756	96.08%
-2 splits	26.21	21.04	1.06	6,316	2.78	3.36	0.082	12.979	95.04%
-3 splits	26.59	19.50	1.07	6,477	2.96	3.29	0.078	12.024	91.90%

Conclusions

The October 2002 testing demonstrated that the combined deployment of Air and Magnetic separation resulted in a product coal that could have significant positive impact on mine and plant operation. Table 5 below summarizes the quality and relative change of the feed and potential products resulting from combinations of air and magnetic separation. Further testing is needed to determine if the same percentage improvement could be seen on other coal seams or even for the full coal deliveries.

Table 5. Summary results for various product combinations- Allair® and ElectriMag™ Dry Cleaning

Quality	Moist	Ash	Sulfur	BTU	Sodium	SO2/MMBTU	Energy Recovery
Feed	30.65	19.72	0.92	5,956	3.31	3.09	100.0%
Product	32.40	12.73	0.88	6,663	4.64	2.63	76.7%
Prod + Fines	30.92	16.20	0.88	6,392	3.78	2.74	97.1%
Prod + Cleaned Fines	31.53	14.11	0.88	6,604	4.25	2.67	95.4%
Percent change	Moist	Ash	Sulfur	BTU	Sodium	SO2/MMBTU	Energy Recovery
Feed							
Product	5.7%	-35.4%	-4.8%	11.9%	40.4%	-14.9%	-23.3%
Prod + Fines	0.9%	-17.8%	-5.0%	7.3%	14.2%	-11.5%	-2.9%
Prod + Cleaned Fines	2.9%	-28.4%	-4.4%	10.9%	28.5%	-13.8%	-4.6%

Mercury measurements were obtained for the ElectriMag™ Belt separator. These measurements showed a 27.5% reduction in pounds of mercury per trillion BTU. Further testing will be needed to determine if similar reductions in mercury are possible from the Allair® Jig.

The technologies applied here resulted in a high energy recovery rate and significant improvement in quality for a coal having high ash and low amounts of pyritic sulfur. Due to the expected low cost of these technologies it is believed that significant opportunities exist to enhance the quality of existing deliveries and to improve mining recovery through recovery of additional coal currently lost in the mining operation.

One of the most serious maintenance and reliability issues for a power plant is the erosive nature of ash combined with high velocity of the flue gas stream. A reduction of 25% in ash combined with lower flue gas velocities as a result of improved coal should decrease the number of unscheduled outages due to erosion problems. The end result of erosion is typically experienced in the form of steam tube or water wall leaks, resulting in significant outages, both scheduled and unscheduled. During these periods base loaded plants must buy replacement power while a valuable asset remains idle.

Selective use of dry cleaning on selected coals or on the entire feed stream can have a dramatic impact on the emission control system design and operation. These dry cleaning technologies show great promise to remove ash and other minerals that sulfur and mercury is associated with. Preliminary data from limited testing shows a correlation between sulfur, ash and mercury. Lignite with high concentrations of ash and pyrite treated with dry cleaning processes should result in greatly reduce the peak levels of sulfur and mercury emissions. This should translate into lower operating cost and potential output increases without the installation of additional emission control equipment.

From the mining side there are many opportunities to lower costs by economically recovering acceptable quality material from substandard and highly contaminated lignite coal. Field observations in a typical lignite operation often identify situations where incidental and planned operations result in waste material containing a significant percentage of good quality coal. With many operations faced with high and increasing striping ratio (yards of waste material removed to recover a ton of coal) the recovery of more energy can be very economic. The typically dry nature of surface lignite mining combined with the simple and low cost characteristics of dry cleaning shows promise to lower the cost of delivering suitable quality coal for power generation.

Plans are underway to seek funding for long term field testing of these dry cleaning technologies. The long term demonstrations will process a wide variety of lignite's under varying operating conditions. These long term field demonstrations will assist in determining the applicability of dry cleaning technologies in surface lignite operations.

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