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Case Study: Biomass Slag Mitigation

Overview

A wood products plant in Oregon is using a waste biomass stream as an **opportunity fuel** in an 80 kpph A-type Nebraska package boiler circa 1970. The plant was forced to take bi-weekly outages to remove black glassy slag from the generating bank tubes. During the annual outages, the plant would take more extreme measures of jackhammering large ash buildup in the bottoms ash hopper and furnace floor. Furnace waterwall tubes had to be scraped clean and replaced regularly. EES provided an **AddChem-30 fuel pretreatment** system to eliminate slag formation by altering ash chemistry. The slagging was eliminated, and the boiler is now running much more smoothly, doubling the downtime between outages, and reducing maintenance.

Background

Solid biomass and agriculturally derived waste have long been viewed as an attractive opportunity for renewable fuel. Biomass/bioenergy currently accounts for ~12.3% of global Total Final Energy Consumption. Biomass is viewed as "carbon neutral" as its combustion releases CO_2 captured during its own growth. However, biomass fuels, especially wood-derived fuels, present challenges as they typically contain elevated levels of calcium, silica, alkalis and/or sulfur, depending on point of source. During the combustion process, the presence of these fuel constituents often leads to significant ash deposition and fouling of heat transfer surfaces. Properties of the ash and/or slag build-up may render sootblowers effectively useless. As a result of slagging/fouling:

- Fuel consumption **increases** for the same energy output
- Frequent and lengthy **downtime** for maintenance
- Heat transfer equipment longevity is **reduced** as evidenced by tube outside surface pitting

The ash mineral analysis (see Figure 1) for the typical and flame retardant (FR) fuel sources shows significant concentration of Na, and boron present. Boron is a known fluxing agent, lowering ash fusion temperatures, with which EES has prior experience for decreasing viscosity of slag in slag tapping boilers (Crane Station). Fouling index analysis from constituents indicated SEVERE fouling potential. The slagging index (Hansel-Halfinger) derived from hemispherical and initial deformation temperatures indicated SEVERE slagging potential.

Elemental Analysis	Typical	FR
SiO2	1.34	0.42
Al2O3	1.21	0.47
TiO2	0.47	0.24
Fe2O3	0.71	0.36
CaO	1.88	0.88
MgO	0.42	0.17
Na2O	21.7	20.1
K2O	1.78	0.9
P2O5	4.42	1.72
SO3	0.12	0.02
Cl	0.01	0.01
CO2	0.13	0.19
Boron	20	23.65
SrO	0	0
BaO	0	0
MnO2	0	0

Figure 1: Ash Analysis of fuel samples.

At elevated temperatures of combustion, gaseous alkali chlorides and oxides of sulfur are released. Sulfur dioxide may continue to oxidize to sulfur trioxide (low reaction rate). SO_x combine with available vapor-phase alkalis to form alkali sulfates and alkali sulfuric acid salts. Sulfates begin to condense and nucleate as temperature reduces along gas path. Continued condensation and nucleation results in aggregation on the relatively low-temperature boiler tubes.

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Solution

EES's approach is to pretreat the fuel with a magnesium-based slurry (AC-30) to shift crystal formation eutectics, producing a greater quantity of higher melting point solids, thereby providing more 'points of failure' in the ash crystal matrix and increasing friability. The ratio of MgO-SiO_2-Al_2O_3 (see Figure 2) determines the melting point of the ash. The goal is to shift the bulk mixture to the highest melting point, MgO. AC-30 fuel pretreatment encourages formation of fully oxidized MgO (periclase) and has the dual benefit of reducing oxygen availability for sulfation. Periclase becomes distributed throughout the ash and provides granular cleavage sites to weaken the aggregate to produce a soft, friable ash instead of a hard, glassy slag.

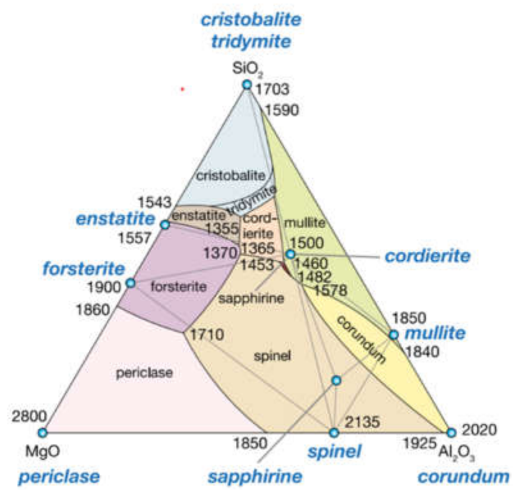

Figure 2: MgO-SiO_2-Al_2O_3 three-phase diagram.

Fuel pretreatment is preferred to in-furnace treatment as it ensures complete coverage and reduces capital and maintenance costs. The AC-30 is typically injected directly on the fuel belt, upstream of the mill. This thoroughly mixes the chemical, minimizes dosage requirements, and ensures complete coverage of the fuel and furnace. After just two weeks of treatment, the results were significant. Ash fusion temperature was increased by 200^{o}F (see Figure 4). The previous slag that had required a hammer and chisel to remove was reduced to a friable buildup that was easily removed with an air hose. The outage downtime was significantly reduced, and the less abrasive cleaning process extends the life of the equipment.

Figure 3: AC-30 Injection nozzle.

Conclusion

EES successfully provided a fuel treatment system to alter the ash chemistry in a biomass fired package boiler. The plant was able to **reduce outages**, **reduce maintenance**, and even altered their long-term outlook on purchasing a new boiler. **Modifying ash chemistry** is a low impact method that can be applied to utilize **opportunity fuels** that may otherwise seem impractical.

	Initial Deformation, Reducing	Softening, Reducing	Hemispherical, Reducing	Fluid, Reducing	Initial Deformation, Oxidizing	Softening, Oxidizing	Hemispherical, Oxidizing	Fluid, Oxidizing
Before AC-30 Treatment	2047	2124	2213	2339	2098	2182	2258	2388
After AC-30 Treatment	2286	2331	2407	2462	2338	2394	2456	2507

Figure 4: Ash Fusion Temperature