

**A VIEW FROM THE PENTHOUSE: USEFUL INFORMATION FOR THE WORLD OF BOILERS**

**THE LOW-NOX BURNERS**

In the last several years, low-NOX burners have been developed and widely installed to meet the EPA requirements for reduction of oxides of nitrogen, or NOX emissions. The term NOX lumps together all of the various oxides of nitrogen into one generic collection. When mixed with rain, these nitrogen oxides along with sulfur oxides (sometimes referred to as SOX) form acids during precipitation, which is the acid-rain problem. These nitrogen oxides come from two sources; that is, nitrogen or nitrates within the fuel and the formation of nitrogen oxide by reaction of nitrogen and oxygen in the combustion air. The formation of these oxides starts at flame temperatures above about 2600°F, where the kinetics are favorable. There is little that can be done about the fuel nitrogen, but the reaction of the gases within the combustion air can be controlled. The higher the flame temperature, the faster the reaction between nitrogen and oxygen proceeds, and the higher will be the nitrogen oxide or NOX concentration within the combustion products.

The route that has been taken to reduce flame temperatures, and thus reduce the amount of NOX is by off-stoichiometric or staged combustion. That is, the complete combustion of the fuel occurs in several stages. The fuel is mixed with less air, oxygen, for complete oxidation of carbon to carbon dioxide and hydrogen to water vapor. With the primary air/fuel ratio less than 1, the hydrogen in the fuel is burned to water vapor in the first stage; and some of the fuel remains as elemental carbon while a portion is burned to

carbon monoxide. Secondary air is added around the primary air-fuel flame to burn the elemental carbon to carbon monoxide and carbon monoxide to carbon dioxide. Finally, tertiary or over-fire air is added to assure an excess of oxygen and lead to complete combustion; so the flue gas at the exit is water vapor and carbon dioxide. The full available heat from the fuel is obtained as the final combustion products are fully oxidized carbon dioxide and water.

The problem with this staged combustion scheme is that all burner adjustments need to be nearly perfect to assure complete combustion within the furnace. Usually that is not the case; and the flue gas contains appreciable quantities of carbon monoxide, hydrogen sulfide, and unburned or elemental carbon. And long lazy flames reach into the top of the furnace and the pendant superheaters and reheaters. Ash deposits from waterwalls and fly-ash deposits on the superheaters and reheaters invariably contain elemental carbon, proof that, at least on the tube surface, reducing conditions exist. Under these reducing conditions, sulfides form in place of or as part of the oxide scale on the steel surface. Sulfur prints of the tube cross-section will be positive for metallic (usually iron) sulfides, further proof of reducing environments.

A sulfur print is a replica of the sulfide distribution which appears as a black or dark brown streak on photographic print paper, see Figure 1; and note the sulfides are on the fire side only. What oxides do form tend to be porous, and the mixture of oxides and sulfides is inherently less protective against further wastage.

When the ash deposit also contains species that are liquid at the operating temperature, porous oxides and sulfides are more readily dissolved in these low melting-point salts. The protective scale re-forms by oxidation or sulfidation, and the cycle continues. Metal wastage occurs by reaction of the steel with oxygen and/or sulfur with concurrent loss of the metal. The result is a thinner wall thickness. Transport of oxygen, sulfur, and carbon to a cleaned steel surface is also facilitated by the liquid ash constituents.



Figure 1

In the high-temperature superheater and reheater, reducing conditions promote carburization of the tube surface. Carburization of a 304H stainless steel or the chromium-molybdenum ferritic steels of T-11, T-22, and T-9 leads to chromium-carbide formation. These carbides reduce the chromium content of the alloy and thus reduce the corrosion resistance. The effect is more noticeable in the higher-chromium materials.

Carburization effects have been seen in the T-11, T-22, T-5, T-9 ferritic grades and 304, 321 and 347 austenitic stainless steels.

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Sulfides have been found within the corrosion debris on the surface of waterwall tubes as well as on superheater and reheater components.

Coal fineness or lack thereof may exacerbate the problems. All of the coal particles need to be small enough to assure complete combustion in the time available during the short residence within the flame. The usual coal-fineness limits are 70% through a 200 mesh and 98% through 50 mesh. However, the 2% that remains on a 50-mesh screen is still a considerable amount of coal. If the plant burns 100 tons/hour, 2% is still 2 tons of partially burned coal that will find its way either into the bottom or the fly ash. Either way, carbon becomes part of all deposits. When incorporated into ash deposits on the superheater and reheater, the elemental carbon will diffuse into the surface of the steel, carburize the surface, and reduce corrosion resistance. Carbon contents up to 0.8% and higher have been measured on superheater ash deposits adjacent to the steel. Depending on the particular alloy, carbon contents up to 0.47% have been measured in 304H. Reduced corrosion resistance translates into more rapid wastage. If there are low melting-point species of potassium and sodium-iron-trisulfate, the combination of liquid ash and unburned coal can lead to exceedingly rapid deterioration.

Thus, it may be necessary to rethink the coal-fineness requirements in low-NOX burners to assure complete combustion and reduce the amount of unburned coal within the flue-gas atmosphere.

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