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Lignite Fuel Enhancement
Dry Process Coal Cleaning

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Abstract

The overall objective of this project is to evaluate dry coal cleaning and drying processes to improve the economics of lignite mining and power production operations by selective removal of coal contaminants. With economic coal cleaning and drying processes in their tool chest the coal producer and consumer can achieve the appropriate balance between fuel quality and fuel cost to achieve optimum combined mine and power plant performance. This paper presents the preliminary findings from the project currently underway.

Introduction

The cost of power production is directly impacted by the cost of the coal supply and the performance of the fuel in boilers. In order to get optimal performance from power plants the supplier, under a properly devised incentive structure, will strive to supply a fuel that will allow for efficient power production. In doing this the supplier of coal inevitably strives to minimize the amount of contamination to insure the fuel results in efficient operation of the power plant. This often translates into a loss of coal through traditional in the field cleaning operations. Each supplier and consumer must select the appropriate balance between fuel quality and fuel cost to achieve optimum performance.

In the situation where the overall economic rewards are shared with the coal supplier and the coal producer the miner will strive to find the optimal balance between mining costs and power production costs.

The objective of this project is to evaluate dry coal cleaning and drying processes to improve the economics of lignite mining and power production operations by removal of coal contaminants. The primary contaminant in the delivered lignite is the adjacent high density earthen material that is loaded coincidentally with the lignite. Additionally some of the contaminants are within the coal. These include minerals that were formed either during the deposition of the coal or were deposited during later geologic alteration of the lignite. Most of the contaminants have a higher density than lignite. Processes that take advantage of density differences to separate contaminants are widely used in the bituminous mining industry. Water can also be considered a contaminant since it lowers the heat content of the fuel.

Traditional coal cleaning processes typically use a liquid medium to remove the high density contaminants. Cleaning processes that employ water medium are not used for lignite because of the adverse impact water has on the heat content and the high cost associated with the disposal of the waste material from wet cleaning operations. The very high clay content associated with most lignite's increases the amount and difficulty of dealing with fines treatment and disposal. While not as efficient as wet processes, dry processes increase the heat content and result in a waste product that is much less costly to dispose of.

This project includes cleaning a wide range of materials that are normally mined or discarded in the mining process to ascertain the change in fuel quality, which will then be used to determine the effect of cleaned coal has on the power plant. Additionally the impact on the coal supplier will be addressed in determining the cost of achieving additional coal recovery and enhancement of the current deliveries. Combined cost and performance impact on the miner and the power producer will be used to determine the appropriate places to utilize the proposed cleaning technologies.

This project also includes performing a test to determine the ability of a proprietary drying process to produce a stable dried product that approximates typical subituminous coal heating values. The rate of spontaneous heating in dried coal and the reabsorbtion of moisture have been problematic for many previous low rank coal upgrading processes.

The work plan for this project consists of the modules outlined as follows:

Module 1.
Design, construct, and operate a portable 5 ton per hour coal cleaning plant.

Module 2.
Parametric optimization and efficiency study of the air jig plant.

Module 3.
Perform advanced fuel analysis of pre and post cleaning activities and its impact on plant performance.

Module 4.
Estimate of probable construction cost for an all weather coal cleaning plant.

Module 5.
Determine the stability of cleaned and dried Lignite

Background

In the past incentives to upgrade lignite's were small. However, because of the increased regulations for SO_x, NO_x, particulate mater, and mercury the cleaning of lignite must be considered. Wet cleaning processes employed widely for higher rank coals are typically not suitable for lignite because it increases the already high moisture content of lignite, further reducing the calorific content of the fuel.

To attain current and future emission requirements dry precombustion cleaning should be viewed as a complimentary tool to conventional emission control equipment. Precombustion can be broadly or specifically applied to the fuel supply system where it will have the greatest benefit.
Typical emission reduction equipment treats the entire flue gas stream resulting in very large and costly equipment and processes. Precombustion cleaning results in removal of a significant percentage of heavy mineral particles that can be disposal of at low cost in some cases. This is because the contaminants are in their original state instead of the chemically altered state created in the combustion processes. The optimal combination of pre and post combustion emission control should be evaluated in comparison to exclusive use of post combustion processes.

Dry cleaning processes are suitable for removing the distinct non coal particles that are liberated during the mining and coal crushing processes. Fine grain minerals bound to the coal matrix will not be liberated by wet or dry cleaning processes. The distinct earthen materials that are mined coincidentally with the coal are prime candidates for separation during the cleaning process. Both wet and dry cleaning processes work better on coarse particles. Fine particle sizes pose significant processing and disposal issues. Dry processing results in less costly disposal of the cleaning process reject material.

Typically improving the quality of coal in lignite operations has resulted in overall higher mining costs and increased loss of coal materials. Dry coal cleaning has the potential to improve the quality of currently mined coal as well as reducing the amount of coal lost during the mining process.

The overall objective is to achieve a fuel that cost less to supply and that will simultaneously improve the operational and economic performance of a power plant

Module 1 | Design, construct, and operate a portable 5 ton per hour coal cleaning plant

Figure 1. | Air Jig Facility September 2004 Coal Creek Station Underwood North Dakota

A portable five ton per hour plant employing dry cleaning methods was designed, constructed, and is currently being operated. The objectives of this program are to determine the total economic and environmental impact of the cleaning processes for combined mine and power plant operations. Parametric studies will be mare being conducted to assist in determining the optimal performance settings for the plant. The primary target of the project is to determine if additional coal can be economically recovered from the mining operation and to evaluate the performance in improving the quality of fuels that are problematic. Typical high quality coal is being tested to determine the benefits of supplying improved quality fuel

Features of the facility include a combination crusher screening plant to process 6 inch minus feed into +1/4 inch coarse and -1/4 inch fine size feed. Automatic primary samplers are installed on the feed, clean coal, dirt, and baghouse conveyors. Trucks and wheeled bins were used to collect the material from the three product conveyors. The trucks and bins were weighed on certified over the road commercial scales. This combination allowed for systematic sampling and the ability to perform mass balance of the processes. The project also includes a sample preparation trailer and a magnetic separator.

The unit was designed fabricated and erected in the June through September 2004. The unit was setup in the coal yard at Great River Energy's Coal Creek Station located south of Underwood North Dakota. Coal was processed from the Falkirk Mine and the Freedom Mine from September through early December 2004. The unit was disassembled and shipped to the Red Hills Mine in Mississippi during December 2004. The Red Hills mine is located north of Ackerman Mississippi. The unit was assembled in January 2005, and is currently processing coal from the Red Hills mine. In April coal from the Red River mine located in Coushatta Louisiana was delivered to Mississippi for processing. The results presented in this paper cover the summarized testing results from the North Dakota operations. All of the mines having coal processed are operated by North American Coal Company (NAC) or its subsidiary companies.

The testing program consisted of mining and testing three different classes of material they are as follows:

1. **Discarded Coal – Opportunity Coal**
   a. Coal seam cleaning
   b. Spoil Rib Coal
   c. Soft or weather coal

2. **Problem Coals – coals currently mined that need blending**
   a. Thin Coal
   b. Coal with Carbonaceous Partings or Blackjack
   c. Higher Ash Coal
   d. High Sulfur

3. **Typical Clean Coal**
   a. Thick lower ash Coal
   b. Coals with thin partings

Throughout the program the Air jig and magnetic separator showed improvement to the overall quality while providing very high energy recovery. The results of the air jig were more consistent and the air jig is capable of handling all size of materials and is more tolerant of surface moisture. The results of the Air Jig on the opportunity coals were sufficient to make a economically viable quality fuel from material currently being discarded in cleaning operations. The following figure and table are for the Top cleanings test. In this test the dragline operated in its typical mode, leaving a mixture of coal and dirt on top of the excavated coal seam. The next operation would be to use a rubber tire or track dozer to complete final cleaning before coal loading operations commence. This time instead of pushing the mixture of dirt and coal off to the side of the pit or up to the dragline the top cleaning was left in a pile.

Figure 2. | Top Cleanings before loading

This pile was loaded and hauled to the air jig, where the top size was reduced to minus 2 inches in size and segregated into plus _ inch and minus _ inch piles. The materials were then batch through the air jig. The quality of this composite feed material is unacceptably low for shipments to the power plant without a significant amount of blending. After crushing and screening the plus _ inch material is greatly improved and could be feasibly delivered to the local power plant, however the ash level and sulfur levels could be problematical with a slight variation in the fuels we would normally blend with. After running the plus _ inch material through the Airjig we have a product that can be shipped without the need to blend with other coals. At the same time the energy recovery is acceptably high. Since this is material currently moved but wasted the cost of this feedstock for dry coal cleaning is very low.

Table 1 | Coal quality for top Cleaning Test

Riv A Top Cleanings	BTU	Ash	Sodium	# SO2 MBTU	#Hg/ TBTU	% of Weight	% of energy
Feed Coal	4921	28,03	2,17	5,94	23,10	100,00	100%
+1/4 inch	5847	18,58	1,93	6,20	25,10	65,00	77%
-1/4 inch	3200	45,56	2,61	5,07	16,10	35,00	23%
Clean Coarse	6163	15,05	2,01	1,94	8,00	63,40	73%
Clean Fine	3247	44,95	2,64	3,68	11,00	34,70	23%
Clean C+F	5143	25,52	2,23	3,22	10,80	98,10	96%
Change	25%	-46%	-7%	-67%	-65%		

Table 1. | Coal quality for top Cleaning Test.

From the preceding table it can be seen that the improvement for coarse plus _ inch material is significantly better than for the minus _ inch material. This was typical for nearly all tests. From an environmental standpoint this process typically returns to the pit material that was left behind in typical mining operations. The quality of the materials we are currently leaving behind is not impacting the ground water quality that is being established in the reclaimed spoil. The quality of the reestablished groundwater table has been very acceptable as demonstrated from the well sampling done at the mine. The net potential effect is greater resource recovery without sacrificing the reclaimed land quality. Placement of the airjig and screen reject is being made into the same stratigraphic area and being covered in the same timeframe as material that was previously discarded.

The following picture and table describes the result from mining a typically high quality coal seam with a thin parting. The parting here is a white clay material that is generally less than 3 inches thick. In the area mined here we occasionally have slightly elevated sulfur levels and occasional problems with boiler fouling. Overall the full seam is approximately 10 foot thick so the thin parting has very little impact on overall quality. The coal losses associated with the parting removal can typically run around 10 percentage points.

Figure 3. | Thick High Quality coal with a thin parting

Table 2 | High Quality Coal with a Thin Parting

Center A1A2Thin Parting	BTU	Ash	Sodium	# SO2 MBTU	#Hg/ TBTU	% of Weight	% of energy
Feed Coal	6142	12,39	0,64	2,92	11,40	100,00	100%
+1/4 inch	6457	9,71	0,70	2,85	11,00	65,00	68%
-1/4 inch	5556	17,37	0,52	3,06	12,20	35,00	32%
Clean Coarse	6601	7,99	0,71	1,59	6,00	63,00	68%
Clean Fine	5616	16,73	0,51	2,97	11,60	33,00	30%
Clean C+F	6257	11,04	0,64	2,02	7,80	96,00	99%
Change	2%	-11%	0%	-31%	-32%		

Table 2. | High Quality Coal with a Thin Parting.

The results of this test were surprising as the average coal quality was lower than expected. In this case the average material was acceptable for normal deliveries although the ash level was above our 11 percentage ash level target. The quality of the feed coal would allow for the power plant to reach peak operating levels without stressing any of the emission equipment except for the need to dramatically increase lime consumption. The cleaned coal has superior characteristics especially with respect to sulfur and mercury reductions.

The reject material from the Air jig was examined carefully and it was discovered that there were many pieces of hard dense rock. It was not known by the mine operations that we had a thin layer of dense black material that contained a significant amount of pyrite in the seam. From previous drilling in this area it was known that we had isolated instances of high sulfur but there was no consistent pattern. Due to the higher density of this black material it was very amenable to the air jig and the resulting sulfur and mercury levels were drastically reduced.

Several other coal seams and opportunity coals were also tested. The range of improvement for various coals are summarized below.

Overall the Air jig performed acceptably, especially considering that this was unit 1 from a ground up design. The vendors, mine operators and power plant personnel did a tremendous job of setting up the equipment and making alterations required for the strict safety standards. Many enhancements were made to the unit to improve performance, and it is the opinion of the author that the earlier results are expected to be the minimum level of performance expected from the air jig.

Table 3 | Quality Improvement Ranges Falkirk and Freedom mine Coal

	Falkirk Mine				Freedom Mine	
	Typical Coal		Opportunity Coal		Typical Coal	
	Low	High	Low	High	Low	High
BTU	1%	6%	19%	25%	1%	2%
Ash	-5%	-23%	-38%	-46%	-9%	-13%
Sodium	0%	2%	-7%	21%	0%	3%
SO2/MMBTU	-8%	-31%	-31%	-67%	-15%	-34%
# Mercury/TBTU	-13%	-32%	-42%	-70%	-22%	-33%
Energy Recovery	97%	99%	72%	73%	96%	98%

Table 3. | Coal Quality Improvement Ranges – North Dakota Lignite Testing.

Module 2 | Parametric optimization and efficiency study of the air jig plant.

Work is continuing on this portion of the project. The University of Kentucky Research Foundation is directing this portion of the Project. The optimization testing done in North Dakota is being verified by further testing at the Red Hills Mine in Mississippi. Significant enhancements have been made to the Air jig after completing preliminary optimization runs at Falkirk. Results from this module will be reported later

Module 3 | Perform advanced fuel analysis of pre and post cleaning activities and its impact on plant performance.

Work is currently underway on this portion of the project. The Energy & Environmental Research Center is directing this section of the project. They will be running advanced ash analysis of the feed and cleaned coals and blends of coal. The objective here is to quantify the characteristics of the fuel and the ash. These analysis will then be used by Black & Vetch to run a balance of plant impact study utilizing the utilizing the VISTA Program.

The results of this study will be used to determine the economic benefit of using the airjig on the entire deliveries of coal to the Coal Creek Station.

Module 4 | Estimate of probable construction cost for an all weather coal cleaning plant.

This section of the project is being executed by Barr Engineering. The task here is to identify the cost of building and operating an all weather facility in North Dakota. This study will address the issues of providing an adequate environment to allow for efficient year round operation. It is envisioned that this will be a stand alone plant for processing opportunity coal. This focus may be modified if the results of the EERC and Vista study indicate positive economics for treating the entire coal delivery to the Coal Creek Station.

Module 5 | Determine the stability of cleaned and dried Lignite

This portion of the project is a demonstration of the ability to produce a stable dried lignite product that is similar to subituminous coal from a heating value standpoint. Select cleaned lignite from the Module 1 testing was blended to provide a typical feedstock coal for the Great River Energy pilot drying plant. The coal was process in two passes through the drier and then cooled before beginning an extended covered storage test. The dried coal was placed in a covered grain trailer. Thermal couples were placed to determine the temperature throughout the trailer. Temperatures were monitored on a continuous basis and the test was completed when the highest thermocouple temperature reached 160° F. Testing began on November 23, 2004 with coal that had been cooled down after drying. The target temperature was reached on January 6th 2005, 44 days later. The increase in temperature was very consistent throughout the test and did not accelerate appreciably as the temperature rose. The coal was dumped from the grain trailer on January 6th, 2005 and was then placed in a stockpile. Thermal couples were placed into the stockpile to determine the temperature gradient as the coal sat outdoor over an extended period. Samples have been taken of the dried coal periodically as shown In the table below.

Figure 4. | Module 5: Pilot Dryer and Dried coal storage trailer

Table 4 | High BTU Drying Test Results

Sample	Total Moisture	As Rec Ash	As Rec BTU	As Rec Sulfur	Sodium in Ash	Lb Sulfur per Million BTU
Ave Feed 11/2/04	35,83	10,01	6,537	0,62	2,30	1,90
1st pass 11/4/04	21,30	12,26	8,003	0,74	2,09	1,86
2nd pass11/16/04	15,40	10,52	8,881	0,75	2,04	1,68
Cooled 11/23/2004	15,70	11,28	8,703	0,78	2,02	1,79
Dumped 1/6/2005	16,59	9,33	8,830	0,95	2,47	2,15
Current 3/23/2005	16,99	10,36	8,695	0,91	2,69	2,09

Table 4. | High BTU Drying Test Results.

The results of this test show that moisture reabsorbtion in the lignite is very slow during the test period and that the increase in heat was slow and predictable. Since placing the coal into the small outdoor stockpile the temperature has been very constant. Further testing in warmer weather will be documented and reported.

Summary

The preliminary findings from this study demonstrate that »Lignite Fuel Enhancement« utilizing Air Jig Technology, magnetic separation and coal drying show significant potential to work independently or in conjunction with power production emission equipment to achieve the best cost performance of a combined mining and power production project.

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