

Chemistry - PI 24

SECONDARY HEAT TRANSPORT SYSTEM - IMPURITIES

Reference: "Corrosion in Action" (a film on video-tape).

The Secondary Heat Transport System can be thought of as a heat sink for the Primary Heat Transport System via the steam generator.

Consider the following questions:

1. What would be the effect of a layer of scale on the secondary side of the steam generator tubes?
2. What would be the source of such a scale?

Effects of Scale

i) Loss of Heat Transfer

While exact calculations require data on scale porosity and thickness, it is sufficient to realize that scale will, due to its low thermal conductivity, act as an insulating barrier for heat transfer from the PHT system to the SHT system. This loss in heat transfer results in:

ii) Higher Tube Metal Temperature

This effect can be shown as follows:

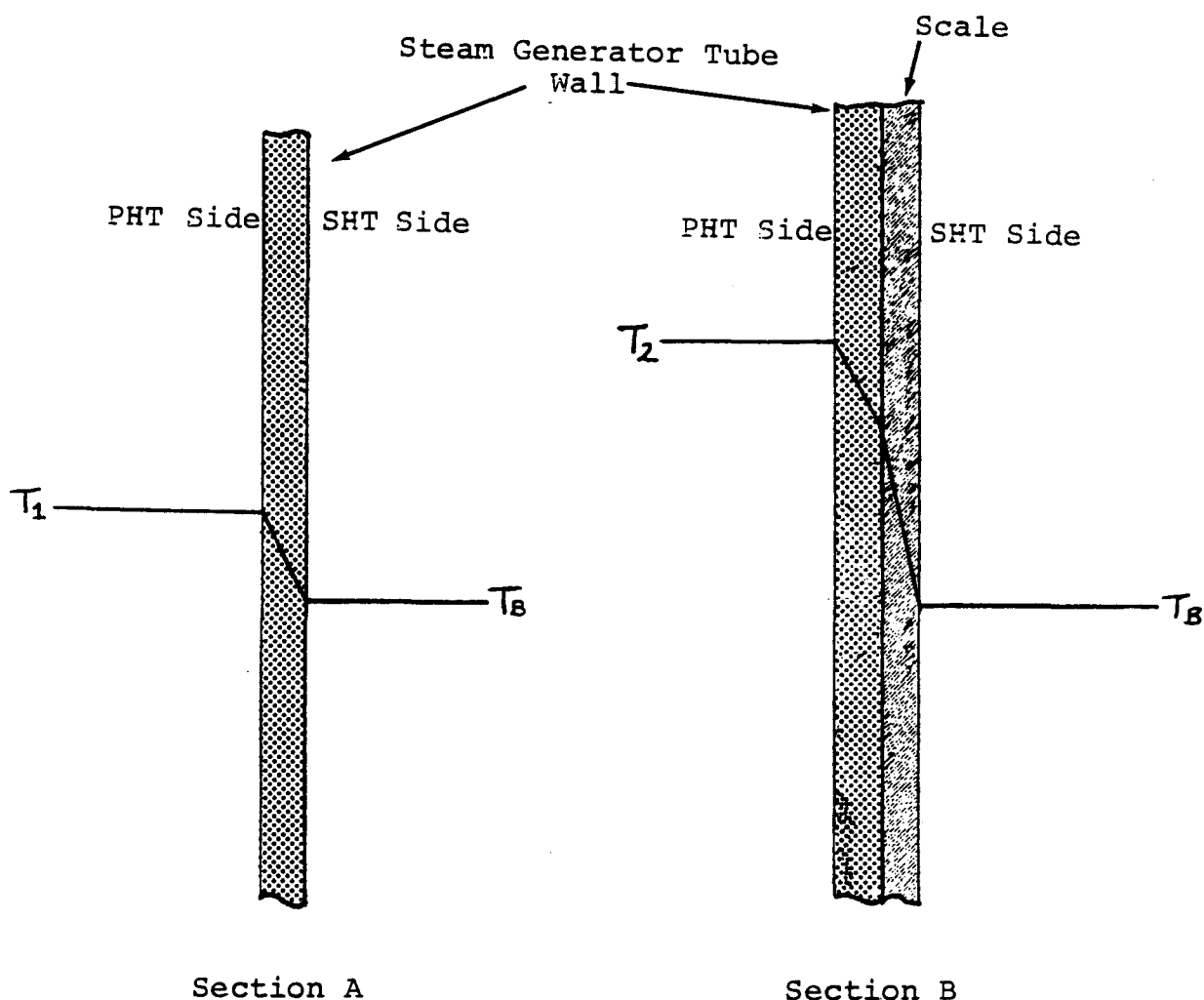


Figure 1

Figure 2

Effect of Scale on Boiler Heating Surfaces

Figure 1 is a drawing of a **clean** steam generator tube showing the normal temperature profile between the PHT system and SHT system with a temperature gradient through the tube. Note that T_B , the secondary side temperature is fixed by the boiling temperature of water at the steam generator secondary side pressure.

Figure 2 shows the same tube with a layer of scale. T_B remains the same since it is fixed; however, due to the insulating effect of the scale layer, the temperature profile is modified and the primary side tube wall temperature rises to T_2 .

If T_2 is high enough, reactor trip sequence will be initiated.

iii) Sludge Pile on Lower Tubesheet

Particulate matter or loose scale will settle in a steam generator and form a pile of sludge on the lower tubesheet. Actual measurements in Ontario Hydro plants have found sludge piles up to 10 cm.

iv) Cracking of Tubes

Given that a sludge pile is porous and that "boiling" does occur in it, any impurities in the boiler water will concentrate in the sludge pile as there is no washing effect from a high water flow at the site of boiling. If these impurities are high in something like chlorides then high chloride concentrations will develop adjacent to the steam generator tubes leading to Stress Corrosion Cracking of the tubes.

v) Denting

If scale forms between a tube a tube support plate and the concentration mechanism outlined above takes place for a chemical species which is corrosive to the tube support plate, then the resultant corrosion products formed on the plate, being higher volume than the original material will exert enough pressure on the tube to crimp it, or **dent** it as this phenomenon is known in the literature.

Source of Scale

There are 3 main sources of scale forming substances. In descending order of probability:

- feedwater system corrosion products.
- condenser leaks.
- Water Treatment Plant malfunction.

If oxygen, and/or carbon dioxide is present in the feedwater, the mild steel piping and other ferrous components will be attacked resulting in the formation of iron oxide. These iron oxides usually break off the surfaces where they are formed and travel with the feedwater as suspended solids or colloids (smaller than suspended solids). They will end up in the steam generator and stay there as the steam generator may be thought of as a distillation unit in some senses. Similarly, oxygen with the aid of ammonia or carbon dioxide may attack brass (Cu/Zn) or cupro-nickel components to form small particles of oxides of copper, nickel and zinc. You should note that the sludge found in steam generators consists mainly of iron oxide with some copper oxide and quite small amounts of nickel and zinc oxides.

A further problem with copper oxides is that if they deposit on steel tubes, a galvanic cell is set up plating out metallic copper at the expense of iron oxide formation from the steel (pitting).

If a condenser tube has even a pin-hole leak, raw water will be sucked into the condenser due to the difference in pressure of raw water in the tubes and the near total vacuum of the turbine exhaust steam in the condenser shell. This raw water will contain mineral salts and may contain suspended solids and/or organics. The big offenders of this group are calcium and magnesium bicarbonates (hardness) and silica (sand). The hardness salts can bake onto the steam generator tubes just as they do in your tea-kettle at home.

Silica is a dual threat. Not only will it form silicates which form a dense tenacious scale, but at the high temperature of the steam generator, silica has the potential to volatilize and travel with the steam only to deposit out on steam system components and turbine blades when the steam temperature drops.

(Silica may appear in raw water as a suspended solid, and/or a colloid, and/or a dissolved species.)

Although a remote possibility when one considers the automatic trip feature provided, Water Treatment Plant (which provides make-up to the system) malfunction could introduce anything between slightly "off-spec" product to regenerant wastes extremely high in mineral content to the feed system.

On the opposite end of the spectrum, from deposition or scaling which cause loss of heat transfer and flow restriction are **corrosion** and **erosion** which cause metal wastage and possible failure.

"What impurities or conditions will cause erosion or corrosion in the Secondary Heat Transport System?"

Erosion

Erosion is caused by suspended particles in a fluid stream doing **physical** damage to metal components by impingement. The sources of these suspended solids are, in order of probability:

- feed system corrosion products.
- metal filings and scraps left from improper clean-up after construction.
- condenser leaks.

Corrosion

Corrosion is metal wastage by **chemical** action.

- i) pH - feed system and steam generator are kept at an optimum pH. By optimum for steel systems, we mean about 9.2 - 9.6 which will be high enough to promote formation of a protective magnetite layer and low enough to prevent caustic embrittlement. This pH is of course, high enough to prevent acid attack.

For systems containing brasses, a somewhat lower pH is favoured to prevent caustic dissolution of the metal. However, systems containing brasses have steel components as well and a compromise pH of 8.8 - 9.2 is usually used. (Main condenser and low pressure feedheater tubes are usually made of brass except for Bruce-B and later stations which are all ferritic).

- ii) Chlorides - If the chloride ion is present in the steam generator system, the components made of austenitic stainless steels will be damaged due to stress corrosion cracking. In fact, great care must be taken at all stages in the life of stainless systems to prevent their being exposed to chlorides, even initial fills for hydrostatic testing must use demineralized water.

Chlorides are present in raw water and will enter the system whenever it is exposed to a source of raw water (condenser leak; Water Treatment Plant malfunction; carelessness).

- iii) Oxygen - If air leaks into the system, oxygen will be present which will corrode steel parts just the way the automobile fender disappears after a few years.
- iv) Ammonia, Carbon Dioxide - Ammonia from hydrazine (see module 21-2) break-down will attack copper containing components (brasses) as will CO₂. Steel components are attacked by Carbon Dioxide.

Carryover

Carryover is the entrainment of boiler water in the steam. Chemically, the problem of carryover centers on the solids contained in boiler water which will lead to deposit formation on steam system components, valve gear, and turbine blading. Mechanical problems associated with carryover are covered in the Turbines course. In general, carryover is caused by two phenomena; foaming and priming.

Foaming is the condition resulting from the formation of bubbles on the surface of the boiler water. The foam may entirely fill the boiler steam space or may be of relatively minor depth. In either case, this foaming condition leads to appreciable entrainment of boiler water in the steam.

Priming is a more violent action, resulting in the throwing of "slugs" of boiler water over with the steam. This action may be similar to the "bumping" experienced when water is boiled in an open beaker or it may be the bulk rise of boiler water level leading to massive carryover.

The chemical causes of carryover are related to the impurities in the boiler water. In general high concentrations of solids in the boiler water, whether dissolved or suspended will lead to high carryover.

The presence of oil in boiler water is highly undesirable from the standpoint of carryover. In combination with the alkaline boiler water, oils have a strong tendency to foam. (Alkalis and oils generally form soaps.)

Boiler water impurities are controlled by "blow down" which will be covered in module 21-2.

Practice Exercises:

Consider each of the six objectives at the front of this module as if it were a question. Write out your answers and have them checked by the course manager or a colleague.

If you have any difficulty picturing the mechanisms in this module be sure to consult the course manager before proceeding.

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