CHLORIDE STRESS CORROSION CRACKING: ***CAUSES & SOLUTIONS***

By Howard Hilborn

Over the years, we at GAYESCO have seen numerous failures of multipoint thermocouple assemblies that have been installed in pipewells. As a result of comprehensive failure analysis of these assemblies, we have compiled a list of the various failure mechanisms. Although many factors contributed to the length of the list, one mechanism accounted for a substantial portion: Chloride Stress Corrosion Cracking (CSCC).

In spite of the fact that CSCC can cause the loss of the entire assembly, and in extreme cases even necessitate the replacement or repair of the pipewell, it is a failure mode that can be eliminated relatively easily. To do this, however, it is necessary for the user to first understand the mechanism of this failure mode, and then take the necessary steps to avoid it.

For CSCC to occur, high chloride concentration and stress levels must be present. These conditions occur in pipewells because of the thermal gradient that exists at the vessel penetrations, where the pipewell goes quickly from process temperature to ambient temperature. Such radical and rapid temperature changes cause mechanical stress on the pipewell, creating a condensate region within.

This becomes a problem only when chlorine-laden air is allowed to enter the pipewell, vaporize in the presence of process temperatures, and then condense in the cooler area of the pipewell that is exposed to ambient temperature. As this cycle continues to repeat itself, chloride ions concentrate. The chlorine-laden air fueling the concentration cell can come from various sources; however, the two most common are cooling towers and steam lances. A third, though less common source, is water that has been allowed to enter the pipewell during turnaround.

Since the thermal gradient zone can't be practically eliminated in most cases, and in fact is not detrimental of itself, the solution is found in eliminating the chloride concentration cell. This can usually be accomplished by installing a secondary seal on the pipewell and keeping the pipwell pressure sealed at all times during operation and turnaround. The additional of a secondary seal has the added benefit of preventing the process from escaping to atmosphere in the event of thermowell failure.

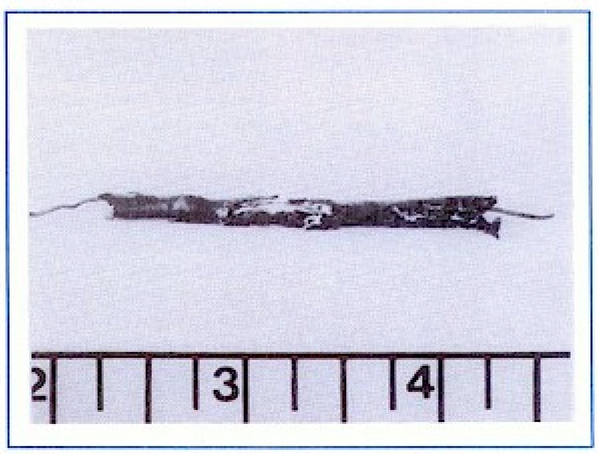

Figure 1

This photo, at 1-1/2 times the actual size, shows the severity of sheath cracking of the affected thermocouple.

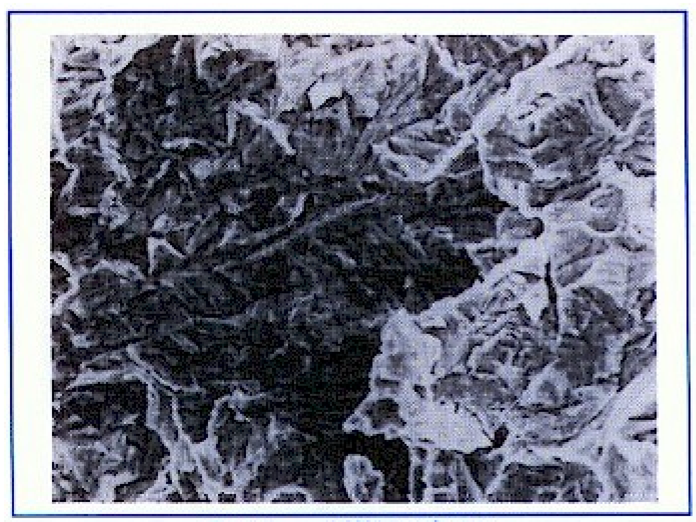

Figure 2 1,000 Magnifications

The transgranular, feathery topography shown is a textbook example of CSCC.

It is important to note here that when a secondary seal is employed in hydrogen service, a pressure tap must be installed between the primary and secondary seals in order to vent the hydrogen buildup that will occur inside the pipewell due to hydrogen diffusion. This pressure tap is also necessary for allowing maintenance personnel to verify that there is no pressure inside the pipewell prior to removing the thermocouple bundle.

In most cases, a properly employed secondary seal is all that is required to completely eliminate CSCC; in extreme cases, however, additional measures need to be taken. The addition of a dry nitrogen purge can be utilized to ensure that the thermowell is free of retained water prior to start up; however, this is only necessary if the pipewell has been left open during installation or thermocouple bundle replacement. In severe cases, using materials with low CSCC susceptibility (such as the inconels) will help to avoid the problem.

A comprehensive metallurgical analysis is required to determine that CSCC is in fact the cause of failure; however, it is usually easy to determine by knowing what to look for, CSCC will always occur in an extremely small region found between the hot process temperatures and the much cooler ambient temperature outside the vessel (usually in the vessel nozzle area or just above it). In addition, the thermocouple sheaths will be severely cracked; and these cracks will exhibit the branching characteristics of a stress corrosion mode of failure.

At this point, one can usually determine with a high degree of confidence that CSCC is the failure mode, although to be 100 percent sure would require the additional analysis of the corroding agent to verify that it was chlorine. Also, metallographic examination would be required to verify that the cracks were transgranular.

By determining if CSCC is a problem in a specific application and taking the necessary steps to prevent it, one can extend the life of the thermocouple assemblies and in extreme cases, even prevent pipewell failure. Considering the cost of downtime and/or loss of temperature measurement capabilities, the slight cost of adding a secondary seal and maintaining a pressure tight well is money wisely spent.

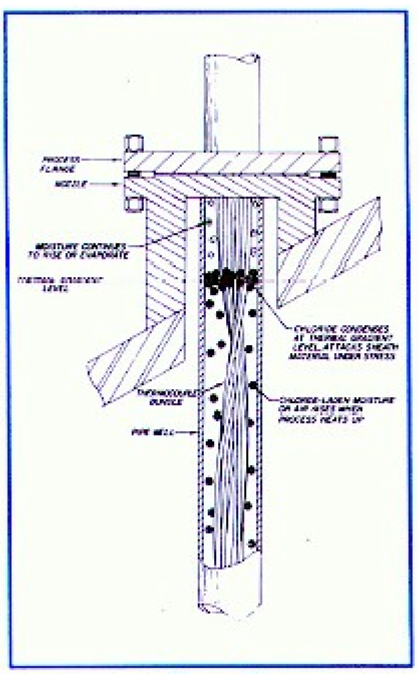

Figure 3

As water evaporates at the thermal gradient zone, chlorine ions concentrate and attack the sheath.