INCREASING FUEL FLEXIBILITY AT POWER PLANTS

or "Why Mills are IMPORTANT"

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Understanding the Business of Coal

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Introduction

The electric power industry is rapidly changing due to deregulation. The author was present one hot day in June of this year, when a southeastern utility company was selling electricity for $5,000.00 per megawatt with $85.00 cost. Typical power cost range from the mid teens at night to about $30.00 on a normal day. The free market place will challenge the power industry in many ways. Fuel is the major cost in electric power. In a regulated industry the cost of fuel was passed on to the customers. Fuels were chosen to minimize problems such as handling, combustion, ash deposits and other operational and maintenance concerns. Tight specifications were used to eliminate or minimize coals that caused problems. These tight specifications raised the price of fuel by minimizing competition. Deregulation is on its way. As the power stations become individual profit centers, plant management must take a more proactive role in fuel selection. When the plant starts to take a more active role in the selection process, it develops improved communication with fuel purchasing as well as a more accurate overall understanding of coal quality. Fuel cost is always a major production cost. Understanding how coal quality impacts plant performance and cost, allows better fuel selection decisions. Utilizing coal specifications that minimize unpredictable problems like slagging and high opacity is even more important. Plant personnel need to become aware of the nature of coal and implement creative solutions for problems arising from differing coal quality. The potential of lowering fuel cost is so significant that most utilities will at least explore their options. How well plants take advantage of their knowledge, may determine, whether they will be able to compete in a free market place. The coal industry Itself can provide many insights on how to survive in this type of market. Coal mines today must remain competitive or be shut down. The consolidation of the coal industry indicates the trends that can occur in a competitive market These trends have already started, and will continue in the utility industry. This paper will discuss several common situations concerning coal quality and potential solutions for the plant to consider.

Coal Handing

The handleability of a fuel is impacted by primarily two items - sizing & moisture. The sizing impacts the surface area and mass of individual particles, and the moisture acts as a binding agent between particles. The sizing of a fuel is dependent on several items. The Hardgrove Gindability Index (HGI) of a coal is a test that indicates how easily the coal breaks up in the mill. High >60 values of HGI mean that the coal is relatively soft and break up easily. These coals have been reported by many utilities to have handling and dust problems. Coals that have had most of the top sizes removes or pond fines are also finer and have had problems. Most coals are spec'ed to be 2x0. This sizing spec is rather loosely used and is rarely enforced. Use your understanding of how the coal is processed and blended to develop ways to minimize fine coal if possible. The moisture in coal exists in two forms. The inherent moisture is in the coal when it is mined. This is approximated using the equilibrium moisture test. The moisture that impacts the handling of a coal is the surface moisture. This is the moisture added during the mining, preparation, transportation and use of the coal. The surface moisture is approximated using the air dry loss moisture test in most bituminous coals. For PRB and other low rank coals use the total moisture minus the equilibrium moisture to calculate the surface moisture. The air dry loss test is a step in the short prox testing of a coal and therefore is available for most coal shipments. Ask your coal Lab about reporting the air dry loss moisture. Controlling this surface moisture is key in controlling the handleability properties of a coal. The following sections offer ideas on controlling dust and handing wet/sticky coals.

Controlling Dust

This discussion focuses on methods for controlling fugitive dust associated with yard operations. One of the most effective and cost efficient means of controlling dust is to use sprinklers to add surface moisture to the outside of the pile. This additional moisture is applied only to the surface of the pile, and only when necessary. The total moisture of the coal is not significantly changed. There are several chemical treatments available that may improve the performance of the water sprays, but are generally expensive to use compared to water. Chemical treatments can be useful when treating only the outside of a pile. Latex materials that become hard can be used to treat inactive areas of the pile to form a crust that is hard enough to walk on without breaking through. This solidification of the sides of the piles complements what the author calls the crater concept. With this type of coal pile management the outside of the pile is inactive, and the main activity of reclaiming and stocking-out occurs within the pile walls. This would look like you were working in a crater of a volcano. In some cases it is more practical to work in a horseshoe shaped crater where one wall has been removed. In both cases the wall around the active portion serves as a wind break that minimizes the amount of dust leaving the pile. Speaking of wind breaks, the strategic planting of pine trees can be both effective and attractive.

Improving Handling

Wet coal handling problems have at times caused problems for just about everyone. The author has noticed sledge hammer marks on coal chutes across the nation. In some cases, the coal yard practices were causing additional problems by allowing additional surface moisture on the coal. These could be practices such as: large flat piles that allow little if any runoff, pushing the coal through low areas that have standing water in them while reclaiming, or ground water level that is actually higher than the pile. "Yes, we have an artesian well coming out the side of the pile" was a quote from one yard supervisor. Practices used by the coal yard can have major impacts on coal moisture levels, so consider all the ramifications wet coal has on plant operations when allowing these practices to continue. Try to control moisture by allowing good drainage of the pile. Try to elevate the reclaim area to allow for good drainage.

When stuck with using wet or hard to handle coal, the use of high molecular weight polypropylene plastic chute liners has been the number one method used to improve the flowability of coal chutes. The attachment method is important for both performance and durability. The use of ceramic tile can certainly extend the life of a high impact area, unfortunately it rarely improves flowability. Stainless steel is usually superior to carbon steel, although both flow better when polished. Air blasts and vibrators are best used intermittently as continual uses can further pack a pluggage. Chemicals can rarely be applied in enough quantity and mixed well enough to solve problems. Your coal suppliers are good references for determining how they improve handling. Remember they have to move the coal every day just like you do.

The coal size impacts the flowability. Large chunks are important because they help break up the initial stages of pluggages caused by fines building up. One plant struggled for days with wet coal problems in the plant, while the coal yard processed the coal through hammer mills as usual. When these crushers were by-passed the plants situation improved considerably. The purpose for crushing the coal in the first place was to assist the pulverizers in their job. Unfortunately, the mills never saw the coal because the feeder was plugged. Increased moisture also decreases pulverizer performance by lowering the Btu value and causing additional coal recirculation to allow drying.

Mill Capacity

The ability of a power plant to pulverize coal for combustion is directly related to the load produced and indirectly impacts other areas such as slagging, ash sales and opacity. One measure of the grinding nature of a coal is the Hardgrove Grindability Index (HGI). This index is used to calculate the variation in tonnage throughput from one coal to another, generally using a set of curves provided from the mill manufacturer. Emphasis is placed on this number by many utilities, but it is only part of the mill capacity equation. Surface moisture, inlet and outlet coals sizing and heating value all play a significant role in determining mill capacity. More utilities are incorporating a heating value adjustment to the HGI. Higher Btu coals can have a lower HGI than the HGI required by lower Btu coals. This has opened up the market place for several utilities that never considered low HGI coals. This Btu adjusted capacity method does allow a greater range of coals to be considered, but does not change the fundamental capacity of the mills. To do this a plant must consider the outlet sizing, at the coal from the mill, and what impacts it has on other boiler and plant components. Obtaining mill fineness samples is hard, noisy and tedious work that does pose some safety concerns.

Consider this, one eastern plant decided that it would emphasize knowledge of coal sizing and its impacts on plant performance. They assigned personnel to perform, almost exclusively, coal fineness testing. These results were compared to changes in mill parameters such as spring tension, bowl clearance, and primary air flow to quantify the performance of the mill. This knowledge led to the expansion of the HGI specification by more than 20 points. The maintenance to keep these mills in shape is influenced significantly by the results of the fineness testing. At a time when many plants are reducing their mill maintenance budget to control costs, one plant is increasing theirs to be able to burn harder to grind coals. The fuel cost savings this mill capacity increase provided amounted to millions of dollars a year. It has been the authors experience that power plants vary in a large degree in the emphasis they place on mill performance. This example shows some of the potential savings from this type of work and should lead to utilities becoming more aware of the wide variety of options to expand coal specifications.

Slagging with Bituminous Type Ash - High Iron

This example will show how a utility was able to lower its ash fusion specification by understanding how different coals behave in the boiler. Typically utilities have specifications for total ash (in percent) and a fixed fusion temperature spec. Published accounts of utilities experience in this area have led many slag specialists to consider the amount of ash loading to be important. When ash levels are expressed in pounds per million Btus, they more closely reflect the levels seen by the boiler. The author has also proposed that the Iron loading (**lbs.Fe2O3/MBtu**) level is an important consideration. In several boiler Eastern/Midwest coal slagging events worked on by the author, the problematic coal had elevated iron loading levels. Using this information several utilities have conducted test burns of coals with lower fusion characteristics. Their strategy was to limit the iron loading by considering lower ash, higher iron coals. These coals had lower than design fusion temperatures but it was suggested that the lower ash levels would offset this. The results of the test confirmed that the iron loading levels more accurately predicted the slagging behavior of the coal than the fusion temperature of the coal. A more detalied look at this subject follows:

Slag Review

Lets start our review with an overview of coal mineralogy and its relationship to coal ash chemistry, melting & slagging properties, and fusion temperature. There are not distinct melting points for coal ash like with ice or other pure compounds, so when melting is mentioned it is used to represent a decrease in viscosity, rather than a melting point. When coal ash melts it occurs on both a large scale and a microscopic scale. On the large or bulk scale the ash behaves like a glass. As the temperature of the material increases, its viscosity decreases. At temperatures less than 2000° F. the ash may appear solid, or at least stiff, such as a Tootsie Roll. On a microscopic scale several minerals may have all ready melted, but their concentrations are low when compared to other minerals with higher melting temperatures. As the temperature is increased the ash becomes less viscous or more liquid like. Many reactions are now occurring between the minerals as they melt and become more fluid. As the molten components mix they become more like molten glass. This molten material starts to dissolve the non molten materials like quartz and other minerals. In this way the melting temperature of minerals such as sandstones and shales are lowered by other minerals such as pyrite and limestone.

The ASTM Fusion Temperature Test is a documented observation of this process occurring in coal ash shaped like a small cone, and placed in a furnace with increasing temperatures. The initial deformation temperature, ID, is usually a hundred or more degrees above where the first low melting temp. minerals start to melt. The remaining fusion temperatures represent an ever increasing amount of molten material, and a lowering of the viscosity of the glass like material. It should be noted that even at the fluid temp. there may be solid or non-melted minerals such as quartz. The atmosphere of the furnace is controlled to either an oxidizing (like air) or a reducing (CO present) condition. This is important due to the oxidation behavior of iron (Fe) atoms. Reduced iron lowers melting and fusion temperatures of ash much better than the oxidized form. In coals that have significant iron levels, like those in the Illinois Basin, the oxidation state of the iron is critical. The difference between the oxidizing and reducing fusion temps. can be hundreds of degrees. This phenomenon is one of the variables that make consistent fusion temperature data hard to obtain.

When trying to determine the behavior of coal ash in a boiler, both the type and size of minerals present is important information. Unfortunately it is both difficult and expensive to determine the actual minerals in coal. The ash chemistry or major and minor elements in coal ash are the next most useful information. This is because melting properties can be estimated and minerals can be inferred. Although the cost of ash chemistry is higher than fusion tests, the information obtained is well worth the expense. The fusion temperature test is a lower cost technique with reasonable turnaround time. Fusion temperatures have been used for years, and are contained in most coal contracts. Unfortunately, fusion temps. provide no mineralogical information, are notoriously imprecise and are influenced by all sorts of factors that cause variability. It is the authors experience that different laboratories can produce fusion temperatures that vary well outside the ASTM guidelines, and both laboratories are performing satisfactorily. This is why the author suggests the use of Ash Loading levels as decribed below:

Ash levels

Ash levels in coal are generally reported from the lab as a percent of ash. This is convenient for the lab but not completely representative of what the boiler sees. Boilers demand Btus, not tons of fuel. A more representative (for the boiler) way to express ash levels is to use pounds of ash per million Btu. These units are easy to calculate using the following expression:

Lb. Ash/MBtu = %Ash/(Btu/lb./10,000)

Proper Coal Fineness is Critical to High Iron Slagging

Coal fineness also plays an important role in being able to utilize coals with elevated iron levels. Many slagging problems associated with high sulfur-low fusion coals can be traced back to poor grinding (fineness) of the coal. Large pyrite particles escape from the mill and do not completely oxidize in the flame. The molten particles contain un-oxidized iron that can flux the aluminosilicates in the ash into low melting type glasses. This effect is most dramatically seen in the difference between the oxidizing and reducing fusion temperatures. The spread between these fusion temps can be several hundred degrees in high iron coals. Again maintaining mill performance can significantly impact the use of lower fusion eastern type coal.

Slagging with PRB and other Lignitic Type Ash - High Calcium

For western coal is is recommended not to use fusion temperatures alone. Plant slagging and fouling potential could be rated using sodium and calcium loading levels. Consider the use of chemical fractionation tests to quantify the organically associated sodium and calcium. We still have a lot to learn about using low rank coals especially in the ash deposit area. Most coal suppliers and plant personnel have little information concerning the organically associated alkalis. Other authors have reported that using the Si/Al ratio as it relates to clay type and mineralogy is key. Clay minerals are common in coals and very hard to quantify. Using silicon to aluminum ratios can help identify type of clays but is influence by many other minerals such as quartz and sandstones. Using advanced analytical techniques such as x-ray diffraction and computer controlled electron microscopy can further assist in understanding your coals mineralogy.

Causes of Ash Deposits

The main causes of ash deposits depend where you work. If you work in steam plant operations the main cause is lousy coal, if your are a coal buyer the main cause is lousy steam plant design, and if you are in engineering the main cause is lousy steam plant operation. All are right in a sense. Scientific analytical investigations reveal that it is usually a combination of all three of these areas.

The following table presents the major causes of ash deposits:

TABLE I - Major Causes of Ash Deposits

Fuel Related	Large pyrite particles that impact the furnace wall before they completely combust
	Clay minerals that contain significant amounts of iron, calcium, sodium or potassium causing them to have low melting temperatures
	Interaction of pyrite, clays and alkalis with alumino silicates to form low viscosity melts
	Extremely fine or organically bound alkalis
Equipment Related	Soot blowers not in operation or used improperly
	Poor pulverization of fuel
	Improper air to fuel ratio
	Burners damaged or improperly adjusted
	Changes in operation of boiler or other equipment
Design Related	Furnace size too small for fuel
	Tube material and/or spacing inadequate
	Soot blowing coverage inadequate
	No means provided to observe slag buildup

Analytical Procedures

Deposit Removal and Reduction Methods

Tube Material Testing

It is generally felt that stainless and other austenitic steels have superior corrosion resistance and do not bond as strongly to deposits. It may be useful to perform several tests to confirm this and to evaluate impacts. A simple and low cost method is to construct test probes. These probes can be constructed from various materials and placed into the furnace for a given time and the resultant deposit evaluated for strength of bonding to the tube and internal strength. The use of two or more metal types on the same probe will provide a good means of comparison. The use of shielding could also be explored.

Industrial Use of Firearms

As an experienced slag gunner, I feel that shotguns offer an effective method for deposit removal. There are inherent safety issues and little if any publications describing effective methods. In discussions with sales reps. from Remington Industrial Products it was apparent that there are many ammunition options.

Safety

In addition to the procedures already in place at your station, the following are offered for your consideration. The proper firearm exists for each situation, consider using firearms that are designed for industrial use. Low recoil ammunition is available, this may be a better option than gun modification. It may be worthwhile to purchase a custom designed mounted gun with safety interlocks inherent to the design.

Methods

There are most likely methods used to shoot slag that are more effective than others. The author has seen all sorts of methods used and indeed there are some operators that are more effective than others in cleaning up the situation. It is recommended that different methods for shooting slag be documented and evaluated for their effectiveness. More effective methods have the potential to reduce the number of shots fired and minimize potential damage to the tubes. The current Remington method offers room for improvement. It indicates that the operator should shoot directly at the tubes using their #2 or #4 loads developed especially for power plants. It also recommends shooting some scrap tubes to determine if any damage to the tube occurs. This may be fine for off-line removal of slag, but does not consider the significant strength differences that tubes may undergo at operating temperatures. It has been the author's experience that most plants prefer that the tubes not be shot at. In addition to the damage to the tubes, the resulting rough surface may provide additional footing for the deposit to adhere.

Video Monitoring Systems

Operators cannot react to something they cannot see. Deposit formation is one of those phenomenon that do not show up on any control room readings until it is too late. Steam temperatures, furnace drafts, gas temperatures and others may give some indication that there are problems developing, but generally do not detect initial stages of formation. Video monitoring systems provide real time information about deposit formation and can allow removal techniques to be initiated before the deposit grows beyond a removable stage. Additionally, the use of tape backup allows the review of removal techniques and a direct comparison their effectiveness. This would be a good method for comparing shooting techniques as mentioned above. A good system will also help remove the operator subjectivity as to the extent of the problem, one man's view is not the same as another. A group can view the monitor together and discuss what they see.

Opacity

The opacity of a unit was running particularly high. The unit was burning a western coal and used S03 injection to lower the resistivity of the ash. In the past, the unit was able to maintain opacity below 10 percent. On the day in question, it was close to 20 percent. The ESP control showed poor performance with low power levels and high rates of sparking. This was the type of behavior the ESP showed when trying to collect unconditioned ash, yet all indications showed that the 803 system was operating. A sample of the ash was taken and it appeared black. Further testing revealed that one of the mills was producing poor fineness, causing the high carbon content in the ash. This elevated carbon content was causing the opacity problems. By bringing the mill performance up to spec, the problem was solved.

Conclusion

This paper was brief, but hopefully has shown the importance of one aspect, mill performance, on many coal quality related issues. At first glance one might not consider the influence mill fineness has on mill capacity, slagging and opacity; this paper has shown that it does indeed, and mill performance is only one of many areas of consideration. The plant personnel of the future will have to integrate their knowledge and experience into the fuel selection process. They should also be more willing to make suggestions and improvements in what they do to accommodate a wider fuel selection. By allowing plant management more access to the nature of coal mining and coal quality, better decisions ran be made concerning fuel choice.