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Technical Publication

Designing for Extremes of Coal Slagging Tendencies

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Many U.S. utilities have had little recent experience with coal firing, and those that have, may not have had experience with the new wide variety coals being mined today. Most of the participants in this meeting are Engineers and have an understanding of the factors that affect boiler design, but for many reasons, the significance of some of the variables affecting the design of modern coal fired utility boilers may no longer be prominent in your minds. It might be useful to review the effect of the extremes of one of the most significant variables, the slagging tendency of coal, on boiler design.

In recent years, broad ranges of coal characteristics or a number of different coals frequently have been included in proposal specifications. As coal supplies become less certain and more difficult to tie down, this has become necessary in many cases. Where required, we are completely in agreement with this practice. However, we believe it is important for our utility customers to understand the impact on costs of producing boilers which are capable of efficiently burning these wide ranges of coals.

Today, we intend to discuss the effect on your capital costs for a boiler capable of burning coals with a range of slagging characteristics that extend from low to severe. For the sake of simplicity, we have assumed that all other coal characteristics are constant, a condition that is unrealistic, but necessary to avoid undue complexity in the discussion. Slagging is considered to be the accumulation of plastic or liquid deposits on radiant heat exchange surfaces. The accumulation of light, dry ash that can be effectively removed by sootblowing is not considered to be slagging. The slagging tendency of coal is a function of the viscosity characteristics of fly ash at elevated temperatures. The unit of measurement of viscosity is poise. (See Figure 1) 10,000 poise is solid matter. 250-T poise viscosity is the theoretical point where coal ash changes from a plastic to a Newtonian fluid and is considered to be the critical point which indicates the slagging potential of coal.

Figure 2, is a typical family of curves which permits determination of slagging tendency.

1. Chemical analysis of fly ash.
2. Calculate dolomite ratio.
3. Calculate base-acid ratio.
4. Determine 250-T poise temperature.
5. Return to the previous curve for slagging factor.

Over the years, we have developed standards for sizing furnaces. The critical parameters that set furnace size are:

1. Slagging tendency
2. Flame shape
3. Area, location, and position of heat transfer surfaces
4. Furnace gas velocities

Figure 3a, shows typical furnace dimensions for a boiler designed to produce 4,500,000 pounds of steam per hour (≈600 MW) burning low slagging coal.

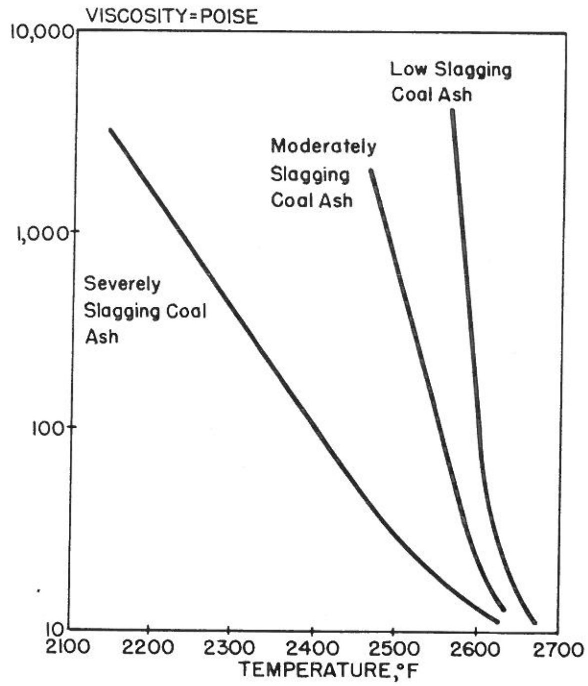

Figure 1. Viscosity of Slag (Oxidizing Atmosphere)

The design objective is to set the furnace height from the burner intercept to the tip of the radiant superheater at the proper level to make the furnace heat absorption sufficient to reduce the gas temperature at the superheater below the 250-T poise temperature of the fly ash.

If the gas temperature at the superheater exceeds this critical temperature, slagging of the superheater will occur. If it is below the critical temperature, the utility is

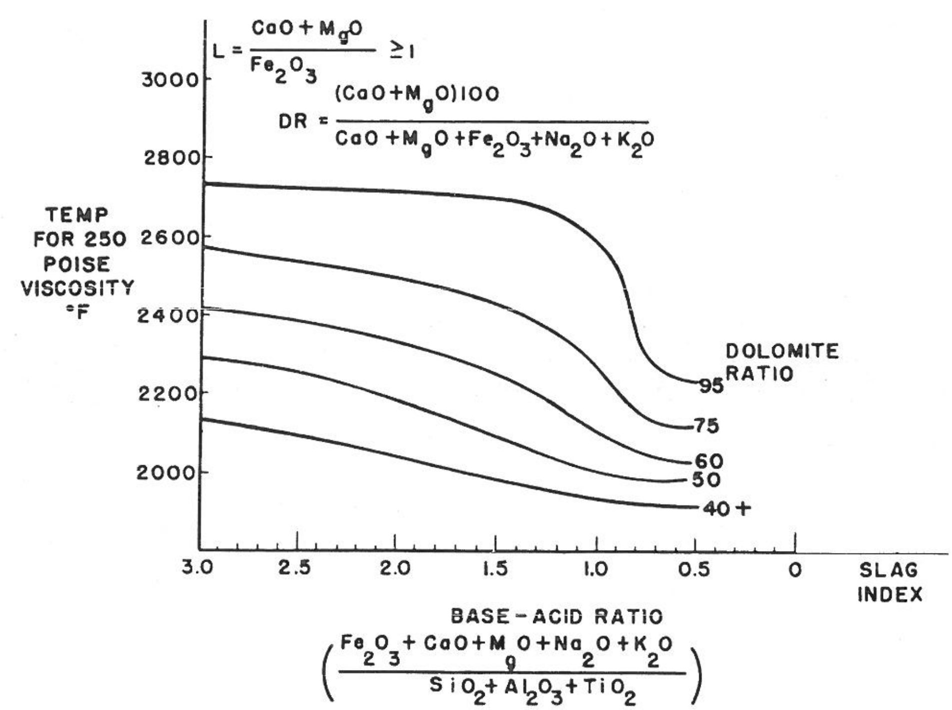

Figure 2. Slagging Tendency Lignite-Type Coal Ash (for Western Coal)

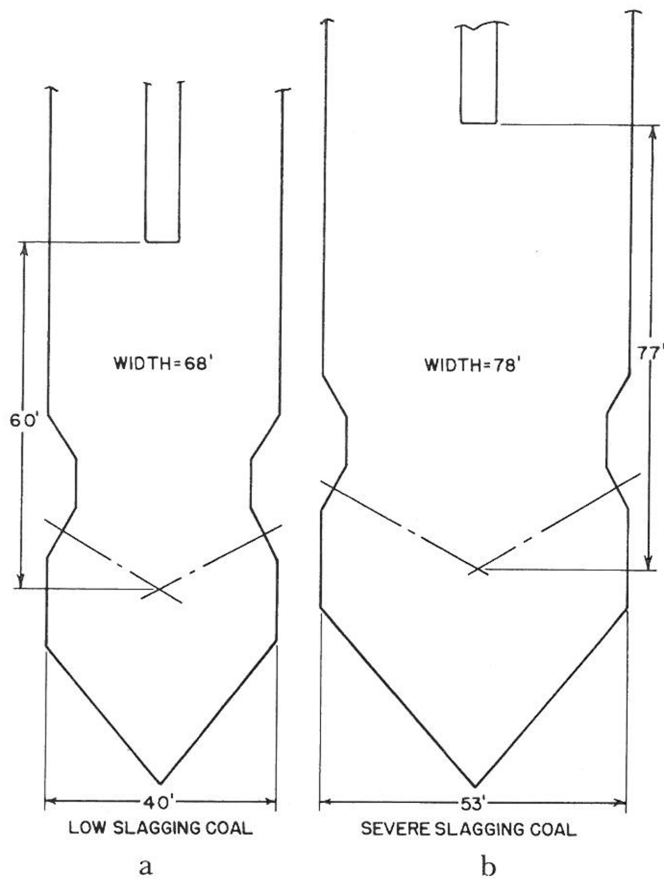

Figure 3. Furnace Dimensions, Two 4,500,000 lbs/hr Boilers

buying more furnace and (as you will see later) other equipment than can be efficiently utilized.

Let me remind you that this discussion has been simplified for the sake of clarity. There are a variety of other considerations, such as *gas velocity* and *burn out time,* which can also cause slagging if they are present in the wrong combination.

Figure 3b, shows the furnace for the same capacity boiler which is designed to burn severe slagging coal, note the greater furnace depth and distance from the burner intercept to the superheater. There is also a ten foot penalty to be paid in furnace width and a larger furnace hopper because of the greater depth.

This comparison shows the direct relationship between the slagging tendency of coals and the size (and weight) of the furnace required to burn it. You have probably related the weight increase to a cost increase already. What you may not have considered completely is the effect of the *furnace size* increase on *other parts of the steam generator.*

STEAM COOLED SURFACES (SUPERHEATER AND REHEATER)

There is a proportional relationship between the amount of steam cooled surface and water cooled surface in a utility boiler that must be maintained if design steam temperatures are to be achieved.

For a given gas temperature at the radiant superheater, the amount of steam cooled surface is proportional to the water cooled surface (see Figure 4). If a change is made to a coal with a lower 250-T poise viscosity temperature, three things must happen to the heating surfaces:

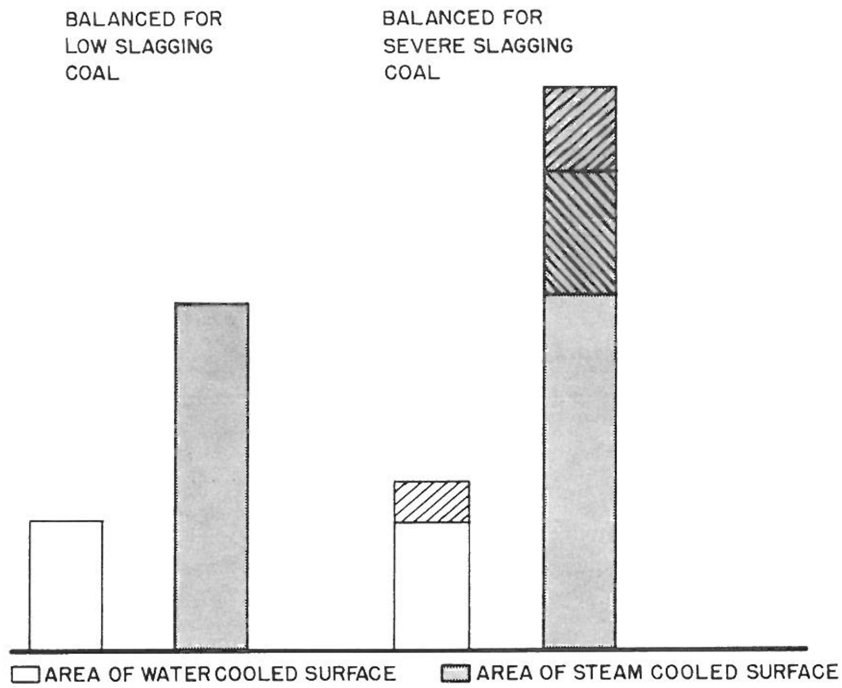

Figure 4. Water Cooled vs. Steam Cooled Surfaces

1. Furnace size must be increased in order to absorb more heat in the furnace walls and reduce the gas temperature at the superheater.
2. Superheater and reheater surface must be increased in proportion to the greater water cooled surface in the furnace.
3. Superheater and reheater surface must be further increased as necessary to make steam temperature with the lower thermal head resulting from greater furnace heat absorption.

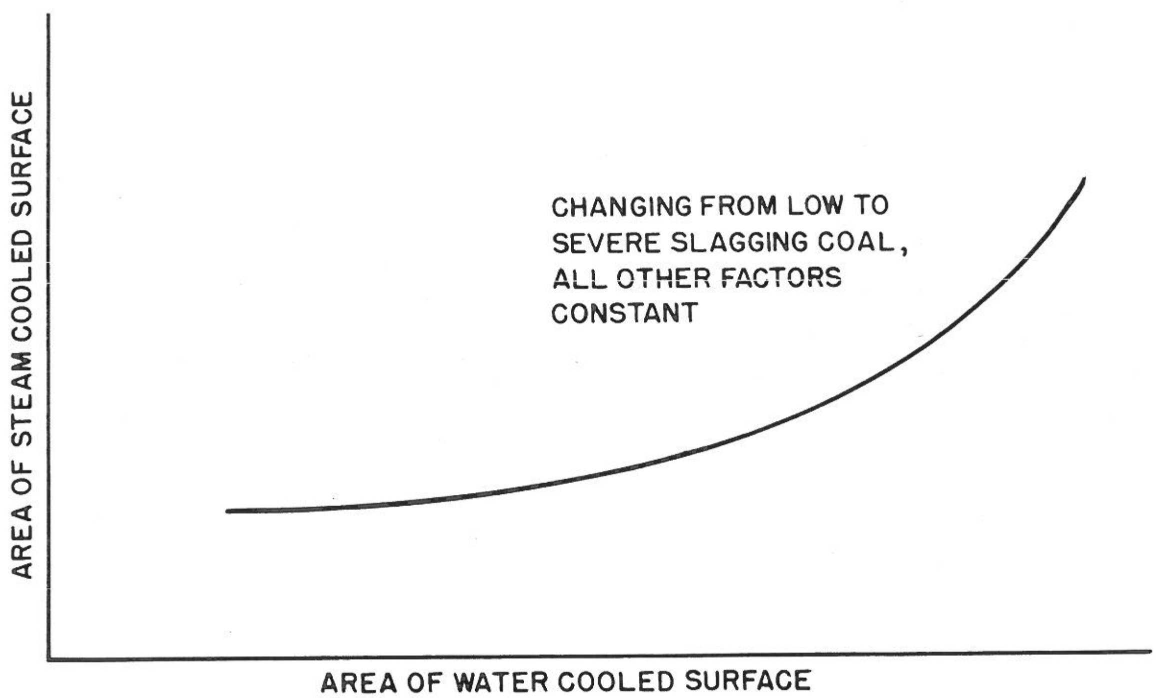

Figure 5. Water Cooled Surface Area vs. Steam Cooled Surface Area

The steam cooled surfaces (superheater and reheater surfaces) increase exponentially with increases in water cooled surfaces (furnace walls and economizer surfaces). (See Figure 5.) This effect ripples through the entire boiler and related equipment increasing:

1. Structural steel weight
2. Boiler enclosure volume
3. Downcomer piping length
4. Coal piping length
5. Soot blower quantity
6. Foundation size
7. Main steam piping length
8. Reheat steam piping length

just to mention a few prominent items.