FINAL TECHNICAL REPORT
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Project Title: **FIELD DEMONSTRATION OF RECOVERY, EFFICIENCY AND COAL QUALITY ENHANCEMENT AT AN ILLINOIS MINE**

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ABSTRACT

The techno-economic feasibility of ultra-fine (100 mesh x 0) coal recovery has been established in this study. It has been demonstrated that application of column flotation and filter press for cleaning and dewatering the ultra-fine refuse from existing coal cleaning plants can increase clean coal recovery by 3-5 absolute percentage points. The host coal company has estimated the pay-back period of such an investment at 13.5 months. A distinct advantage of this technology is the ability of the filter press to produce very low moisture product, which results in minimal impact on the overall clean coal product heating value when this product is blended with the coarse clean coal.

A pilot-scale circuit comprised of a Turbo column and a Technicas Hidraulicas Filter Press was demonstrated at two Illinois coal mines in this project. A clean coal product with 8% ash at a yield of 43% and 19-20% total moisture was obtained on a consistent basis under actual plant operating conditions at one mine. At the other mine, a 9% ash product at 24.1% moisture was achieved at a yield of 53%. At the first mine, it was predicted that the overall clean coal recovery will increase by as much as 3.5% with only a minimal reduction in the heating value of the overall clean coal product. After accounting for penalties/premiums for product quality, overall increase in profitability by $8 million per year was predicted. At the second location, the application of plant optimization in conjunction with fine coal cleaning suggested the potential to increase clean coal recovery by 5%. When optimization was conducted to improve product quality while maintaining Btu sales constant, reductions in sulfur and mercury in the clean coal by 7.5% and 9.3%, respectively, were indicated.

To achieve the realization of a “near-zero solid waste discharge” from mine sites, additional studies were directed towards developing beneficial use applications for flotation tailings as landfill liner and top cover applications. Exploiting the presence of abundant clays in flotation tailings in engineered combinations with coal combustion byproducts, disposal area liner materials were designed to achieve hydraulic conductivity less than the prescribed 10^{-7} cm/s. Engineered mixes were also designed for use as top cover materials. These soil-like materials were vegetated for two generations as leachate and vegetation growth were monitored. One developed mix exhibited satisfactory vegetation performance and leachate characteristics comparable to natural soil.

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EXECUTIVE SUMMARY

With funding support from the Illinois Clean Coal Institute and the participating coal company, this research focused on demonstration of an economical ultra-fine coal cleaning circuit utilizing commercially available technologies for improving clean coal recovery and enhancing clean coal quality from cleaning plants. The ultra-fine coal cleaning circuit utilized column flotation technology for cleaning 100 mesh x 0 ultra-fines that are conventionally discarded in refuse ponds. The cleaned fines were dewatered using a Spanish-designed, recessed plate and frame pressure filter marketed as the Technicas Hidraulicas Filter Press (THFP). Beneficial use applications that synergistically combined flotation tailings with coal combustion byproducts (CCBs) were also developed in this study. These applications included low-permeability landfill liner materials and top soil cover materials supporting vegetation and producing benign leachates for use in landfill and mine reclamations. A summary of research in these areas accomplished as part of this study is provided herein.

Fine Coal Cleaning Studies at a South-Western Illinois Mine

In-plant studies on the column flotation and filter press circuit for cleaning ultra-fines were conducted at a South-Western Illinois (SWI) coal mine. After initial optimization experiments, the circuit was operated for 36 hours over the course of 4 days. Hourly samples from the flotation and dewatering circuits were collected to obtain an estimate of variability due to changing plant conditions. Over the period of this testing, the circuit feed ash content was 47.1±2.8% at a feed solids content of 4.7±1.0%. The flotation circuit produced a product ash content of 10.0±1.2% at a mass yield of 51.7±3.0% and a combustible recovery of 87.9±1.6%. The filter circuit dewatered this product to 24.1±1.0% total moisture content. During continuous operation, circuit performance was extremely stable even as feed ash content variations ranging from 42.6% to 52.6% and feed solids content variations ranging from 3.3% to 8.0% were encountered. During the last day of testing, it was observed that product ash content could be reduced significantly without sacrificing combustibles recovery by increasing froth depth. For this day of testing, average product ash content of 8.96% was achieved at a combustible recovery of 88.5% compared to a product ash content of 10.47% at 87.9% combustibles recovery achieved earlier. This difference in product ash contents was statistically significant at better than 99.9%. Hence, it was concluded that the demonstration circuit could produce approximately 9% ash product at 24% total moisture content. This corresponds to a product as-received heating value of 9,824 Btu/lb (12,943 Btu/lb on a dry basis).

Laboratory Tests

Encouraged by excellent results from the first demonstration, professionals of the participating coal company wanted to investigate the applicability of this technology at one of their other coal mines in South-Eastern Illinois (SEI) since the estimated payoff at that location was potentially higher. Before embarking on a detailed in-plant pilot-scale testing of this technology at that mine, a bench-scale laboratory study was conducted to determine the amenability of that location's ultra-fines towards flotation and dewatering.

These studies involved flotation release analysis studies and dewatering studies using vacuum and pressure filtration. A representative fine coal refuse sample was obtained from the SEI coal mine. The release analysis on this sample indicated that a 9.5% ash content product could be recovered at a mass yield of 44.5%. This corresponded to a combustibles recovery of 90.5% and ash rejection of 92.4%. Results of dewatering tests conducted on the fine coal flotation product from the two mines consistently indicated that the coal from the SEI mine dewatered better than that from the SWI mine both in terms of the filter cake total moisture as well as dewatering time. The SEI flotation product produced a filter cake with approximately 10% lower moisture content. Dewatering was also achieved at a considerably lower cycle time. Based on these results, it appeared that the flotation-dewatering performance that could be achieved at the SEI mine would exceed even the excellent performance achieved at the SWI mine. Results of these laboratory studies were extrapolated to predict that a filter cake containing 22-23% total moisture could be produced after column flotation and filter press dewatering of the SEI mine fine coal refuse. Hence, a detailed in-plant study to establish performance and generate data for scale-up and engineering economic evaluation was planned at the SEI coal mine.

Fine Coal Cleaning Studies at a Southeastern Illinois Mine

In-plant pilot-scale column flotation and filter press dewatering studies were conducted at the SEI coal mine. The circuit was fed a blend of nominally -100 mesh classifying cyclone overflow and the clean coal sieve bend underflow. Tests were conducted over two shifts for optimizing operating conditions. Following this, the circuit was continuously operated under optimum conditions for two shifts. Over this period, the circuit produced a 7.6% ash content and 13,569 Btu/lb (dry basis) product from a feed containing 53.3% ash and 6,858 Btu/lb (dry basis) heating value at a mass recovery of 43%. Flotation tailings had an ash content of 87% and were comprised of mostly Illite and Illite-montmorrilonite mixed-layer clays. The clean coal product from the flotation column dewatered to a very low total cake moisture content of 19.9%, averaged over the 2-shift operating period. This level of moisture content compares favorably to the best commonly used dewatering technologies treating the same particle size ranges. The filter cake discharged from the press without any difficulty and exhibited good handling characteristics making it suitable for conveying and blending with coarse clean coal.

Engineering Economics of Fine Coal Cleaning

Encouraged by the excellent technical performance of the ultra-fines cleaning circuit, the participating coal company developed detailed implementation plans and conducted detailed engineering economic evaluations after seeking input from the project team, equipment suppliers, construction companies and based on in-house experience and data. The developed circuit was compared side-by-side with an alternative partial ultra-fines cleaning option involving flotation columns and screen bowl centrifuges. The capital cost of the developed circuit was estimated at approximately $10 million to process about 115 tph of feed. The capital cost for the alternative was estimated at $4.1 million. The annual incremental profit from the two options was estimated at $8 million and $4.5

million, respectively, after accounting for operating costs. It is to be noted here that the product quality from the column-filter circuit was superior to that from the column-screenbowl circuit. With this, pay-back periods for the two options were determined to be 13.5 months and 11 months for the column-filter circuit and the column-screenbowl circuit, respectively. These pay-back periods are very attractive from virtually any stand-point. The company however decided in the favor of the second option owing to the lower initial capital investment associated with it. The superior ability of the column-filter circuit to reduce mercury in the clean coal product was not considered. Also, benefits from co-management of flotation tailings and CCBs were not considered in the engineering economic evaluation. Increased impoundment life as a result of higher ultra-fines recovery may also be valuable at several locations. The benefit associated with this was also ignored in this evaluation. In any event, the project economics demonstrated that the developed technology delivers an excellent return-on-investment while improving profit performance more than any other technology currently in place.

Opportunities for Coal Quality Enhancement

One of the major goals of this study was to develop options for preparation plant optimization resulting from the implementation of the ultra-fines cleaning circuit for maximizing recovery and improving the quality of the clean coal product in terms of heating value, sulfur and trace element contents. To achieve this goal, three alternate optimized plant operation scenarios were developed. These were:

1. Add the ultra-fines cleaning circuit and optimize the entire plant to maintain the same product lbs SO_2/mmbtu as the current product.
2. Add the ultra-fines cleaning circuit and optimize the entire plant to maintain the same product as-received Btu as the current product.
3. Add the ultra-fines cleaning circuit and optimize the entire plant to maintain the same Btu sales as present while producing a product with the least amount of sulfur, mercury and ash content at the highest heating value.

Results indicated that with the addition of the ultra-fines cleaning circuit, overall plant production can be increased by as much as 72 as-received tons per hour or 5% in terms of yield while maintaining the all-important lbs SO_2/mmBtu levels the same as before addition of this new circuit. If the current as-received product heating value was to be maintained at the same level after addition of the ultra-fines circuit, production was projected to increase by 21 tph. If the primary goal was to improve product quality to the maximum possible while still maintaining current contract Btu sales, simulations indicated that a reduction in SO_2 generation potential by 7.5% and a reduction in the mercury content of the clean coal by 9.3% could be achieved. With this scenario, the mine would be able to retain existing contracts by having the ability to supply a better quality product or be able to enter new markets requiring more stringent pollutants control. With the increasing focus on mercury emissions, the ability of the ultra-fines cleaning circuit addition to achieve a 9.3% reduction in mercury may have a tremendous impact. The evaluated scenarios range from very liberal market conditions for the mine as in scenario 1 to very conservative conditions in scenario 3. At most mines supplying a variety of customers with different contractual obligations, the most common scenario involved would be somewhere in between scenarios 1 and 2. In either case, the option of ultra-fines cleaning is attractive. Scenario 3 on the other hand would give the mine a very important tool to survive and thrive in environmentally stringent market conditions, which may presumably exist in the near future.

Low-Permeability Liner and Engineered Soils Development Studies

To achieve a "near-zero solid waste discharge" from the mine site, beneficial use applications were also developed for the tailings from the flotation column. Upon compaction, these flotation tailings with high clay content in conjunction with engineered compositions with Fluidized Bed Combustion (FBC) ash and F-ash were demonstrated to achieve hydraulic conductivities significantly lower than the 10^{-7} cm/s required for materials to be usable as landfill liners. Developed materials also indicated the appropriate strength and plasticity characteristics making them suitable for such an application. Compositions of flotation tailings and CCBs were also demonstrated for application as daily cover materials for landfills as well as for use as top-cover for mine reclamation. This engineered mix supported healthy vegetation, particularly in the second generation of growth, and exhibited benign leachate characteristics.

Future Work

From the engineering economic evaluation, it became apparent that reducing the capital cost of the filter would make the technology even more attractive and produce pay-backs lower than any other competing alternatives while providing the biggest increase in profitability and recovering all of the value from the mined coal. In response, the PIs have developed concepts to increase filter capacity by 25-30% while improving dewatering performance. These concepts have undergone preliminary testing and have indicated significant promise. However, additional work is needed to further test these concepts and to commercialize them. If targeted improvements in filter capacity are achieved, capital costs would be reduced correspondingly making the developed technology universally applicable.

Conclusion

This project has established that ultra-fine coal recovery from preparation plants is a technically and economically attractive proposition. To maximize profitability and the energy utilization of mined coal, the entire ultra-fine reject from preparation plants needs to be cleaned and coal recovered using the developed technology. With the application of this technology, options also exist to significantly increase clean coal recovery while also improving clean coal quality in terms of hazardous air pollutants such as sulfur and mercury generated during utilization of coal.

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