

WATER TREATMENT
OF
CLOSED HOT WATER HEATING AND CHILLED WATER SYSTEMS

Presented at

ALBERTA
Public Works, Supply and Services
Property Management Division
Water Treatment Coordinators' Meeting
Edmonton, Alberta

April 9th 1987

by

G.F. Yuzwa, P.Eng.

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

1.0 CLOSED WATER SYSTEMS

1.1 Description

A closed hot water heating or chilled water system, a typical schematic diagram of which is indicated in Figure 1 overleaf, is a system where hot or chilled water is circulated throughout the building to provide space heating or cooling.

The principal components of these systems consist of a heating or cooling source, circulating pumps, pressurized expansion tank, automatic air vents, heat exchangers, chemical pot feeder, cartridge filter, and metered water make-up.

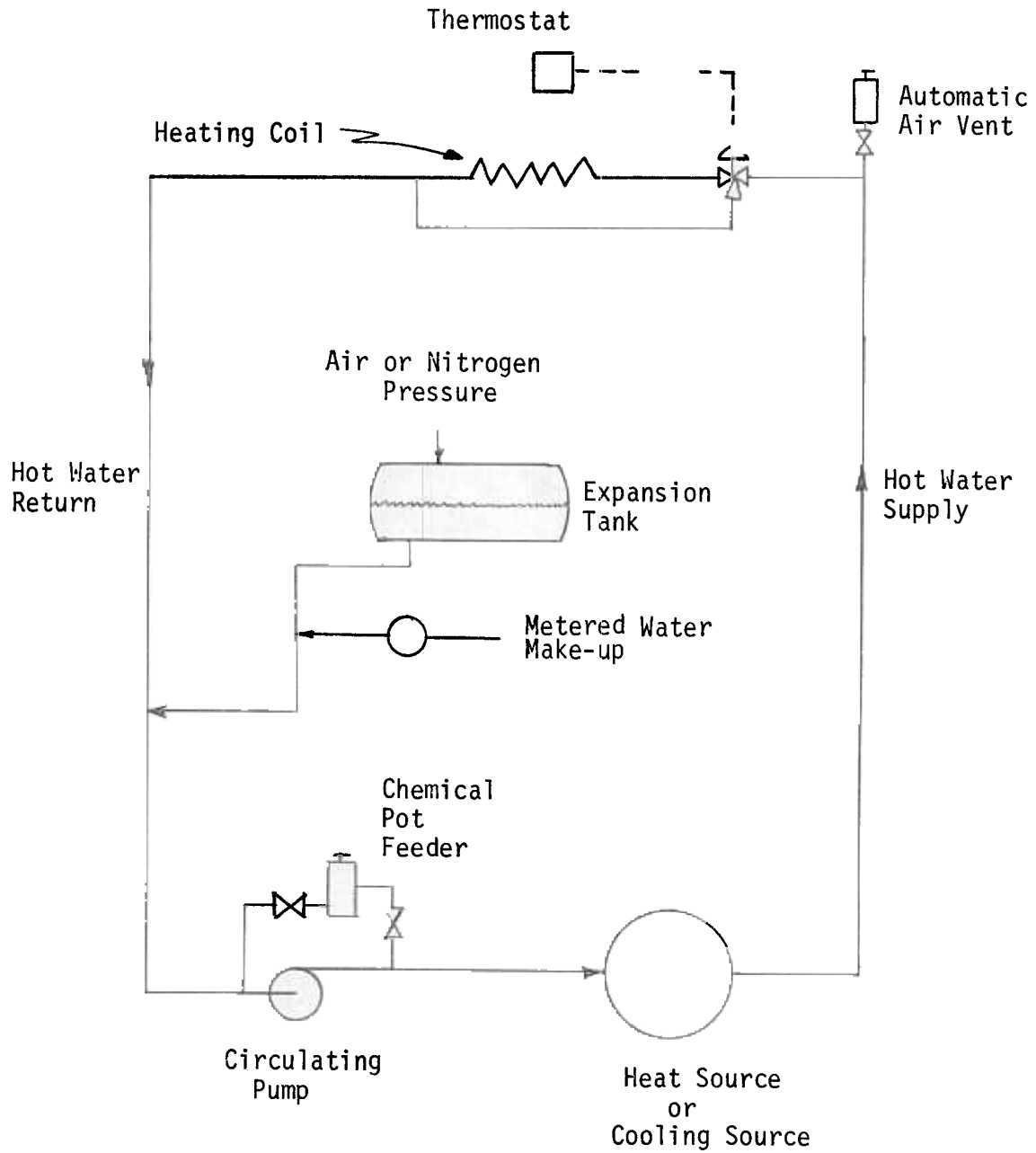
1.2 Operation

Circulating velocities tend to be in the 3-5 feet per second range and the temperature change in the circulating fluid will generally average 10-15 F for the average system. Maximum temperature can be as high as 180 F for hot water heating systems and as low as 30 F for chilled water systems.

These systems theoretically use very little make-up water, generally averaging 0.1-0.5 % of system capacity per day.

Conditions during operation are generally steady, but some systems are subjected to frequent on-off conditions.

Figure 1: Schematic Diagram of a Typical Closed Hot Water Heating/Chilled Water System



2.0 WATER TREATMENT OF CLOSED WATER SYSTEMS

2.1 Introduction

Corrosion, scale, fouling, and microbiological growth are considered the four major problems in all types of circulating water systems. Of these, corrosion is usually of major importance, but all four of these problems can exist in closed circulating systems.

Corrosion is an electrochemical process in which the development of a corrosion cell results in metal loss. Corrosion cells can be established by the presence of dissolved oxygen, a dissimilar metal coupling, or differential concentration cells. Dissolved oxygen may enter the system via the make-up water and/or the air in-leaks at pumps, valves, or expansion tank. Galvanic corrosion occurs when two dissimilar metals are physically joined in an aqueous media. Differential concentration cells are established by solid deposits and crevices in the system.

Scale develops on the surfaces of a water system when the concentration of a component in the water becomes greater than its maximum solubility concentration. At the temperatures encountered in a hot water heating system, scale will precipitate with each addition of hard water to the system. In time, scale will plug lines, reduce heat transfer, and promote corrosion.

Fouling materials such as corrosion products, sand, cutting oils, joint compounds, and construction debris are found in closed circulating systems due to residue from the construction of new systems or new sections of old systems and from incomplete or inadequate corrosion control. In addition to clogging areas of the system, these materials establish the conditions necessary for the development of differential cell attack.

Due to the combined effects of lack of sunlight, low oxygen, and usually little nutrient, microbiological growths are not common in closed circulating water systems.

2.2 Non-chemical Treatment

Corrosion and scaling in closed circulating water systems may be minimized by performing the following non-chemical steps:

- (a) thoroughly clean and flush new systems and new portions of old systems with treated water and minimize the time between cleaning of the system and the addition of permanent chemical treatment;
- (b) eliminate or minimize water losses and air in-leakage into the system by "tightening up" connections and minimizing system draining and/or flushing;
- (c) eliminate bimetallic couples by the installation of dielectric unions;
- (d) change cartridge filter element on a routine basis.

2.3 Proprietary Chemical Treatment

Proprietary chemicals are products which are composed of a mixture of various "off the shelf" or generic chemicals and water. They are given a brand name and patented by the supplier in order to prevent duplication by competitors. Therefore, the exact composition of proprietary chemicals is not available to the end user.

The most prevalent proprietary inhibitors which are used for the chemical treatment of closed circulating water systems are the nitrite based and the molybdate based inhibitors. Both of these inhibitor types are "barrier" treatments (ie., they create a protective film on the wetted metal surfaces, rather than treating the water).

2.3 Proprietary Chemical Treatment (continued)

In addition to water, the proprietary nitrite based inhibitors usually contain sodium nitrite (in order to react with iron and create a protective film on the metal surface), sodium borate (in order to buffer the pH of the water to the 9-10 range for best iron film formation), a copper inhibitor (in order to provide protection against the corrosion of copper based alloys because of the high pH), and a sequestering agent (in order to prevent the precipitation of deposits because of the high pH). These inhibitors are effective for very "tight" systems, but the nitrite is converted to the ineffective nitrate form by air ingress into the system. Also, the high residual nitrite concentration of 900-1200 ppm as NaNO_2 which are carried in the system elevates the TDS to a point where there is additional wear on mechanical seals and valve seats. The high nitrite concentration may also lead to microbiological growths in the system since it is an excellent nutrient, thus necessitating the addition of a biocide. Due to the very high nitrite concentration in these inhibitors, they should not be used for indirect heating of potable water systems. The effective cost of nitrite based inhibitors, assuming that there is no air in-leakage into the system, is approximately \$26.00 per 1000 imperial gallons of water added to the system.

In addition to water, the proprietary molybdate based inhibitors usually contain sodium molybdate (in order to react with iron and create a protective film on the metal surface), sodium nitrite if there is insufficient oxygen in the system (in order to act as an oxidizing agent for the molybdate reaction with iron), morpholine (in order to increase the pH of the water to the 9-10 range for best iron film formation), a copper inhibitor (in order to provide protection against the corrosion of copper based alloys because of the high pH), and a sequestering agent (in order to prevent the precipitation of deposits because of the high pH). These inhibitors are effective for very "tight" systems as well as for systems with high make-up and air ingress. Eventhough only 60-75 ppm molybdate as Mo is required for protection against corrosion in closed circulating systems, the effective cost of molybdate based inhibitors is approximately \$60.00 per 1000 imperial gallons of water added to the system.

2.4 Generic Chemical Treatment

Generic chemicals are chemicals which are readily available from general chemical suppliers as "off the shelf" single component items. The exact composition of generic chemicals is readily available.

Ever since the demise of chromate as a corrosion inhibitor due to environmental reasons, the most prevalent generic inhibitors which are used for the chemical treatment of closed circulating water systems are sodium silicate and sodium sulfite. Both of these inhibitors are "barrier" treatments (ie., they create a protective film on the wetted metal surfaces). However, sodium sulfite also scavenges the dissolved oxygen in the water, thus preventing its corrosive reaction with iron.

Sodium silicate hydrolyzes in water to form negatively charged colloidal particals which migrate to the anodic area of the corrosion cell where they form a film with solid corrosion products. At low TDS concentrations, silicates are very effective as a corrosion inhibitor, but at TDS concentrations above 500 ppm, they are ineffective inhibitors due to the instability of the colloidal system. They also give rise to pitting corrosion if used at low concentrations. However, the principal draw back of this treatment is the fact that the protective film is difficult to form and it is easily destroyed. For flowing systems, sodium silicate is added to maintain a residual of 25-40 ppm as SiO₂ and the pH is controlled within the range of 8.0-9.5. The effective cost of sodium silicate as a corrosion inhibitor is approximately \$0.55 per 1000 imperial gallons of water added to the system.

2.4 Generic Chemical Treatment (continued)

Sodium sulfite not only reacts with the dissolved oxygen in the system to prevent oxygen pitting corrosion, but it also reacts with iron and copper corrosion products in the system to form a protective film on these metal surfaces (ie., black magnetite on iron surfaces). Its reaction rate is acceptable at the temperatures which are encountered in hot water heating systems, but the reduced reaction rate at lower temperatures necessitates a catalyst addition. Normally the TDS of the system is low since only 50-100 ppm sulfite as SO₃ are maintained. However, continued addition of sulfite, because of air ingress into the system, increases the TDS of the system to a point where the water may become corrosive, galvanic corrosion is more prevalent, and wear on mechanical seals and valve seats increases. Corrosion of iron and copper is kept to a minimum by controlling the pH, usually with very small amounts of caustic, within the range of 8.5-9.5 pH units. However, pHs higher than this range lead to corrosion of copper based material in the system, whereas pHs lower than this range lead to corrosion of iron in the system. The effective cost of sodium sulfite treatment, assuming that there is no air in-leakage into the system, is approximately \$0.65 per 1000 imperial gallons of water added to the system.

2.5 PMD Program

The philosophy of the PMD Water Treatment Program is to reduce the need for chemical treatment of building heating and cooling systems through diligent attention to the mechanical design, operation, and maintenance of these water systems.

Therefore, the PMD program for treating closed hot water heating and chilled water systems incorporates attention to these mechanical aspects as well as chemical treatment based on the use of sodium sulfite as an oxygen scavenger.

2.5 PMD Program (continued)

In addition to the non-chemical treatment steps indicated in Section 2.2, the mechanical aspects which require attention are as follows:

- (a) Limit the amount of make-up water by:
 - installing a water meter in the make-up line;
 - locate and repair system leaks immediately;
 - adjust pump seals with packing so that there is minimum leakage;
 - ensure that pumps with mechanical seals have zero leakage;
 - do not drain or fill these systems seasonally--if maintenance or inspection is required, only those portions of the system that are affected should be drained;
- (b) Ensure that there is positive suction on the circulating pump(s) at all times;
- (c) Ensure that there is a water level in the expansion tank at all times;
- (d) Ensure that all automatic vents are closed during operation.

2.5 PMD Program (continued)

Ideally, these systems are totally closed (ie., no water make-up and no air ingress) so that the initial scaling and/or corrosion of the system soon uses up the dissolved oxygen and hardness. Thereafter, corrosion and scaling should be negligible. However, since no system is ideal, the following chemical treatment provides an insurance against corrosion and scaling for the majority of these systems:

- (a) Sodium sulfite must be added such that a sulfite residual concentration of 50-100 ppm as SO_3 is maintained in the system;
- (b) Cobaltous chloride must be added to closed chilled water systems at a rate of 20 ml per pound of sodium sulfite added;
- (c) If the pH of the system water is less than 8.5, caustic must be added in very small amounts in order to control the pH within the range of 8.5-9.5 (note: pHs less than 8.5 are corrosive to iron; pHs greater than 9.5 are corrosive to copper based materials).

Phosphate addition is not recommended since it will precipitate hardness, thus increasing wear on pump seals and valve seats. Rather, if there is make-up to a system because of water losses which can not be located, consideration should be given to softening the make-up water (note: since soft water is corrosive at higher temperatures, the system should be filled with hard domestic water and the complete system drained and re-filled when the soft make-up water has displaced the original fill water).

2.5 PMD Program (continued)

The following control tests are recommended for closed hot water heating and chilled water systems:

- (a) At least once per month--or more frequently if the sulfite is being consumed--determine and record the sulfite concentration in the circulating water--it should be 50-100 ppm SO₃ (note: do not blow down system to reduce the sulfite as this action will admit oxygen to the system)--continued sulfite addition indicates that air is gaining entrance to the system;
- (b) At least once per month, determine and record the pH of the circulating water--it should be 8.5-9.5 pH units --add very small amounts of caustic as required (note: low pHs are corrosive to iron, high pHs are corrosive to copper);
- (c) At least once per month, determine and record the TDS of the circulating water--a steady increase in TDS is an indication that the system is losing water and/or consuming sulfite--the entire system should be drained, flushed, refilled, and treated with sulfite when the TDS reaches approximately 2000 ppm in order to reduce galvanic corrosion;
- (d) At least once per month, record the make-up water meter reading--it should be negligible;
- (e) At least once per month, visually inspect a water sample from the system--it should be clear and free of suspended material--this is a general indication of the state of the system and an indication of the frequency of cartridge filter element replacement.