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TREATMENT OF OPEN RECIRCULATING COOLING WATER SYSTEMS

By

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INTRODUCTION

At the Water Treatment Coordinators' meeting in April of 1981, the paper entitled "Treatment of Cooling Waters" was presented by the writer. This paper gave a general overview of such topics as types of cooling water systems, scale formation, forms of corrosion, prediction of scaling/corrosion, measurement of corrosion rates, organic growths, external treatment for scale and corrosion control, chemical treatment for scale control, chemical treatment for corrosion control, and microbiological control.

Although some of these topics are also dealt with herein, it is the intent of this paper to provide the reader with specific set points for field operation based on a minimal amount of theoretical discussion on the treatment of open recirculating cooling water systems within buildings managed by ALBERTA Public Works.

Therefore, such topics as system description, scale and corrosion control, biological control, and monitoring of scale and corrosion are presented herein.

SYSTEM DESCRIPTION

The basic components of an open recirculating cooling water system consist of a wet cooling tower, a heat exchanger, a circulating pump, a manual bleed-off valve, and metered make-up water with a float valve. However, additional components such as an automatic bleed-off system, louver screens, a by-pass filter, a chemical feeder, an acid injection system, and a softener may also be present. The physical arrangement of these components are indicated in Figure 1 of Appendix A.

Cooling towers remove heat by evaporative cooling of a stream of water that continuously passes through a heat exchanger. However, during this process, only pure water is evaporated, thus resulting in a concentration build-up of the constituents in the circulating water. There is also a build-up of air-borne constituents (ie., poplar fluff, dust, carbon dioxide, sulfur dioxide, etc.) in the circulating water due to the scrubbing action of the water as it contacts the air. It is because of this build-up of constituents that the circulating water of open recirculating cooling systems must be treated for scale, corrosion, and bacteriological control.

SCALE AND CORROSION CONTROL

The scaling or corrosive tendency of a water is dependent on whether or not it has the ability to precipitate scale or to dissolve scale. If a water has the ability to precipitate scale, it is said to have a scale forming tendency, whereas if a water has the ability to dissolve scale, it is said to have a corrosive tendency.

In order to enable one to predict whether or not a certain water is scaling or corrosive, mathematical calculations of the Langelier Index and the Ryznar Index are required.

The Langelier Index is defined as the difference between the actual pH and the pH at which a given water would be saturated with calcium carbonate. This latter pH, indicated as pHs, is termed the saturation pH. The actual pH of a water is determined by its temperature, and its alkalinity and free carbon dioxide concentrations. Similarly, the saturation pHs of a water is determined by its temperature, and its calcium, alkalinity and solids concentrations. These points are summarized in the following equations.

$$LI = pH - pHs \quad (1)$$

pH - varies with temperature, alkalinity, & free carbon dioxide

pHs - varies with temperature, alkalinity, calcium, & solids

When the Langelier Index is positive, the water has a tendency to deposit scale, but when it is negative, the water tends to dissolve scale and, by inference, is corrosive. When the Langelier Index is zero, the system is theoretically in balance. However, an index of -0.5 to +0.5 is unreliable for predicting scaling tendency. Therefore, by controlling the parameters which are used to calculate the Langelier Index, one is able to control the scaling/corrosive tendency of a water. For example, a decrease in calcium (ie., softening) will increase its pHs and will therefore decrease its scaling tendency. If this causes the water to in turn become corrosive, then its solids may be increased by increasing the cycles of concentration of the cooling water, thus not only is the scaling tendency eliminated but there is also a savings in water consumption.

The Ryznar Index is an empiricle index which utilizes the same parameters as the Langelier Index but it is based on a study of operating data with water having various Langelier Indexes. It is presented in the following equation.

$$RI = 2 \times pHs - pH \quad (2)$$

SCALE AND CORROSION CONTROL (continued)

For this index, the value of 6.5 is the neutral point. Values of 6 or less indicate scaling and values of 7 or more indicate a corrosive tendency.

The control points for the Langelier and Ryznar Indexes are determined by the type of water treatment program which is used and the quality of the make-up water.

When a corrosion inhibitor such as chromate is used, the water is intentionally controlled at a negative Langelier Index and a Ryznar Index greater than 7, whereas when a scale inhibitor such as hexameta phosphate is used, the water is intentionally controlled at a positive Langelier Index and a Ryznar Index less than 6 in order to take advantage of the corrosion protection offered by a thin film of calcium salts.

Since the disposal of chromates into sanitary sewer systems has been reduced to a level of 5 ppm maximum for most municipalities, this treatment program is no longer recommended for use in buildings managed by ALBERTA Public Works.

A scale inhibitor program utilizes either proprietary or non-proprietary chemicals. However, softening of the make-up water is required when non-proprietary chemicals are utilized. If the cooling system is operational only during a portion of the year, it is more economical to utilize proprietary chemicals, even though they are far more expensive than the non-proprietary chemicals. However, if the cooling system is operational year round, it is more economical to purchase a softener and use non-proprietary chemicals.

Since the control set points vary somewhat for each proprietary chemical, they should be obtained from the supplier of the particular chemical being used. Therefore, only the control set points for the non-proprietary chemical program are developed herein.

The non-proprietary chemical program utilizes sodium hexameta phosphate feeding in conjunction with softening of the make-up water. Sodium hexameta phosphate is added to the basin of the cooling tower such that a poly phosphate residual concentration of 10-20 ppm P₀₄ is maintained in the cooling system. Softening of the make-up is required because the phosphate can not handle the full hardness load.

SCALE AND CORROSION CONTROL (continued)

However, since 20-50 ppm of hardness are required to react with the hexameta phosphate in order to lay down the protective harness film, hardness leakage from the softener must be encouraged. If there is insufficient natural hardness leakage from the softener, it may be increased by increasing the flow rate through the softener or partially by-passing the softener.

As stated earlier, a scaling tendency must be encouraged in order to lay down the thin protective film by adjustment of the Langelier Index to 1.0-1.5 and the Ryznar Index to 5.5-6.5. Since this adjustment is dependent on the quality of the specific water, the appropriate water quality parameters for each major city in the province are indicated in Table 1 below.

Table 1: Domestic Water Quality

<u>City</u>	<u>pH</u>	<u>Calcium ppm CaCO₃</u>	<u>Alkalinity ppm CaCO₃</u>	<u>Dissolved Solids, ppm</u>
Lethbridge	7.8	120	110	170
Claresholm	7.8	135	190	240
Calgary	8.0	135	145	174
Red Deer	7.6	85	152	162
Ponoka	8.3	60	580	720
Edmonton	8.3	92	118	180
Grande Prairie	8.2	125	80	180
Peace River	7.9	105	120	168
Fort McMurray	7.8	90	170	210

Based on the quality of waters indicated in Table 1, the Langelier & Ryznar Indexes, pH, Alkalinity, and TDS set points are indicated in Table 2 overleaf.

SCALE AND CORROSION CONTROL (continued)

Table 2: Control Set Points for Various Treatments *

City	Treatment	LI	RI	pH	Alkalinity	TDS
Lethbridge	Nil	+1.4	5.4	8.3		340
	Softening	+1.2	6.4	8.8		1190
	Acid	+1.1	6.3	8.5	800	1870
Claresholm	Nil	+1.0	6.1	8.2		240
	Softening	+1.2	6.4	8.9		1200
	Acid	+1.0	6.5	8.5	900	1920
Calgary	Nil	+0.8	6.4	8.1		174
	Softening	+1.3	6.3	8.9		1044
	Acid	+1.0	6.5	8.4	750	1914
Red Deer	Nil	+0.7	6.8	8.1		162
	Softening	+1.2	6.5	9.0		1134
	Acid	+1.0	6.6	8.6	1000	1944
Ponoka	Nil	+1.6	5.5	8.7		720
	Softening	+1.3	6.6	9.2		2160
	Acid (hard)	+1.1	5.9	8.0	300	2160
Edmonton	Nil	+1.3	5.6	8.3		360
	Softening	+1.0	6.9	8.9		1260
	Acid	+1.0	6.7	8.6	1000	1980
Grande Prairie	Nil	+1.1	5.9	8.1		360
	Softening	+1.1	6.6	8.7		1440
	Acid	+0.9	6.6	8.4	700	1980
Peace River	Nil	+1.4	5.5	8.3		336
	Softening	+1.4	6.0	8.9		1334
	Acid	+1.3	6.0	8.6	1100	1848
Fort McMurray	Nil	+0.8	6.6	8.2		210
	Softening	+1.3	6.5	9.0		1470
	Acid	+1.0	6.7	8.6	1200	1890

* Note: In addition to the control set points indicated, sodium hexameta phosphate must be added such that a poly phosphate residual concentration of 10 - 20 ppm P₀₄ is maintained

SCALE AND CORROSION CONTROL (continued)

The "Nil" treatment indicated in Table 2 refers to the use of domestic water in the cooling system, whereas the "Softening" treatment refers softening the make-up and "Acid" refers to softening the make-up (except for Ponoka) and metering acid to the basin of the cooling tower.

With regard to the "Nil" treatment, the quality of water in these cities dictates that only one cycle, and in some cases only two cycles, of concentration may be tolerated, otherwise there would be massive precipitation of hardness in the system.

When water is softened, it becomes corrosive. Therefore, in order to counteract this effect, the TDS of the system is allowed to increase to such a point that the water will have a slightly scaling tendency. This also reduces water consumption.

When acid is added to softened water, its alkalinity is reduced and it becomes even more corrosive than only softening. Therefore, the TDS is increased in order to counteract this effect. Thus, the water consumption is reduced even more than straight softening. However, an upper limit of 2000 ppm TDS is recommended in order to minimize galvanic corrosion.

Acid treatment of unsoftened make-up water is not recommended unless the system is very large and the make-up water is low in calcium hardness.

Since the high temperature and alkalinity will in time convert the poly phosphate to ortho phosphate (ie., hexameta phosphate converted to trisodium phosphate), precipitation of the hardness will occur and the suspended solids in the system will increase. Should the suspended solids increase beyond 100 ppm due to this reason or due to the accumulation of crud from the atmosphere, the system should be drained and flushed and consideration should be given to a by-pass filter installation.

It must be emphasized here that the control set points indicated in Table 2 are based on the quality of domestic water indicated in Table 1. Should the quality of domestic water differ from that indicated, these set points must be revised accordingly.

BIOLOGICAL CONTROL

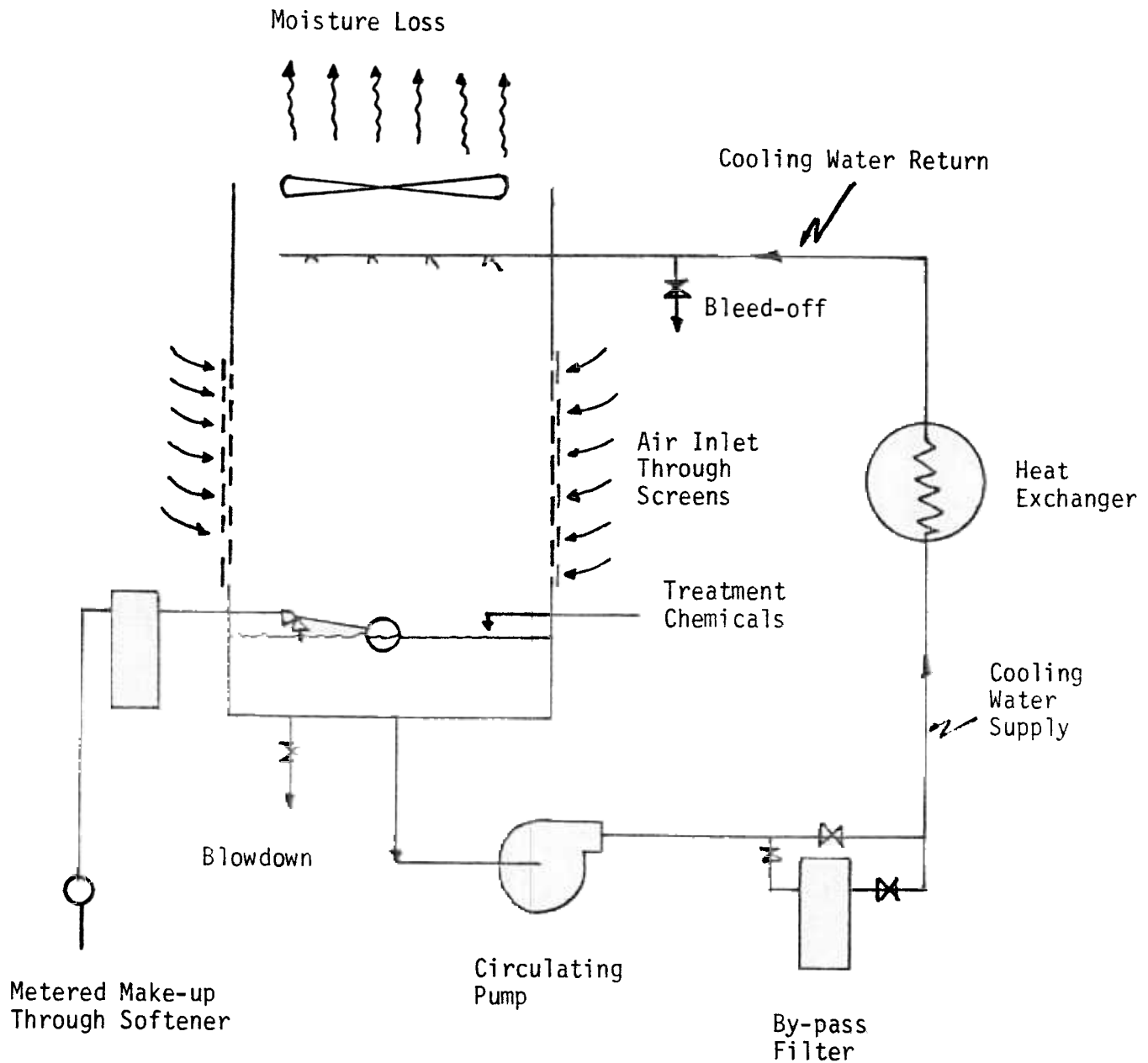
The operating temperatures of most cooling systems within buildings managed by ALBERTA Public Works are not high enough to presents any real problems associated with organic growths. In most cases shock chlorination with sodium hypochlorite solutions is sufficient. However, if problems do arise with this basic treatment, then a proprietary product should be considered since at the operating pH levels of the scale inhibitor program (ie., pH range of 8-9), the biocidal properties of chlorine are weak to negligible. Also, at these high pH levels, especially with a high alkalinity, low hardness water, chlorination for biological control oxidizes the lignin in cooling tower wood to aldehydes and acids.

MONITORING OF SCALE AND CORROSION

Since it is the intent of the scale inhibitor program to produce a thin protective film of scale, corrosion should be negligible (ie., less than 5 mils/year). However, this must be confirmed by monitoring the results of corrosion coupon testing as indicated in Appendix A. Monitoring of scaling is accomplished by visual inspections of high temperature zones (ie., chiller condenser tubes) since these are the first areas to become excessively scaled to the extent that heat transfer efficiency is affected. At this point, acid cleaning of these localized areas is recommended.

APPENDIX A

Figure 1: Schematic Diagram of Typical Open Recirculating Cooling Water System



INSTRUCTIONS FOR CORROSION TEST COUPONS

The results from corrosion test coupons are valuable only when the coupons are used properly. Tests must be made at locations where water temperature and flow velocity past the coupon are similar to conditions in important plant piping and equipment.

Except for situations where you are interested in a specific trouble area,

AVOID

- high velocity locations (ie., immediately downstream of centrifugal pump discharge)
- low velocity locations (ie., storage tanks, cooling tower sumps, condensate receivers)

DO

- keep the metal coupon in a dry place before installation
- select a location where the coupon will be continuously submerged
- install mounting plugs with directional mounting groove parallel to flow
- use steel screws with steel coupons, brass screws with copper coupons
- use insulating gasket between screws and coupon
- leave coupons installed for at least 30 days

DO NOT

- cut or trim coupon to fit it into a pipe line
- jam coupon against inside of pipe
- handle coupon more than is necessary
- use excessive amounts of pipe dope which may coat coupon
- locate coupon where oils may accumulate

It is often desirable to use coupons in several locations at the same time. One reason for this is that test results from several similar test locations permit the calculation of an average corrosion rate. A second reason is to make possible a comparison of corrosion rates in different areas.

Detailed installation information is indicated in Figures 1, 2, 3, 4, & 5 overleaf.

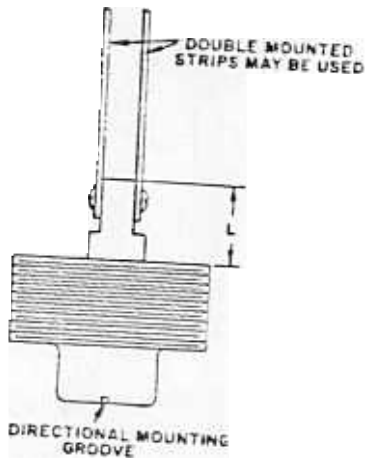


FIGURE 1
CORROSION TEST COUPON AND MOUNTING PLUG

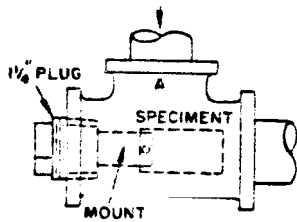


FIGURE 2
TEST UNIT IN TEE

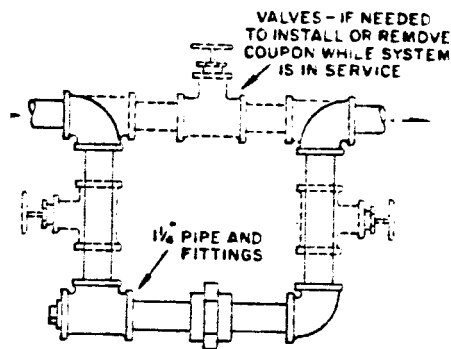


FIGURE 3
PIPING ARRANGEMENT TO COMPLETELY SUBMERGE COUPON

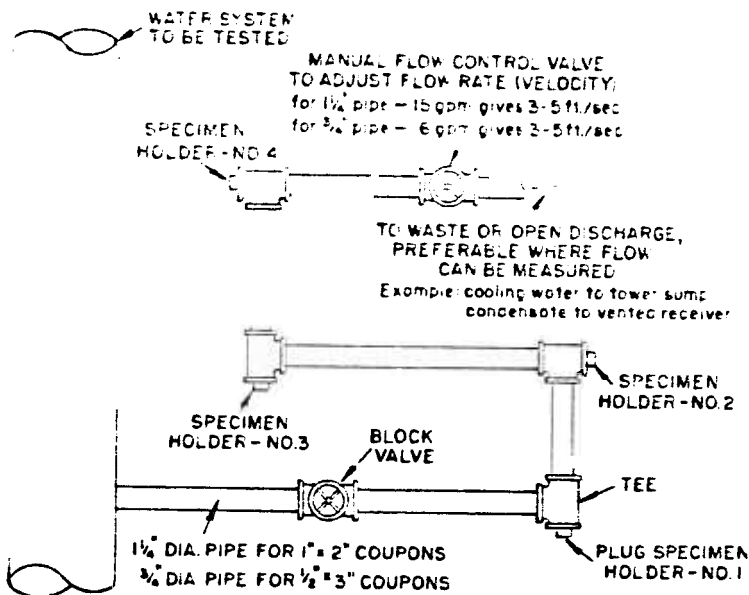


FIGURE 4
COUPON TEST MANIFOLD

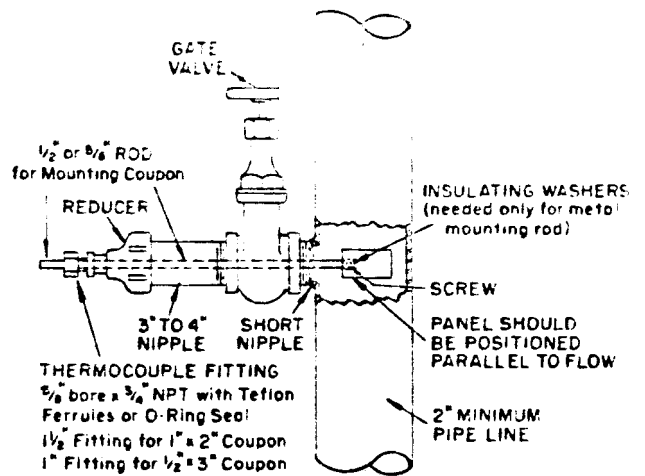


FIGURE 5
IN SERVICE INSTALLATION OF CORROSION TEST SPECIMENS FOR PIPES LARGER THAN 2" DIAMETER