Cold End Corrosion in a Boiler and Its Prevention
written by: Dr V T Sathyanathan • edited by: Lamar Stonecypher • updated: 5/25/2011

Using fuels with sulfur in steam generating units yields a potential hazard of sulfur corrosion at the cold end of the boiler. The severity depends on many factors like percentage of sulfur in the fuel, excess air, moisture in flue gas, etc. Many options are available to contain cold end corrosion.

Boilers generating steam for use in power generation and process power plants use different type of fuels. These fuels contain sulphur to differing percentages. The higher the percentage of sulphur, the higher will be the risk of cold end corrosion in the boiler. The sulphur in the fuel during combustion gets converted to sulphur dioxide.

Depending upon the other impurities present in the fuel and excess air levels, some portion of the sulphur dioxide gets converted to sulphur trioxide. The presence of moisture in the flue gas due to moisture in fuel and air, sulphur dioxide, and trioxide, combines with moisture and forms sulphuric acid and sulphuric acid. These acids condense from around 115 degree centigrade to slightly higher than 160 degrees, depending upon the concentration of SO$_3$ and water-vapour. The basic reactions taking place are:

\[
\begin{align*}
S + O_2 & \rightarrow SO_2 \\
SO_2 + O_2 & \leftrightarrow SO_3 \\
H_2O + SO_2 & \leftrightarrow H_2SO_3 \\
H_2O + SO_3 & \rightarrow H_2SO_4
\end{align*}
\]

Depending upon the ppm of SO$_3$ and water-vapor concentration, the dew point temperature can vary from around 90 degree centigrade to 140 degree centigrade.

Condensation of these acids results in metal wastage and boiler tube failure, air preheater corrosion, and flue gas duct corrosion. In order to avoid or reduce the cold end corrosion the gas temperature leaving the heat transfer surface in boiler is kept around 150 degrees centigrade, ranging from 120 to 155. It is very important that the metal temperature of the tubes is always kept above the condensation temperature. It may be noted that the metal temperature of the tubes is governed by the medium temperature of the fluid inside the tubes. This makes it necessary to preheat water to at least 150 degrees centigrade before it enters the economizer surface. In the case of an air pre-heater, two methods are used to increase the metal temperature. One is an air bypass for air pre-heater, and the second is using a steam coil air pre-heater to increase the air temperature entering the air pre-heater.

The amount of SO$_3$ produced in boiler flue gas increases with an increase of excess air, gas temperature, residence time available, the amount of catalysts like vanadium pentoxide, nickel, ferric oxide, etc., and the sulphur level in fuel.

The flue gas dew point temperature increases steeply from 90 degree centigrade to 135 degrees centigrade with sulphur percentage increasing up to 1%. A further increase in sulphur percentage in fuel gradually increases the dew point temperature from 135 degree centigrade to 165 degrees centigrade at 3.5% sulphur in fuel.

Prevention of cold end corrosion

There are many methods used world over to contain cold end corrosion. These methods fall in the category of in-combustion reduction and post-combustion reduction.

The in-combustion reduction methods include:
- Burning low sulphur fuel
- Low excess air burners
- Fuel additives
- Fluidized bed combustors

Going in for low sulphur fuel sometimes become economically unviable for the process for which the steam generators are used. Today many low excess air designs are available in the market. These burners adopt many ways to reduced excess air requirement without affecting the unburnts in the flue gas after combustion. Fuel oil additives like simple magnesium oxides are used to contain cold end corrosion due to sulphur. The magnesium oxide is injected in to the furnace or mixed with fuel which combines with sulphur oxides to form magnesium sulphate. In fluidized bed combustors, lime addition is a simple method used to reduce sulphur corrosion.

The post-combustion technologies adopted are:

- Designing with higher exit gas temperature
- Air bypass across air pre-heater
- Ammonia injection
- Flue gas desulphurization (FGD)

Designing boilers with higher exit gas temperature reduces the boiler efficiency. As a rule of thumb approximately every 20 degree centigrade increase of flue gas temperature at boiler outlet reduces the efficiency by 1%. Hence this is not a preferred method in the present days.

Air pre-heater bypass is for mainly for startup purposes until the metal temperature can be maintained above condensation temperature even when the cold air enters. Some designers use steam coil air pre-heater for full operation of the boiler.

Ammonia injection was a method adopted by a few designers in certain process plant boilers burning high sulphur oil due to the availability of ammonia. Ammonia is injected in the economizer region where the temperature of flue gas is below the ammonia dissociation temperature and sufficient time is available for the chemical reaction. Ammonia combines with sulphur trioxide to form ammonium sulphate. The rate of ammonia injection will depend upon the SO$_3$ concentration. The problem with this method is it produces a high volume of loose deposits of ammonium sulphate, which increases the pressure drop in the flue gas path. Removal of these deposits is done by water washing of the air pre-heater online.

Flue gas desulphurization is a very common method adopted in the present day. Here the flue gas with acid vapors is scrubbed to remove it as a byproduct. Most of the FGD processes use alkali to scrub the flue gas. Many designers of FGD adopt the limestone gypsum process. This process has gained acceptance due to the saleable gypsum byproduct. Sea water availability makes it possible to use it as an absorbent of sulphur oxides in acid form. There is another process called the Wellman-Lord Process, which is a regenerative process that uses aqueous sodium sulphite solution for scrubbing flue gas. The saleable byproduct, depending on the plant’s design, could be elemental sulphur, sulphuric acid, or liquid SO$_2$. There are many working plants using this technology in Japan, USA, and Germany. The Sodium Bicarbonate Injection Process is a direct injection method adapted to de-sulphur the flue gas. Here the sodium bicarbonate is injected in the duct after the air pre-heater and before the dust removal system like an electrostatic precipitator or bag filters.
Source: