1 Minimum Recommended Feedwater Temperatures

When analyzing requirements for installation of a RETROMISER Fuel Economizer, or a similar heat recovery device, there are two important items that must be considered, namely:

- the sulfur content of the fuel being burned, and
- the temperature of the feedwater at the inlet of the fuel economizer or heat recovery device

If the temperature of the inlet feedwater is not maintained at proper levels, certain byproducts of the fuel being burned have the potential to cause low temperature corrosion.

2 The Corrosive By-Products Of Combustion

Oil, natural gas and coal all contain the elements carbon and hydrogen. They may also contain a certain amount of sulfur. During the combustion process, these elements are rapidly oxidized. If sulfur is present in the fuel, it will combine with oxygen to form sulfur dioxide (SO_2) and sulfur trioxide (SO_3). It is the presence of these sulfur oxides in the flue gas that represent the largest potential cause for corrosion.

Sulfur dioxide, for example, will dissolve in any free moisture that may be present in the flue gas to form sulfurous acid (H_2SO_3) -- a powerful corrosive.

Depending on the sulfur content of the fuel, the amount of excess air in combustion, and the flame temperature, approximately 1% to 2% of the sulfur dioxide is further oxidized into sulfur trioxide. When combined with superheated water vapor, sulfur trioxide forms sulfuric acid vapor (H_2SO_4).

3 SO_2 And SO_3 Dew Points

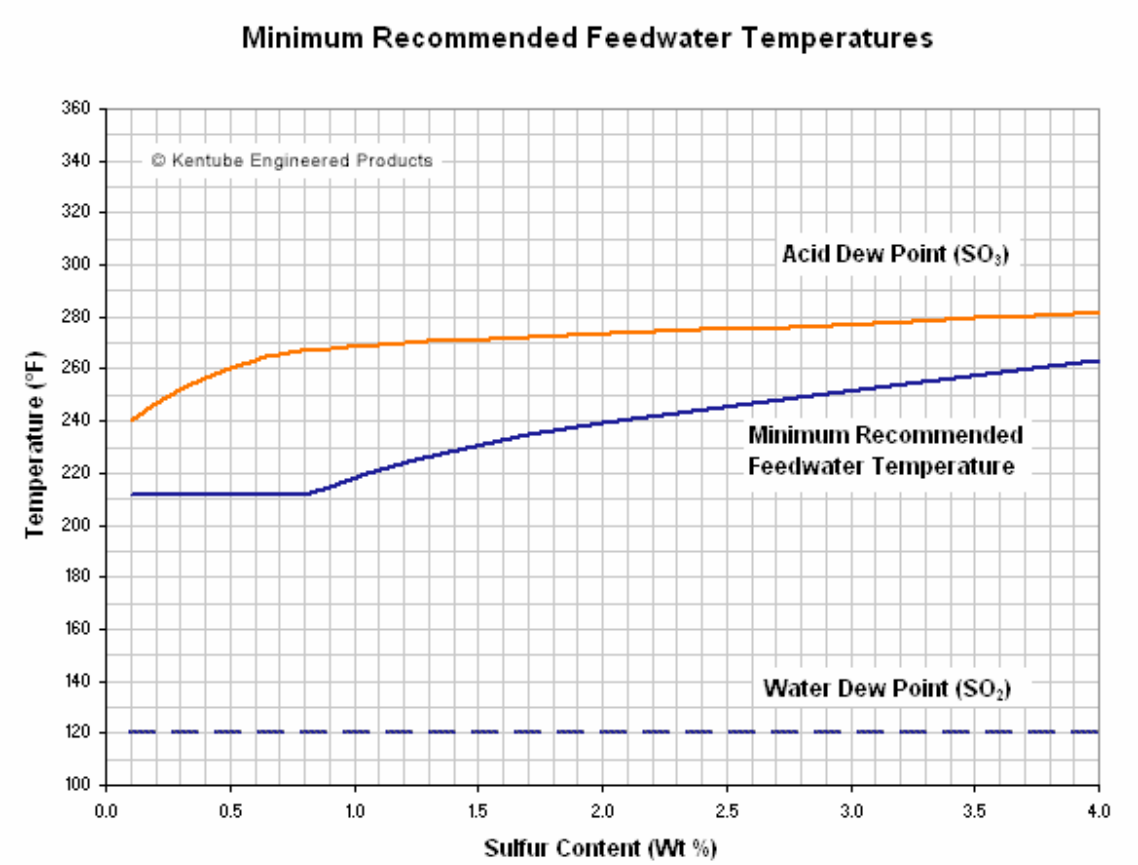
Determining the dew point, or temperatures at which moisture begins to condense out of a gas, makes it possible to calculate when SO_2 and SO_3 gases in the flue gas form the acids that cause corrosion. These calculations, as illustrated on the graph, also indicate that sulfur dioxide (SO_2) and sulfur trioxide (SO_3) do not condense to an acid at the same temperature.

Sulfur dioxide will form sulfurous acid when it can dissolve in the free moisture in the flue gas. Therefore, it is the temperature at which water vapor condenses out of the flue gas, or the "water dew point," that determines when sulfurous acid formation takes place. Depending on the type of fuel being burned, the water dew point will range between 100 degrees F and 150 degrees F. When SO_3 combines with superheated water vapor to form sulfuric acid vapor, the formation of sulfuric acid (H_2SO_4) begins to occur at what is know as the "acid dew point." The variables that determine both the formulation of the H_2SO_4 vapor and its dew point include -- the amount of excess air in combustion, the moisture content of the gas, and the amount of sulfur in the fuel. Under normal boiler operating conditions, the acid dew point, or the temperature at which the sulfuric acid vapor begins to condense, is in a range between 240 degrees F and 280 degrees F.

4 Inlet Feedwater Temperature vs. Corrosion Potential

Condensation of these acid vapors from the flue gas is the result of the flue gas contacting the metal heating surfaces in the heat recovery unit. The temperature of the flue gas in contact with these surfaces will be virtually the same as the temperature of the metal. The metal temperatures, in turn, will be within a few degrees of the feedwater flowing through the tubing.

It is the temperature of the metal surfaces of the finned tubing, not the average temperature of the flue gas as it exits from the economizer, that determines whether or not corrosive acids will condense out of the gas as it passes through the economizer.



Based on this fact, Kentube has established minimum recommended feedwater temperatures for feedwater entering the RETROMISER fuel economizer.

When sulfur dioxide (SO_2) gases pass through the economizer, the minimum feedwater temperatures indicated will maintain the metal surfaces of the heating elements well above the water dewpoint and eliminate the possibility of sulfurous acid (H_2SO_3) corrosion.

As far as sulfur trioxide (SO_3) gases and sulfuric acid (H_2SO_4) formation is concerned, research studies indicate that relatively little condensation takes place at the acid dew point. In fact, maximum condensation does not occur until temperatures are approximately 80 degrees F. to 100 degrees F. below the acid dew point. Additionally, less than 2% of the sulfur dioxide in the flue gas is converted to sulfur trioxide. It is evident, therefore, that only minimal amounts of

sulfuric acid will condense on the heating surfaces at temperatures between the recommended feedwater temperature level and the acid dew point.

The data presented in the above chart is based on information derived from low temperature corrosion studies conducted by the Petroleum Engineering School of the University of Tulsa. Maintaining the feedwater temperatures at the levels indicated will optimize overall performance and minimize the potential for low temperature corrosion attack in the RETROMISER fuel economizer, even when high sulfur fuels are being used.