MANAGING SLAG BUILDDUP IN COAL-FIRED BOILERS

As they strive to minimize electricity generation costs, some U.S. utilities have found it beneficial to switch the coals they burn. Some Eastern and Midwestern utilities are making increased use of low sulfur Western U.S. fuels, especially those from the Powder River Basin area. In addition, imported coals from countries such as Indonesia and Colombia are becoming economically competitive in some regions of the U.S. As they change their coal suppliers, these utilities are finding they are firing coals that have ash properties that are substantially different from those for which their boilers were designed. In some cases, this has led to more severe problems with ash slagging and fouling, and incidents of unmanageable slag buildup in the furnace and convective pass slagging have become common. Led by Drs. Carlos Romero, Nenad Sarunac and Richard Conn, the Energy Research Center is involved in two initiatives intended to help utilities control ash slagging. Conn is a specialist in behavior of coal minerals and Romero and Sarunac are experts in optimization of combustion and sootblowing operation.

According to Conn, “The slagging and fouling characteristics of a coal depend upon the composition and particle size of the mineral matter and inorganic constituents. However, this type of information cannot be obtained from the ash chemical analysis commonly used to assess coal ash deposition tendencies. Traditional indices such as the base to acid ratio, slagging factor and fouling factor were developed based on this ash analysis for use with Eastern bituminous coals, but they do not apply to imported coals or lower rank coals such as PRB. The problem becomes even more complex when blends of coals are used, particularly blends of Eastern and Western U.S. coals. To overcome this problem, new techniques have been developed for characterizing the inorganic constituents in coals. These techniques include chemical fractionation, which is a leaching procedure for quantifying “reactive” alkalis, and computer controlled scanning electron microscopy (CCSEM) for quantifying the form and particle size of minerals. Based on these analyses, parameters such as melting point of mineral constituents, fly ash composition and ash particle size distribution can be determined. As a result, a better assessment of slagging and fouling potential can be made, compared to that obtained using conventional ash chemical analysis.

Utilities experienced in burning off-spec coals know that, in addition to mineral properties, furnace operating conditions can have a large effect on slagging. They have found, often by trial and error, what limits to set on furnace exit gas temperature and economizer O₂ level and what modifications to traditional sootblowing schedules

Field data showing furnace exit gas temperature as a function of unit load. Load levels above 325 MW increase the potential for convective pass slagging.
are needed in order to reduce the risk of severe slagging with a particular coal or coal blend. Indeed, coal slagging and fouling behavior depend on temperature and O₂ distributions in the furnace as well as on parameters such as coal particle size distribution and particle residence time in the furnace.”

Sarunac adds, “The task of avoiding severe slagging has been complicated, in some cases, by conversion of boilers to low NOₓ firing systems and by use of combustion optimization techniques. Combustion optimization, which involves adjusting boiler control settings to change the way the boiler is operated, has typically been employed as a way of reducing NOₓ emissions or improving heat rate. However, the boiler control settings which affect NOₓ and heat rate can also have an effect on waterwall slagging. For example, both economizer O₂ level and burner tilt angle affect NOₓ and heat rate in a tangentially-fired boiler. As these parameters are adjusted, the furnace temperature distribution, furnace stoichiometry and coal particle residence times are also affected and these changes then affect the location of ash deposits, the rate of ash buildup and the strength of the deposit.”

Drs. Romero, Sarunac and Conn have combined their backgrounds in coal mineral properties, boiler operations and combustion optimization to develop a systematic approach for identifying which boiler control settings affect slagging and determining what limits to place on them to avoid unmanageable slag buildup. The process begins with laboratory tests to determine which coal minerals are present and in what quantities. Other laboratory tests provide information on how the minerals react as combustion conditions change. Field tests, in which boiler control settings are changed and measurements are made of the impacts on parameters such as furnace exit gas temperature, furnace O₂ level, rate of slag buildup and boiler section cleanliness, are then carried out.

Finally, analyses and comparisons of the laboratory and field data are performed to establish limits on control settings. If this is being done as part of a NOₓ reduction or heat rate improvement program, compromises in NOₓ emissions or heat rate may be needed to satisfy slagging constraints.

Sootblowing strategy can also be an important tool in controlling slag buildup and the Center is also involved in developing techniques for optimizing sootblowing practice.

According to Romero, “Sootblowers are used to control the severity of ash and slag buildup. But other important things can happen when a group of sootblowers is activated. Sootblowing results in an abrupt change in localized heat transfer, and this can result in unfavorable energy distributions which can lead to a loss of thermal performance and increased unit heat rate. Activation of sootblowers located in areas where they are ineffective in controlling steam temperatures or removing ash deposits, result in the waste of high quality steam or ineffective use of auxiliary power. Frequent activation of sootblowers also causes erosion and corrosion damage to tubes, induces high stress levels in tubes and shortens tube life. Sootblowing can also contribute to control of NOₓ emissions. Many field studies have demonstrated a reduction in NOₓ emissions by optimizing the operation of the furnace sootblowers.

The challenge in developing an effective sootblowing strategy is to determine which portions of the boiler to clean and on what schedule. The strategy should consider the tradeoffs of slag control, NOₓ emissions, opacity, steam temperatures, heat rate and other factors such as tube life and sootblower steam and air consumption. Typically, boiler operators are provided with little or no quantitative information on ash deposition levels or guidance regarding appropriate sootblowing operations. In most cases, the operators are left on their own to determine when to blow soot. As a result, they often wind up employing sootblowing strategies which reflect their own personal preferences and level of understanding of the relationships between sootblowing and boiler performance.

As a solution to this problem, we have developed a technique for obtaining systematic data on sootblower performance and then using this information to develop sootblowing schedules and strategies. We’ve used this approach on several boilers and this has resulted in substantial improvements in sootblowing practice.”

Sarunac adds, “As a complement to the sootblowing optimization tests described by Carlos, we are developing an intelligent software package for optimizing sootblowing practice. We believe this software will eliminate operator variability when selecting sootblowing schedules, make it much easier to adapt to changes in fuel quality and maintenance condition of the equipment and provide an easy way of handling changing optimization objectives. For example, this opens up the possibility of using different sootblowing strategies during the ozone season than are used during the remaining months of the year.

The software will at first be available for use in an advisory capacity. A later version will be capable of operating for closed loop
control. We have been working on the software since last Spring and we expect to have it ready for field use in the second half of 2001.”

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