Washed Coal from a Utilization Perspective

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Introduction

One day in my life concerning coal quality has struck me more than most. We asked a group of utility and power plant people what properties of coal they liked and what caused them concern. As each person provided their response you could see that each had their own view. Some wanted dustless coal, others coal that has good flow through chutes. Many wanted large, lumpy coals, the engineers wanted coal that was dry and easy to grind. The maintenance folk preferred coal that had low abrasion properties. The environmental people liked low sulfur and low ash levels. Then, the ash sales department wanted high ash to dilute the carbon and increase the sales volume. The fuel purchasing group liked low cost coals. Near the end of the discussion I asked if the group was describing coal or natural gas. I have worked with power companies that burn all sorts of coals from lignite and sub-bituminous, dozens of bituminous coals and high rank coals such as low volatile bituminous and anthracite. In twenty years I have not come across a coal that would meet everyone's preferences.

The challenge in this type of paper is to express the benefits and concerns associated with coal properties and provide several tools to help individuals be able to make their our evaluations. The paper will basically follow the flow of the coal through the plant after short discussions about coal quality and coal washing.

Coal Quality

There are many influences that determine coal quality. Depositional environment, geological forces, ground water, mining methodology and care, coal preparation (washing), and storage all influence the coal a power plant ultimately uses. Good sampling and laboratory practices can quantify many quality parameters. An understanding of coal quality and quality impacts on power plant performance can help utilities determine what parameters are most important and cause the most concern. This paper attempts to describe the major coal quality impacts on most pulverized coal-fired plants, what washed coal is, and the benefits and concerns that using washed coal can create. Coal is generally purchased on a cost per calorific value basis. This basis is an improvement over buying coal on a cost per ton basis, but does not take into account other important quality parameters such as HGI (Grindability), ash deposits, abrasion and pollution control. These parameters can significantly impact the cost of utilizing a particular coal.

One significant calculation that is not regularly provided by laboratories that is critical to understanding coal quality impacts is unit mass per calorific value (CV). This can be expressed in Kg/M-Kcal, Kg/MJ, lb./MBtu or any other similar units that might be in common local use. This calculation is performed by dividing the percentage of the element or parameter by the calorific value and correcting the units to work out. Remember that boilers use calories, not kilograms or percentages. By converting the lab data into a per calorific value the levels that the boiler sees will be displayed. Table I below shows both the percentage values and heating values received from the laboratory, and the levels of ash and moisture converted to kilograms per million kilocalories. The data below was taken from reference (1)

Table I – Coal Analyses with Values Converted to Mass/Heating Value

	Raw Coal	Washed Coal
Moisture	6.0%	8.0%
Ash	38.5%	30.0%
Calorific Value (CV)	4100 Kcal/Kg	4800 Kcal/Kg
Moisture Loading	14.6 Kg/M-Kcal	16.7 Kg/M-Kcal
Ash Loading	93.9 Kg/M-Kcal	62.5 Kg/M-Kcal

Coal Preparation Practices or What is Washed Coal?

Coal preparation covers a wide range of coal processes from simply crushing the coal to elaborate gravity separation and thermal drying. Most of the processes impact and alter the coal quality. Rotary breakers can remove large rocks and debris from raw coal. Washing coal generally describes a water based process where the denser material (rocks and high ash coal particles) are separated and removed from the coal. The coal generally is processed through water separation machines. The resultant cleaned or washed coal has less ash and more moisture than the raw coal product. This paper will use the following characteristics to compare washed coal to a raw product of the seam:

Washed Coal Characteristics

Less Ash
Higher Moisture
Smaller Sizing
More Consistent
Less Abrasive
Lower Slagging Potential
More Expensive in Cost per Calorific Value
Improved Power Plant Operation

Coal Handling

Coal handling represents two items: 1) the dustiness and the flowability of the coal and 2) the quantities of material handled. How a coal handles, (item 1) is highly subjective. The past experience of the coal handler, the equipment design and condition and coal properties all effect the dust levels and the flowability. There are not many good measures of these properties. The coal size is a major parameter that influences the handling characteristics. Finer or smaller sized coal generally has more dust forming sizes associated with it. Finer coal has more surface area, hence the ability to pick up and retain additional surface moisture. Surface moisture strongly influences both the dustiness and the chute pluggage potential of a coal. Surface moisture can be estimated using the air dry loss for high rank bituminous and anthracite coals. Lower rank coals can use the difference between total moisture and the equilibrium moisture measurements to estimate surface moisture, although any estimate of the surface moisture of low rank coals is harder than high rank coals due to their sponge like nature.

The dustiness and flowability of a coal is primarily impacted by the surface moisture of a coal. Experience has provided the following approximate ranges (2) found in Table II.

Table II Approximate Surface Moisture Impacts on Coal Handlability

Surface Moisture	Properties
0-4	Dusty
3-6	Okay
5+	Sticky

As shown these are general numbers and may not fit your coal exactly. Other coal properties such as fines and clay content influence how the coal responds to changing moisture levels.

Washed coals generally handle well, especially if the ultra fines have been removed. In many cases the 100 x 0 mesh material is removed by wet screening the coal. This process also removes fine clay type material that can cause the coal to be sticky when in a wet state.

Consider that a washed coal could have 10-25% higher calorific value. This would correspond to handling 10-25% less coal. This reduction in gross volumes of coal can provide additional time in the yard to address concerns arising from the finer size and higher moisture levels.

Mill or Pulverizer Capacity

Pulverizer capacity is influenced by a coals Hardgrove Grindability Index (HGI), the moisture levels, the calorific content and the size of the coal. The HGI of a coal should not be greatly influenced by washing. The capacity of a mill in tons per hour should stay about the same. The increase in calorific value would correspond to the increase in capacity of that mill. Using the data from Table 1, the CV increases from 4100 to 4800 Kcal/Kg. This represents an increase of 17%. The higher moisture levels of washed coal can impact the drying ability of the mill. If the percent moisture is taken into consideration there appears to be an increase in moisture levels of 33% (from 6% to 8%). If the moisture levels are expressed on a mass per unit heating value the moisture increase is only 14 % (from 14.6 Kg/M-Kcal to 16.7Kg/M-Kcal). Even when the impact of the moisture gain is accounted for, mill capacity still will increase near 15%. This 15% capacity increase could be advantageous for several reasons. Higher electric loads can be maintained with milling and feeding equipment out of service for repairs. Auxiliary power consumption can decrease, resulting in improved net efficiency. There will be less wear on the milling equipment due to less tons of ash being processed, especially if the ash material removed during the washing process is highly abrasive i.e. sandstone, quartz, or pyrite.

Ash Deposits

Ash deposits inside the furnace can cause several concerns. Referred to as slag, clinkers, fouling deposits or fouling, these type of deposits can be a direct reflection to the ash loading levels. Many deposits form when the soot blowers, water lances and cannons cannot remove the deposits faster than they are forming. Several papers and models from authorities show a strong correlation of ash loading levels and increased slag potential. (3),(4) There are many causes of ash deposits. A section from the authors short course on ash deposits is provided below:

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.
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> The Table III presents the major causes of ash deposits:

TABLE III - 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

It has been the authors experience that high ash levels not only contribute to ash deposit formation, but can cause secondary impacts that can contribute to deposit formation. The wear and tear on mills caused by high ash can impact the combustion process, potentially increasing the slagging tendency. The increased cycle duty of soot blowers when utilizing higher ash coals also impacts their maintenance. The maintenance of mills is generally given a higher priority than soot blowers, one soot blower being out of service rarely gets highest priority, where a mill out of service can. The relationship of ash levels with maintenance is not well defined for most situations, however the use of mass of ash per unit heating value (Kg/Mkcal) should be more proportional than the percent ash.

Particulate Emissions

In pulverized coal combustion the majority of the ash is ground with the coal, passes though the flame and the exits the boiler as fly ash. The amount of ash in the flue gas at this point proportional to the ash loading value of the coal (Kg/Mkcal), although not all the ash forms fly ash. Typically it is assumed that 80% of the ash can reach the economizer section of the boiler. Actual measurement of the ash loading, along with proper coal sampling can quantify this value. Pollution control equipment such as electrostatic precipitators (ESP), generally has a constant efficiency. If an ESP has 98% efficiency, an increase in the ash loading produces a corresponding increase in outlet emissions. Again, ash loading is more proportional to emissions than straight use of percent age. It has been noted in the literature (5) that the low sulfur content of Indian coal results in poor ESP performance due to high ash resistivity. Fly ash resistivity calculations (6) are possible using ash elemental analysis. The author has found that using the simple ratio of ash divided by sulfur (ash/sulfur) can qualitatively estimate ash resistivity. Values of the ash/sulfur for good ESP operation usually fall in the 3 - 10 range. This range is well below the ones found in typical Indian steam coals. If the form of sulfur in coal is organic, rather than pyritic, as Indian may be, coal washing does not readily remove the sulfur. If this is the case, a slight increase in percentage sulfur can occur in the washed coal. The increased heating value of the washed coal results in a net equivalent or lowering of total sulfur emissions. In TableIV below an example of the ash to sulfur ratio is shown

Impact of Coal Washing on Ash/Sulfur Ratio

	Raw Coal	Washed Coal
Ash %	38.5	30.0
Sulfur %	0.6	0.7
Ash/Sulfur	64.2	42.9
Sulfur Loading Kg/MKcal	1.46	1.46

Although the ash to sulfur ratio does not enter the good range, it does drop significantly, indicating a potential for improved ESP performance based on ash resistivity improvement.

Ash Disposal and Utilization

The amount of ash generated by a power plant is more accurately estimated using the ash loading calculation as a comparison, than the percent ash levels. Steam plants need calories, not tons of fuel, to operate. Steam plant efficiency is measured in Kcal/KWatt, not tons/KWatt. Again, coal washing not only decreases the ash, but increases the calorific value. In our example shown in Table I, the ash loading levels are about 2 / 3 of the raw coal. This contrasts with about 3 / 4 calculated from the percent ash reduction. Using washed coal at a plant would extend a given ash disposal site by 50%.

Conclusion

This brief paper covers the impact that washed coal has on power plant operation. Although coal washing increases the cost of coal, the plant may recover most, and in many cases gain when all the plant costs are included. When evaluating the impact of washed coal on a plant, please consider the following.:

Handling less tons of coal
Coal may be less abrasive, improving maintenance
Mill capacity will increase
Less ash deposit formation
Improved ESP performance, less particulate emissions
Lower sulfur emissions
Less ash to dispose

There may be additional factors that are plant specific issues. It has been the authors experience that utilizing washed coal is generally advantageous to the power plant.

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