WATER TREATMENT PRACTICES

FOR

CHILLER BY-PASS SYSTEMS

Prepared by

G. Yuzwa, P.Eng.

Montreal Engineering Co. Ltd.

Presented at

Alberta Government Services

Water Treatment Coordinators' Meeting
In Calgary

October 14, 1982

1.0 Introduction

In order to reduce utility bills, some Alberta Government Services buildings by-pass and shut down the chiller units during the early and latter portions of the air-conditioning season. During these periods, heat is dispersed by cooling towers.

The operation and water treatment practices of these systems are the subject of this report.

2.0 Absorption Chiller

2.1 Requirements of Refrigerant – Absorbent Materials

Absorption systems (i.e. absorption chiller or absorption refrigerator) require both a refrigerant and an absorbent material which together must satisfy the majority of the following requirements:

a) **Absence of Solid Phase**: If solid forms, flow would stop and equipment would shut down.

b) **Volatility Ratio**: Refrigerant should be much more volatile than absorbent so that the two can be easily separated.

c) **Affinity**: If absorbent has a strong affinity for refrigerant, the amount of absorbent is reduced. However, too great an affinity is associated with high heat of dilution.

d) **Pressure**: Moderate operating pressure is desirable. High pressures necessitate the use of heavy wall equipment; low pressures necessitate the use of large volume equipment.

e) **Stability**: Chemical stability is required due to the severe operating conditions.

f) **Corrosion**: Fluids themselves or any substance resulting from their instability should not corrode materials used in equipment.

g) **Safety**: Fluids must be non-toxic and non-flammable if they are used in units servicing occupied dwellings.

h) **Viscosity**: Low viscosity is desirable to reduce pumping problems and to enhance heat and mass transfer.

2.0 **Absorption Chiller** (continued)

2.1 Requirements of Refrigerant – Absorbent Materials (continued)

i) **Latent Heat**: It is desirable that latent heat of the refrigerant be high so that circulation rate of the refrigerant and absorbent can be kept at a minimum.

No known refrigerant–absorbent pair meets all of these re-requirements. However, the ammonia–water and water–lithium bromide systems are considered to come the closest.

The disadvantages of the ammonia–water system include a low volatility ratio, high toxicity, and high operating pressures.

The disadvantages of the water–lithium bromide system include the possibility of solid formation, low operating pressures, and high viscosity.

However, the advantages of this latter system (i.e. high safety, high volatility ratio, high affinity, high stability, and high latent heat) outweigh the disadvantages, thus resulting in its extensive commercial use.

2.2 Operation

There are four major sections associated with the absorption machine. These include the evaporator, absorber, generator, and condenser sections.

The cycle starts at the evaporator and absorber sections schematically shown in Figure 1.

2.0 **Absorption Chiller** (continued)

2.2 Operation (continued)

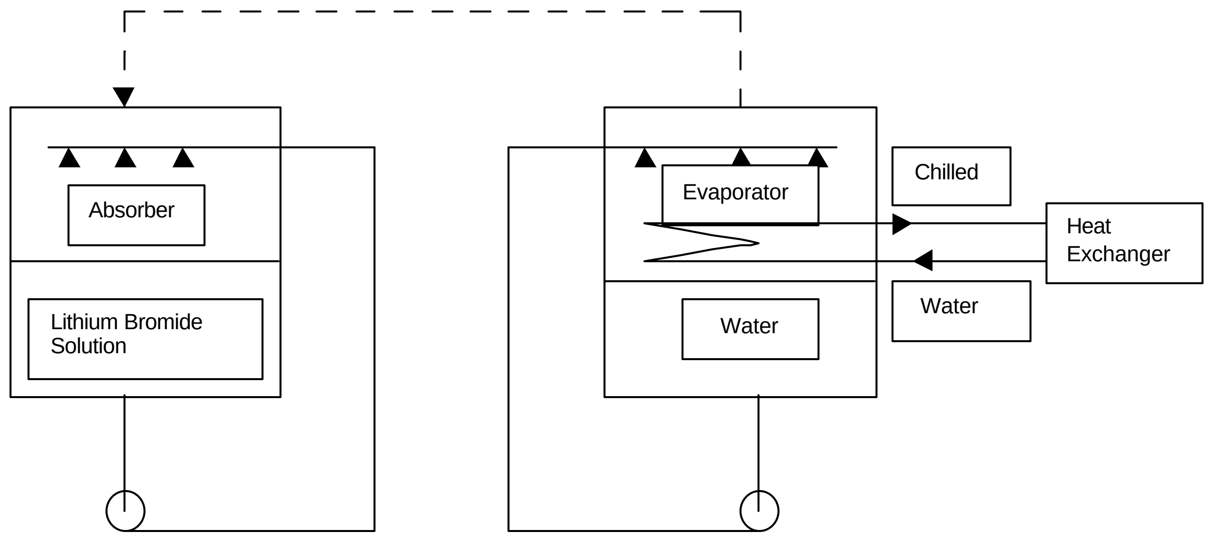

Figure 1 Evaporator – Absorber Sections

As illustrated, the absorber, partially filled with lithium bromide/water solution and the evaporator containing water are connected to each other.

Initially, both sections are evacuated so that only water vapour and lithium bromide solution are present. As the lithium bromide solution absorbs the water vapour, the water in the evaporator boils, thus generating more vapour and causing the rest of the water to be cooled. A pump is used to circulate water in the evaporator section through a spray header to enhance vaporization. The chilled water coil located in the evaporator and carrying return water from air-conditioning coils is cooled by flash cooling of evaporator water on the outside of the tubes. The lithium bromide solution circulating pump enhances the absorption of water vapour in the absorber section.

2.0 **Absorption Chiller** (continued)

2.2 Operation (continued)

As the lithium bromide solution continues to absorb water vapour, it becomes diluted, thus reducing its ability to absorb water vapour.

Therefore, a generator section is added as shown in Figure 2.

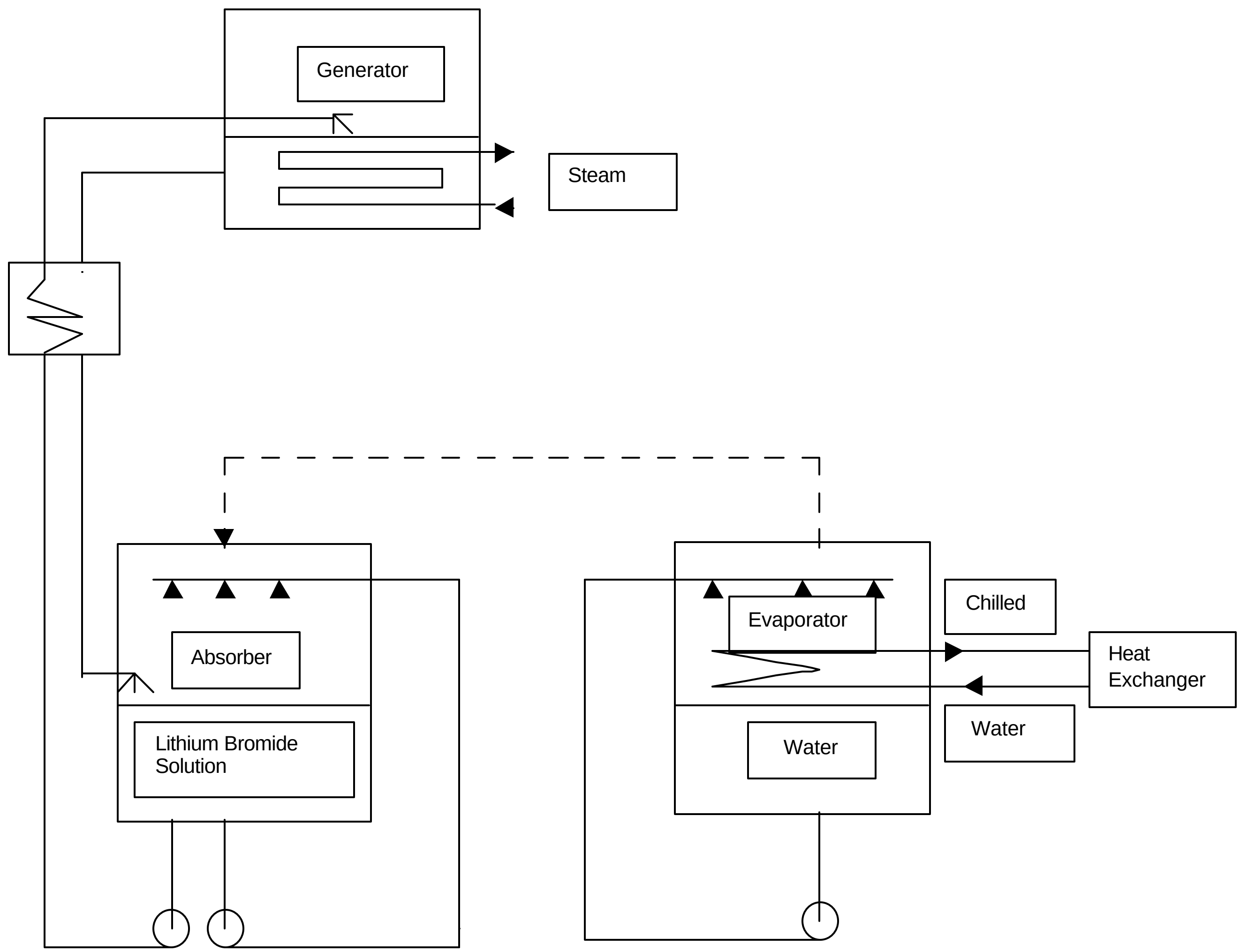

Figure 2: Evaporator – Absorber – Generator Sections

2.2 Operation (continued)

Lithium bromide solution is pumped from the absorber section to the generator section where heat is applied (i.e. steam or hot water) to boil off the water vapour, thus making it more concentrated and better able to absorb more water vapour on its return to the absorber section.

Since the weak solution going to the generator must be heated and the strong solution coming from the generator must be cooled, a heat exchanger is used to save energy.

In order to complete the cycle, a condenser section is added as shown in Figure 3.

2.0 **Absorption Chiller** (continued)

2.2 Operation (continued)

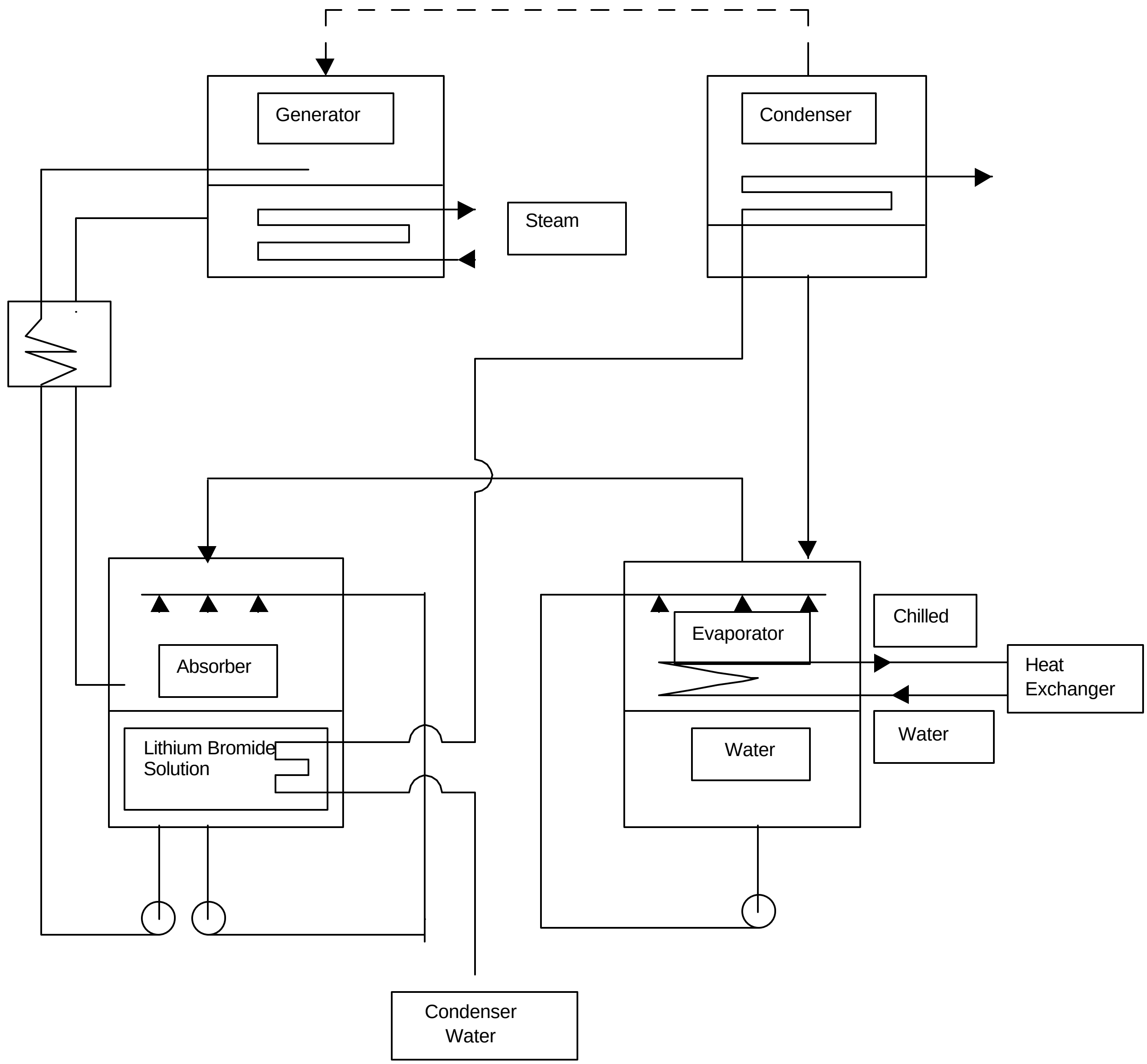

Figure 3: Evaporator – Absorber – Generator – Condenser Sections

2.0 **Absorption Chiller** (continued)

2.2 Operation (continued)

Water vapour boiled from the solution in the generator passes over to the condenser where it is condensed on the condenser tubes and returns to the evaporator, thus completing the cycle without loss of water.

Before going to the condenser section, the condenser water initially passes through the absorber where it picks up heat of dilution, which is developed by the lithium bromide solution, as it absorbs water vapour.

Realistically, the evaporator and absorber sections are combined into one vessel which is designated the absorber section, whereas the generator and condenser sections are combined into another vessel which is designated the generator section – all of which is shown in Figure 4.

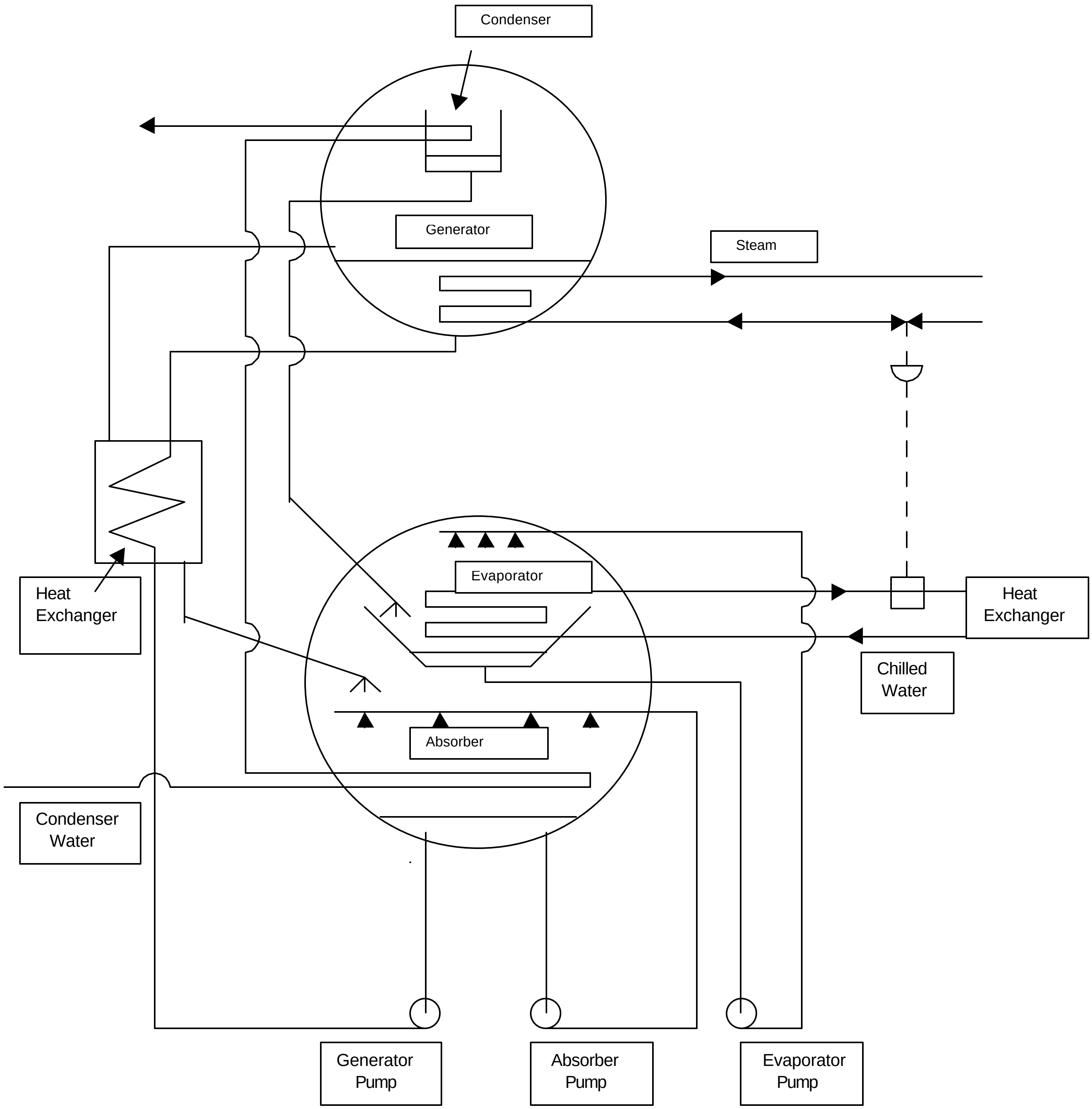

Figure 4: Basic Schematic of Absorption Chiller

2.0 **Absorption Chiller** (continued)

2.3 Water Treatment

The chilled water loop, which operates both internally and externally, to the chiller should be considered as being a closed cooling water system which has a negligible amount of make-up. Chemical treatment to combat problems of corrosion and fouling include filling the system with water having a pH within the range of 7.0 to 8.5, and maintaining a residual of sodium sulfite at 20 – 60 ppm.

The condenser cooling water, if “once-through”, is not normally chemically treated. Chemical treatment methods of recirculating systems is indicated in Section 3.3.

3.0 **Cooling Towers**

3.1 Operation

Cooling tower systems, a typical example of which is schematically shown in Figure 5, reduce the temperature of water by conduction and evaporation.

Conduction is directly proportional to the amount of water – air surface interface and the difference between the water temperature and the ambient air dry bulb temperature. This sensible heat transferred by direct air contact amounts to 1 Btu for each pound of water cooled 1^{o} F.

Heat transfer by evaporation is proportional to the difference between the water temperature and the ambient air wet bulb temperature. Approximately 1,000 Btu’s of heat are removed when one pound of warm water is evaporated. This latent heat is given up by the recirculating water, thus lowering its temperature.

In practice, warm process water is pumped to the upper portion of the tower above the fill where it enters distributors which spread the water evenly over the fill. The water cascades downwards as droplets and is collected in the basin for use in the cooling system. Heated water is returned to the tower for cooling and reuse.

3.1 Operation (continued)

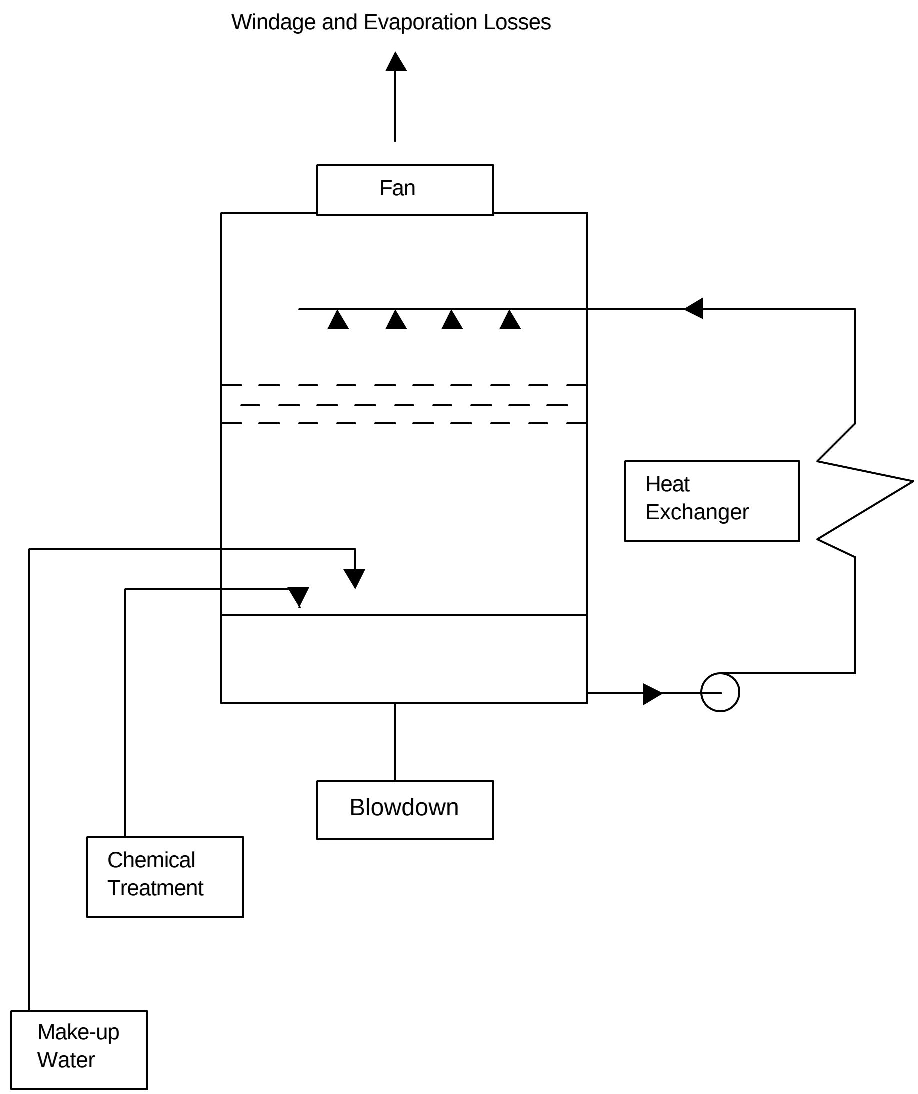

Figure 5: Schematic of Open-Recirculating System

3.0 **Cooling Towers** (continued)

3.2 Types of Towers

The two major categories of cooling towers are the natural draft and mechanical draft.

Natural draft towers can be further sub-divided into atmospheric and hyperbolic towers. Natural draft towers maintain a flow of air upward through the tower because the cool, heavy air at the bottom forces the lighter, water saturated air out the top. Considerable windage is required to obtain full heat transfer with this type of tower. Hyperbolic towers utilize their great height, which provides a chimney effect, to move large volumes of air upward through the tower.

Mechanical draft cooling towers use fans to control the airflow. When fans are located at the air entrance at the base of the tower, it is called a forced draft tower; when fans are located at the top of the tower, it is called an induced draft tower.

3.3 Water Treatment

Water related problems associated with the operation of cooling towers include corrosion, fouling, scaling, and microbiological growths.

The first element of cooling water treatment is the control of cycles of concentration, resulting from evaporative losses, by regulating the bleed or blowdown from the system. Target cycles of concentration are determined by calculating the Ryznar Index, the value of which is a function of the make-up water characteristics. Actual cycles of concentration are calculated usually by comparing the concentration of chlorides in the make-up water to the concentration of chlorides in the recirculating water. Proper control of cycles of concentration reduces both scaling and corrosion.

A second element of cooling water treatment is the maintenance of a protective concentration of corrosion inhibitor. This inhibitor is commonly in the form of chromate, phosphate, zinc, or proprietary compound, the concentrations of which are largely dependent on the characteristics of the make-up water.

3.0 **Cooling Towers** (continued)

3.3 Water Treatment (continued)

Feed of sulfuric acid, used to control the scaling or fouling nature of the circulating water, is a frequent third control element.

Feed of chlorine and/or biocide, used to eliminate micro-biological activity is the fourth control element.

4.0 Chiller By-Pass Operation

4.1 Arrangement

In order to economize on the power consumption of a chiller, these units are sometimes by-passed and shut down during the early part and the latter part of the air-conditioning season.

A typical by-pass arrangement is schematically illustrated in Figure 6.

As indicated, connections on the hot and cold side of the chiller circulating water are made to the hot and cold side of the cooling tower circulating water and isolating valves are added.

During the early and latter parts of the air-conditioning season, the chiller is isolated and shut down, thus allowing the cooling tower to provide cooling for the air-conditioner.

As the system cooling load increases, the cooling tower may not have the capacity to remove the required amount of heat. During these periods, the cooling tower is isolated and the chiller is brought into operation.

4.0 **Chiller By-Pass Operation** (continued)

4.1 Arrangement (continued)

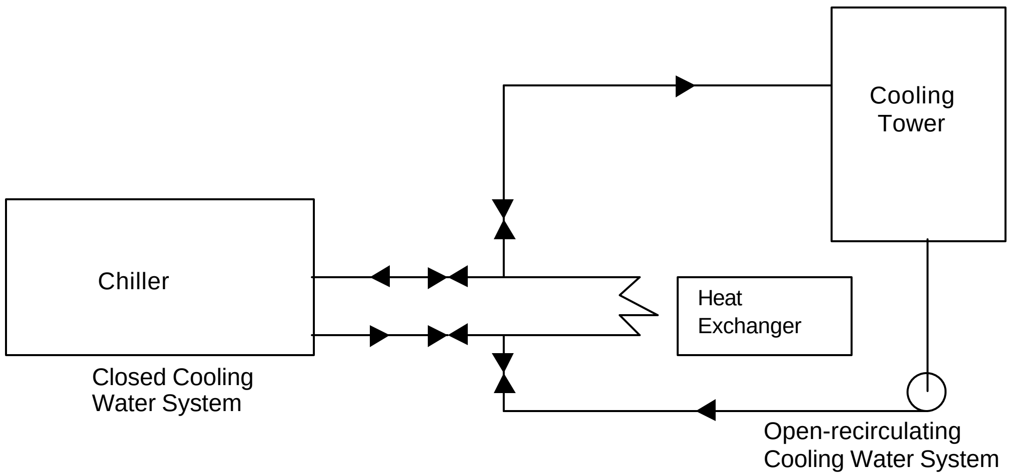

Figure 6: Schematic of Chiller By-pass Arrangement

4.2 Water Treatment

As previously indicated, normal water treatment of chiller circulating water consists of oxygen scavenging with sodium sulfite residual control.

When the chiller is by-passed, the air-conditioning coils and a portion of the chiller circulating water piping is exposed to the oxygenated circulating water from the cooling tower. When the chiller is brought back into operation and the cooling tower isolated, this oxygenated water is distributed throughout the chiller circulating water system. In essence, the closed cooling water system is turned into an open-recirculating system and back to a closed cooling water system again.

4.0 **Chiller By-Pass Operation** (continued)

4.2 Water Treatment (continued)

Since the water related problems associated with the open-recirculating system are more severe than with the closed cooling water system, it is more advisable to chemically treat the entire system as if it were an open-recirculating system all of the time. That is, a treatment program consisting of a corrosion inhibitor (i.e. chromate, phosphate, zinc or proprietary compound) and micro-biological control would offer protection during both phases of operation.

Alternately, the entire system could be treated as a closed cooling water system (i.e. maintenance of sodium sulfite residual) with the addition of a cooling coil at the cooling tower, as illustrated in Figure 7.

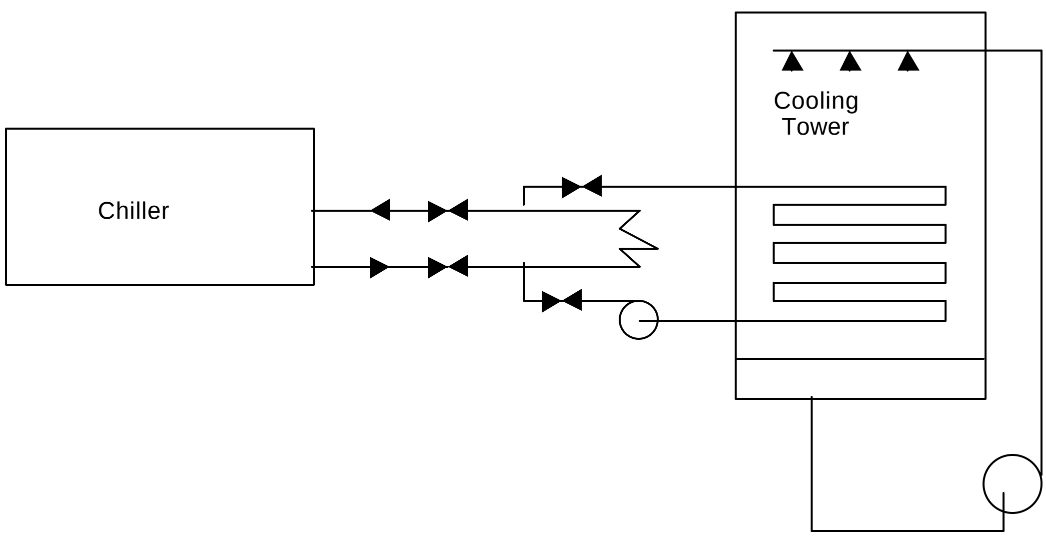

Figure 7: Schematic of Alternate Chiller By-Pass Arrangement