IDENTIFICATION OF PROBLEMS ASSOCIATED WITH SODIUM SULPHITE TREATED CLOSED WATER SYSTEMS

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by

G.F. Yuzwa, P.Eng.

H2O ENGINEERING LTD.
539 Edgemont Bay N.W.
Calgary, Alberta
T3A 2K7

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DESCRIPTION OF A CLOSED WATER SYSTEM

A closed water system (see Fig. 1 overleaf) is a heating or cooling system in which heated or chilled water is circulated throughout the building or through coils in an HVAC system in order to provide space heating or cooling.

The principal components of these systems consist of a heating or cooling source (ie., boiler, chiller, convertor), automatic air vents, circulating pumps, pressurized expansion tank, heat exchangers, chemical pot feeder, by-pass cartridge filter & flow indicator, water meter, backflow prevention device, pressure regulator, low-water fuel cut-off controller, flow switch, and interconnecting piping, valves & fittings of mixed iron, copper & bronze metallurgy.

The quantity of make-up water for a closed water system generally averages less than 0.1% of the system volume per day (ie., for a 1,000 gallon system, the water make-up rate should be less than 30 gallons per month). Therefore, they are referred to as being closed systems.

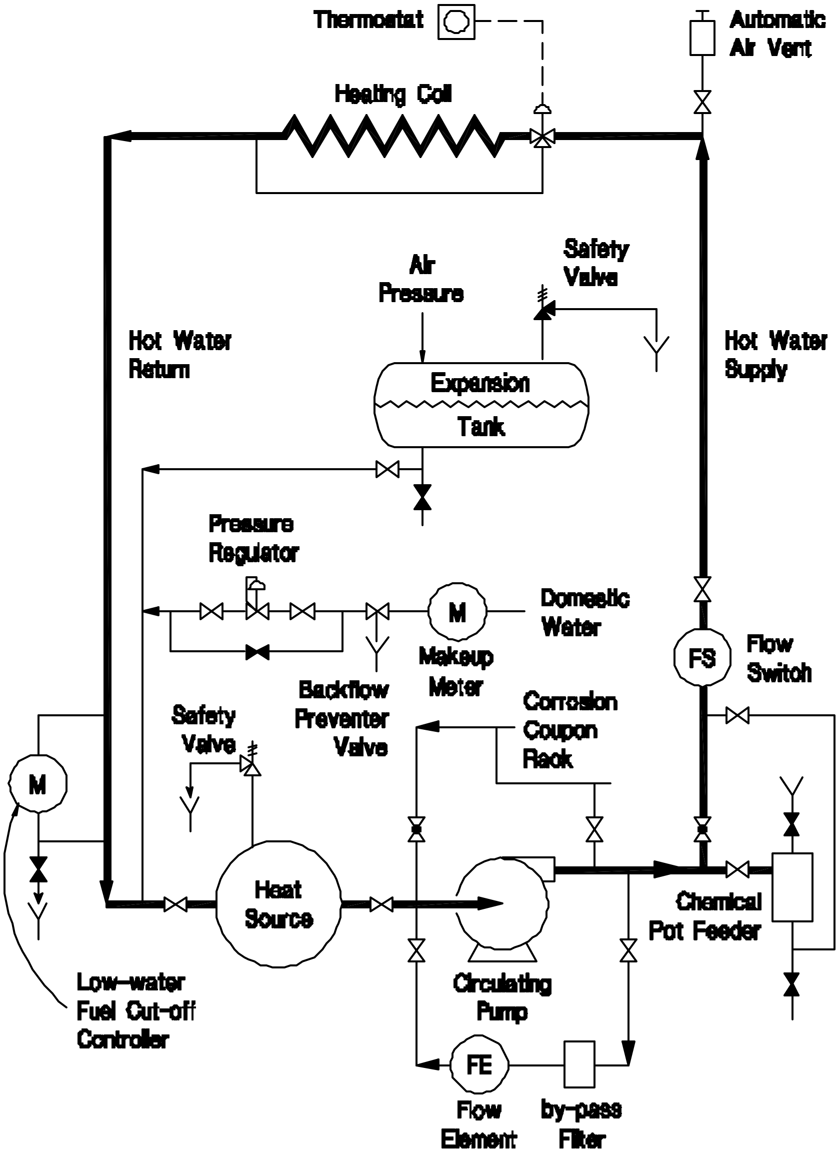


Fig. 1: Schematic Diagram of a Typical Closed Water System

IDENTIFICATION OF PROBLEMS

General

When a new system is filled with domestic water the first time, the hardness salts are precipitated evenly on system piping, and the dissolved oxygen is consumed by local corrosion, thus leaving a reduced salt concentration and inert nitrogen in the system. In this perfectly closed state, the water in the system will not cause further corrosion or scale formation.

However, since the system can not be a perfectly closed one in reality, sodium sulphite is added as an oxygen scavenger & protective film former such that a residual concentration of 50-100 ppm SO_3 is maintained, and sodium hydroxide (ie., caustic) is added as required in order to elevate the pH level to within its control range of 8.5-9.5.

If repeated additions of sodium sulphite and/or sodium hydroxide are required in order to maintain the sulphite & pH levels within their respective control limits, a chemical control problem exists and it must be addressed in order to prevent corrosion and/or scale formation in the system.

The maximum acceptable sodium sulphite addition rate in grams/month is equivalent to 2% of the system capacity in imperial gallons. That is, if the system capacity is 1,000 imperial gallons, the maximum acceptable sodium sulphite addition rate would be 20 grams/month.

System Pressure

A positive pressure at all points in the system will prevent the ingression of air into the system, and thus reduce the sodium sulphite consumption. Therefore, in order to ensure that there is a positive pressure at the top of the system at all times, a **minimum static pressure** must be maintained according to the following equation by the addition of air to the expansion tank:

$$P = (H/2.31) + 5$$

where P: pressure at the circulating pumps with the circulating pumps shut off, psig;

H: elevation of the system piping above the circulating pumps, feet

Note that the setting of the pressure regulator in the water make-up line must also be set at this same pressure in order to ensure that water is admitted when it is lost from the system.

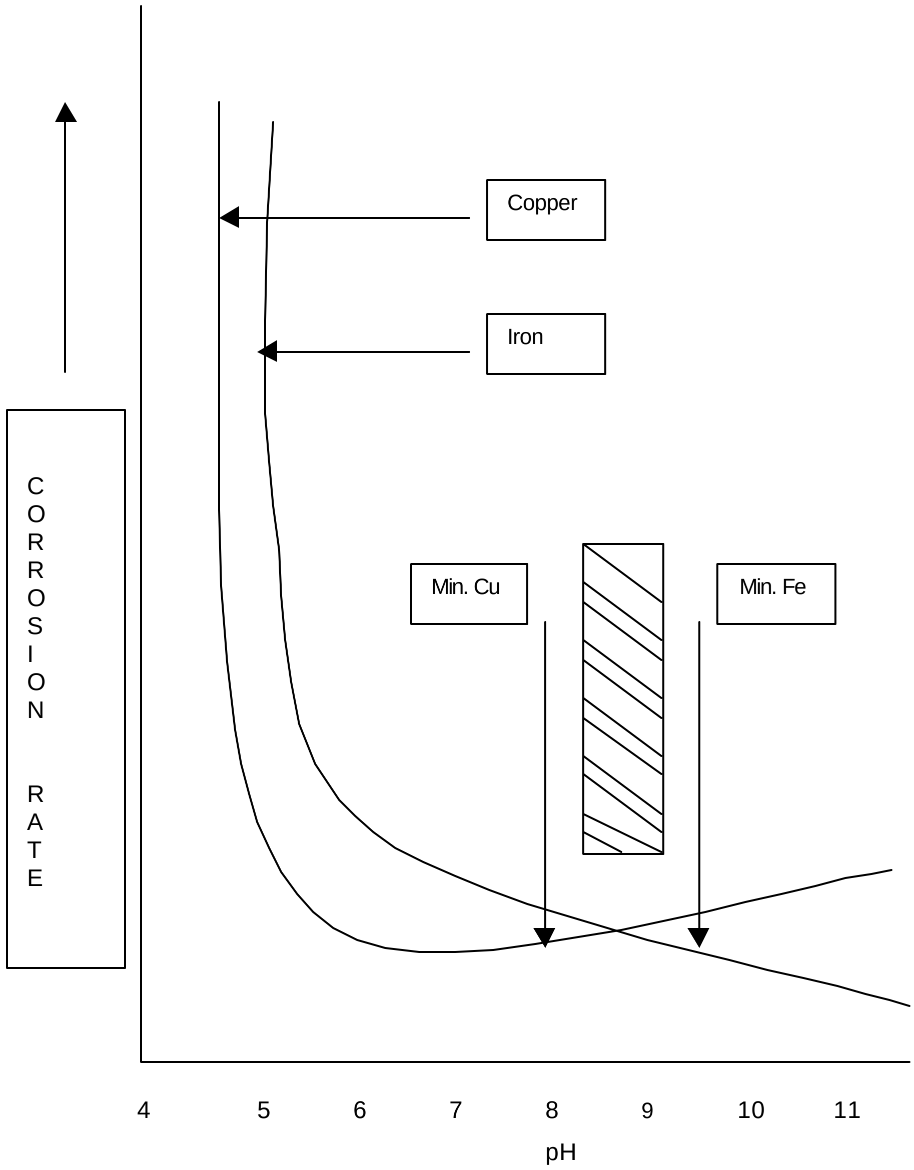
System pH Level

As indicated in Figure 2 overleaf, the lowest corrosion rate for copper material in a water system occurs at a pH level of 8.0 and the lowest corrosion rate for iron material in a water system occurs at a pH level of 9.5. Since most closed water systems are constructed of both iron and copper material, a pH control range of 8.5-9.5 is generally utilized in order to limit the corrosion rates for both of these materials to a minium amount.

High pH levels in a closed water system are caused by excessive caustic addition and repeated sodium sulphite additions. Therefore, high pH levels are reduced by flushing the system and re-filling it with fresh water, and by correcting the problem which causes the need for the repeated sulphite additions. If flushing of the system is not successful, small quantities of acid may be added to the system to reduce its pH level (see Fig. 2: Corrosion Rates of Iron and Copper vs. pH Level on following page).

Low pH levels in a closed water system are caused by inadequate caustic addition and the presence of sulphate reducing bacteria, the former of which is removed by draining the system and filling it with fresh water, and the later of which is removed by sterilizing the system as indicated later in this report.

Fig. 2: Corrosion Rates of Iron & Copper Vs. pH Level



System TDS Concentration

Sodium sulphite is added to the system in order to scavenge dissolved oxygen and to create a protective film on the metal surfaces as per the following equations:

$2Na_2SO_3 + O_2 = 2Na_2SO_4$

sodium sulphite plus dissolved oxygen equals sodium sulphate

$Na_2SO_3 + 3Fe_2O_3 = 2Fe_3O_4 + Na_2SO_4$

sodium sulphite plus ferric oxide equals magnetite plus sodium sulphate

$Na_2SO_3 + 2CuO = Cu_2O + Na_2SO_4$

sodium sulphite plus cupric oxide equals cuprous oxide plus sodium sulphate

However, if sodium sulphite is repeatedly added to the system in order to maintain its residual concentration of 50-100 ppm as SO_3, the salt concentration, namely the sodium sulphate concentration, in the system will increase accordingly until excessive galvanic type of corrosion is encountered at salt concentrations greater than 2000 ppm.

Therefore, if the TDS concentration of the water in the system is at or approaching the 2000 ppm level, the water in the system must be replaced with fresh water in order to prevent galvanic corrosion.

Future occurrences of high TDS concentrations in the system may be prevented by determining the reason for the repeated sodium sulphite additions (ie., low system pressure, excessive water loss, etc.) and performing the necessary corrective actions.

System Hardness Concentration

As indicated previously, when a new system is filled with domestic water for the first time, the hardness salts are precipitated evenly on the system piping, thus leaving a reduced salt concentration in the system.

The hardness and alkalinity concentrations in the raw water determine the amounts of carbonate & non-carbonate hardness in the water. However, in most cases, the major portion of the hardness concentration in Alberta raw water supplies consists of carbonate hardness (ie., calcium bicarbonate). The maximum carbonate hardness concentration that can be maintained in solution is determined by the following typical equation:

$$Ca(HCO_3)_2 \quad + \quad heat \quad = \quad CaCO_3 \quad + \quad H_2O \quad + \quad CO_2$$

calcium bicarbonate plus heat equals calcium carbonate plus water plus carbon dioxide

Calcium carbonate has a solubility of approximately 13 ppm, whereas the solubility of calcium bicarbonate is determined by the dissolved carbon dioxide concentration, but it can be as high as 500-1000 ppm. Therefore, if the carbon dioxide concentration is removed from a raw water supply by heating & venting, as in a closed hot water heating system, the hardness concentration greater than 13 ppm will be precipitated on the metal surfaces, and if no further water is added to the system, the hardness concentration should be 13 ppm.

If there are repeated sodium sulphite additions to the system in order to maintain its residual concentration within its control limits, and if the hardness concentration in the system is greater than approximately 30 ppm $CaCO_3$, the repeated sulphite addition is due to an excessive water make-up rate (ie., the higher the hardness concentration, the higher the water make-up rate). Note that water make-up may not register on the water meter at low flow rates.

Therefore, the reasons for the water ingression into the system (ie., leaking pump & valve seals, leaking boiler tubes, etc.) must be investigated and the necessary repairs must be made in order to reduce the water make-up rate and the sodium sulphite consumption.

System Bacteria Contamination

Since sulphate reducing bacteria are anaerobic bacteria which obtain their energy by reducing the sulphate or sulphite ions in water to form hydrogen sulphide, closed water systems that are treated with sodium sulphite provide an ideal environment for their growth. That is, the oxygen concentration is very low and the sulphite concentration is very high.

Sulphate reducing bacteria are present in a water system if there is a typical "rotten egg" odour of the water and if repeated additions of sodium sulphite & caustic to the water system are required in order to maintain the sulphite & pH levels within their respective control limits.

Therefore, if all of these symptoms are present, the metal surfaces of the water system must be completely sterilized in order to prevent the resulting corrosion, rather than continuing with the repeated additions of chemicals.

Future occurrences of this type of bacteria may be reduced by flushing out the expansion tank periodically and by circulating the system contents occasionally during its shutdown season.