Temperature and Corrosion Rate…
More Complex Than You Think

There’s a rule of thumb that the corrosion rate of a metal doubles for every 10°C increase in temperature. Thus, if the corrosion rate is 10 mpy (mils per year) at 30°C, expect it to be 20 mpy at 40°C, 40 mpy at 50°C, etc…

The rule is applicable in many situations, but it is important to recognize caveats where it should not be applied, as described below.

Thermodynamic Basis
Strictly speaking, the rule is based on when the corrosion rate is controlled by a chemical reaction, such as dilute sulfuric acid attacking carbon steel. Even in these situations, the corrosion rate increase with temperature may vary from 1.5 to 2X with each 10°C rise in temperature. But if the corrosion rate is controlled by other factors, such as the presence of oxygen in the corrosive environment, it may not be true.

Oxygen In System
Oxygen can play a major role in corrosion. For example, in a closed system constructed of carbon steel, the presence of oxygen drives the corrosion reaction. Once the oxygen in the environment is used up by the corrosion of the carbon steel, the corrosion rate falls to very low values, whatever the temperature.

The same is true in an open system as oxygen is driven off with increasing temperature. For example, the corrosion rate of Monel in sulfuric acid is affected by the presence of oxygen – the more oxygen the greater the corrosion. See what happens when oxygen is driven out of the solution by increasing temperature in the graph below. As the temperature is increased beyond a certain point in the aerated solution the corrosion rate falls to the value for the air-free solution.

Scale formation may also occur with increasing temperature and initiate underdeposit corrosion, which is not temperature dependent. It often occurs on heat exchanger tubes in cooling water.

Passive Alloys
The final consideration is the nature of the alloy. Some alloys develop a protective (passive) film in specific environment, like carbon steel in concentrated sulfuric acid; or they may develop it naturally, like stainless steel and titanium. As temperature increases, and as long as the passive film remains intact, corrosion rate does not increase. But once the passive film is overwhelmed by the increase in temperature, corrosion rate increases rapidly.

With chloride containing environments and stainless steel, there is usually a threshold temperature at which pitting occurs (penetration of the passive film leading to severe localized attack). Since a pit is a location where solution is trapped and is ever changing compared with the bulk process environment, the rate of propagation may no longer be temperature dependent.
The same argument applies to other forms of localized corrosion, such as stress cracking or erosion corrosion, although they are usually dependent on several factors at once.

**Surface Temperature Matters**

It is important to know the actual surface temperature of the metal in contact with the process environment. Hot wall effects, as in reboiler tubing heated by steam will make the ID of the tubing in contact with the process much hotter than the bulk process environment. Consequently the corrosion rate may be higher than anticipated.

With condensers, where cooling water or refrigerant is on the shell side, the reduction in temperature might lead to condensation of a corrosive species. This is sometimes called shock cooling or the cold finger effect.

May 2008