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Coal Ash Chemistry

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Flyash. Face it. It's a fact of life. As a residual of the combustion process, operators and engineers are going to have to deal with it, but before the ash is recycled into building products, it has to make its way through the boiler. So, our friends at SEFA have a great answer concerning flyash. Use it as a concrete additive – thus putting this material, often thought of as a waste product, to good use in making stronger and better concrete. Whether your coal is 5% ash, 10% ash or somewhere in between, most likely, you will have some issues with the ash in your coal. The focus should be how does one minimize the impact of the ash so that there is not excessive opacity from the precipitator, excessive slagging in the furnace, or other issues. So, perhaps one could call this Slag Management 101. This newsletter focuses on some basic facts and fundamentals regarding the chemistry of ash.

What is in the Coal

While some folks think of coal as pure carbon, it's more than that. Coal contains carbon. However, many of the incombustibles (or mineral ash constituents) in the coal include quartz, pyrite, clay, and carbonates. Table 1 provides a list of the various incombustibles in coal.

Component	Bituminous	Subbituminous	Lignite
SiO ₂	20-60%	40-60%	15-45%
Al ₂ O ₃	5-35%	20-30%	10-25%
Fe ₂ O ₃	10-40%	4-10%	4-15%
CaO	1-12%	5-30%	15-40%
MgO	0-5%	1-6%	3-10%
SO ₃	0-4%	0-2%	0-10%
Na ₂ O	0-4%	0-2%	0-6%
K ₂ O	0-3%	0-4%	0-4%
LOI*	0-15%	0-3%	0-5%

*The carbon remaining after burning in a laboratory furnace, wight "loss on ignition."

Table 1 - Range of chemical composition for fly ash produced from different coal types (expressed as percent by weight).

Ash Deposits

While much of the large particle ash goes to the bottom-ash hopper, a substantial percentage is entrained in the flue gas. In fact, about 80% of the ash is fly ash on a typical

pulverized coal boiler cyclones and CFB units have a lot more bottom ash (cyclone furnaces are over 70% typically). Abrasive ash particles suspended in the stream can cause erosion challenges within the boiler. Usually the ash erosion is worse in PC boiler where the flue gases (and the ash) have cooled to below about 1500°F. Furnace temperatures in the boiler can reach 3,000°F and above. This is well above the melting temperatures of most ash constituents. This can result in slagging issues within the boiler. Furthermore, some coals are less forgiving than others and depending on the mineral ash constituents, the melting point of the ash (referred to as the ash fusion temperature) in an oxidizing or reducing atmosphere can often range well below the design furnace exit gas temperature (FEGT) going into a superheater (SH).

For PRB fuels (powder river basin), often the fusion temperature is below peak flue gas temperatures at the superheater gas inlet.

So, when wet sticky ash sticks to the water walls, superheater and/or the re-heater at the furnace exit, the design heat absorption rates vary and thus depending where the deposits are, a higher FEGT may be required to achieve a desirable production of steam at a given temperature and pressure.

Minimizing the potential for these ash related problems is one of the primary goals for boiler engineers. While the combustion characteristics of coal play a role in the design of a furnace, understanding the ash characteristics is equally important when evaluating alternative coal sources. For example, particle size distribution with biomass and/or a furnace heat release rate with co-firing natural gas or oil can have a significant influence on the furnace gas temperatures and/or equalization of the furnace exit temperature.

Ash deposits formed from the combustion process are a challenge. There are two basic forms of ash deposits: molten ash (slag) and alkali salts. Molten slag that builds on the furnace walls (wall slag) is shed naturally as boilers cycle through their load range. It is usually controlled by water wall de-slaggers using air, steam, and in some instances, water). Most boilers have some slag and it can be mitigated with modern soot blower and water cannon technologies. However, if not controlled, excessive wall slag can lead to:

1. Excessive wall slag flowing to the bottom of the furnace can cause ash bridging/plugging of the bottom ash hopper.

2. Wall slag acts as an insulator and impedes the heat transfer to the lower furnace walls. This decrease in lower furnace heat absorption will increase the furnace exit gas temperatures (FEGT) and promotes excessive molten ash to deposit in the superheater and convection pass region.
3. Slag buildup around the burners (eyebrows) can interfere with the coal and air flow and has caused increased NO_x levels and even wind box fires.

Alkali salts are formed from fouling in the convection pass. These sulfates, primarily calcium sulfate and sodium sulfate, bond with the flyash.

The main cause of ash deposits varies depending on the coal, equipment, and design of the furnace. Having the greatest coal in the world can help, but if the equipment is not operating properly due to budget cuts and extended time between overhauls, then the ash deposits can increase to the point that they impact capacity, reliability, efficiency and environmental compliance. Table 2 provides major causes of ash deposits in three categories.

Fuel Related	Equipment Related	Design Related
Large pyrites particles that impact the furnace wall before they completely combust	Pulverizers not optimized	Furnace size too small for fuel
Clay minerals that contain significant amounts of iron, calcium, sodium, and/or potassium causing them to have low melting temperatures	Poor pulverization of fuel. Non-optimized airflows	Tube material and/or spacing inadequate. Furnace designed for a different fuel.
Interaction of pyrite, clays, and alkalis with aluminum silicates to form low viscosity metals	Improper air-to-fuel ratio in the burner belt.	Soot blowing and water lances not optimized for the fuel used.

Table 2 - Major Causes of Ash Deposits

As stated earlier, the majority of the in-organics in coal consists of silicon oxides, ferric oxides, and aluminum oxides. Silicon and aluminum oxides are acidic oxides whereas the iron, calcium, sodium oxides are basic oxides. Thus, the base-to-acid ratio (B/A) plays a role slagging and fouling index; the greater the concentration of basic oxides to acidic oxides, the greater the tendency for the chances of slagging and fouling. Furthermore, the amount of sulfur in the coal plays a direct role in the slagging index. If the coal contains iron pyrite (FeS₂) then the slagging can significantly increase. However, the addition of the iron and the sulfur from iron pyrite increases the concentration of ash constituents that have a markedly reduced melting temperature, especially in a reducing atmosphere (no free oxygen). The melting temperature may be as much as 300°F lower just because of the absence of free oxygen. Therefore, as the amount of sulfur increases, the slagging potential increases exponentially.

Keep in mind that slag production is typically a buildup process. Since ash is a product in the coal, the amount of ash matters. However, as fuels may change, ash needs to be considered in terms of Btu's, not in pounds of coal. For example, Fuel A has 9% ash content and a heating value of 11,000 Btu's/pound. Fuel B has 7% ash content and a heating value of 7,500 Btu's/pound. To get the equivalent heating value of Fuel A, one would have to burn 1.47 pounds

of Fuel B. However, 1.47 pounds of Fuel B will produce more ash than Fuel A. Therefore, while B has lower ash content, to obtain the same heating value, more coal will have to burn, thus producing more ash.

Minimizing the Ash Deposits

The main goal is to capture all of the ash content and prevent excessive slagging formation. On a pulverized coal fired boiler, it starts at the pulverizers! When one reviews the "13 Essentials of Optimum Combustion", nine (9) of them are related to the pulverizer. Achieving optimal fineness (75% passing through 200-mesh) is the key. Low fineness may cause problems associated with delayed combustion. Moreover, coarse particles require additional furnace residence time for carbon burnout and can cause slagging in the upper furnace. In our experience very good fuel fineness is absolutely essential with a coal ash of high slagging potential.

Next, one must consider that air and fuel imbalances can result in high excess air at some burners while others operated with less than the theoretical air. Thus, a reducing atmosphere in the burner zone can promote slagging, especially with coals that have high iron content. High coal/air ratios may delay combustion resulting in higher temperatures in the upper furnace and at the furnace exit. Thus, by having the fuel lines balanced in fuel flow within ±10% or better, one is more likely to lower the chances of a reducing atmosphere in the boiler. Even a small area of less than a square foot (at the SH inlet) if in a reducing environment can start a slagging incident that can and has shut down a large PC boiler. Just one stream of fuel rich combustion products from one burner can cause this.

Finally, sootblowers are the primary means of dealing with furnace wall slagging and convection pass fouling. It is important to remember that the use of this equipment should be used as a preventive measure instead of corrective. If the furnace slag accumulates to the point of it becoming wet or like a plastic, the removal becomes much more difficult. Therefore, operators should continually update the soot-blower sequencing requirements when fuel characteristics may change.

In conclusion, flyash is a by-product of the combustion process. Minimizing the amount of flyash by purchasing low ash high Btu fuels sounds good, but in the real world economics, fuels vary widely and often are far different from the boiler's originally designed fuel. Applying the "13 Essentials" will help you to achieve the results that you seek. These are time and results proven. For more information on how you can use our resources to help you achieve optimal combustion performance, contact Storm Technologies today.

For all other inquiries, please email storm@stormeng.com or you can contact us at (704) 983-2040.

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