HVAC Energy Conservation through Cooling Water Treatment

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WATER used in air-conditioning systems may create problems with equipment, such as scale, corrosion, and organic growths. Scale formation is one of the greatest problems in air-conditioning systems that have water cooled condensers and cooling towers. Corrosion is always a problem in an open water recirculating system in which water sprays come in contact with air. The organic growth we are greatly concerned with is algae or slime. Since algae thrive on heat and sunlight they will be a problem in cooling towers.

The quality of water is therefore very important in determining the performance of both chiller and cooling tower that utilize water for cooling. Improper water treatment or no treatment at all will increase your energy consumption and operating costs while decreasing your mechanical equipment's efficiencies and life expectancy.

This course discusses the waterside problems encountering the open re-circulation cooling water systems, discusses how energy is dissipated from the air conditioning equipment and how effective implementation and tight monitoring of the water treatment programs can conserve it. The course is divided into 7 Sections:

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SECTION - 1	Energy Drain in Vapor Compression Systems
SECTION - 2	Cooling Water Problems
SECTION - 3	Scale Control
SECTION - 4	Corrosion Control
SECTION - 5	Control of Organic Growths
SECTION - 6	Turbidity Control
SECTION -7	Water Treatment System Controls and Monitoring

SECTION - 1   ENERGY DRAIN IN VAPOUR COMPRESSION SYSTEMS

Before we come to the discussion on waterside problems, let's first refresh some fundamentals and understand little about work and energy input to the refrigeration chillers.

The vapor compression system is the dominant system today for cooling and refrigeration and is being used in almost all kind of application. It consists of four components:

1. The **compressor** raises the pressure of the initially low-pressure refrigerant gas.

2. The **condenser** is a heat exchanger that cools the high-pressure gas so that it changes phase to liquid.

3. The **expansion valve** controls the pressure ratio, and thus flow rate, between the high- and low-pressure regions of the system.

4. The **evaporator** is a heat exchanger that extracts heat from the air causing low pressure liquid refrigerant to evaporate and change phase from liquid to vapor (gas).

A schematic flow diagram of the vapor compressor system and its components is shown below:
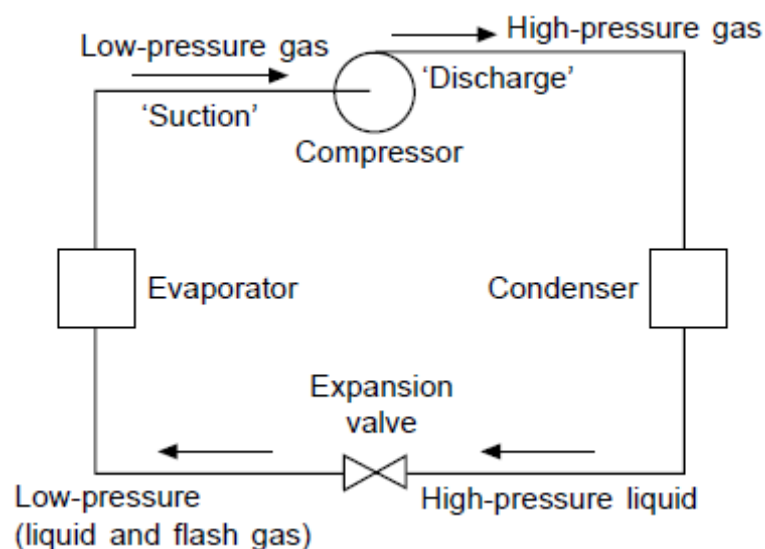
A pressure-enthalpy diagram or p-h diagram is often used to calculate the energy transfer and to analyze the performance of a refrigeration cycle:
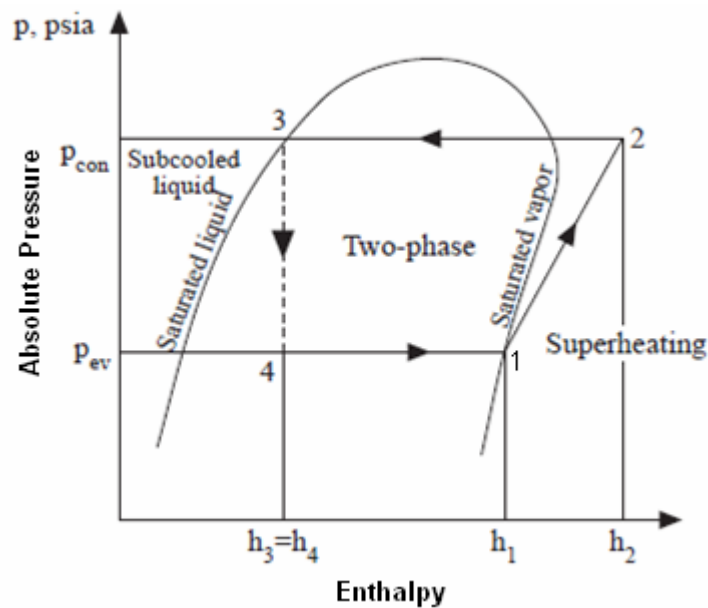
There are four processes in an ideal single-stage vapor compression cycle:

1. **Isothermal evaporation process 4–1:** The refrigerant evaporates completely in the evaporator and produces refrigeration effect q_{rf}, in Btu/lb:

   $q_{rf} = (h_1 - h_4)$

   Where

   h_1, h_4 = enthalpy of refrigerant at state points 1 and 4, respectively, Btu/lb. The enthalpy difference between point 1 and 4 represents the heat absorbed by the refrigerant in the evaporator or is known as *"refrigeration effect"*.

2. **Isentropic compression process 1–2:** Vapor refrigerant is extracted by the compressor and compressed isentropically from point 1 to 2. The work input to the compressor W_{in}, in Btu/lb, is

   $W_{in} = (h_2 - h_1)$

   Where

   h_1, h_2 = enthalpy of refrigerant at state points 1 and 2 respectively, Btu/lb.

   The nodes 2 and 1 on Y-axis represent the condensing pressure (p_{con}) and evaporating pressure (p_{ev}) respectively. The pressure differential between port 2 and 1 is "*the work or energy input for compression*". The greater the

difference between the condensing pressure and evaporating pressure, the higher will be the work input to the compressor.

3. **Isothermal condensation process 2–3:** Hot gaseous refrigerant discharged from the compressor is condensed in the condenser into liquid, and the latent heat of condensation is rejected to the condenser water or ambient air. The heat rejection during condensation, q_{2-3}, in Btu/lb, is

- $q_{2-3} = (h_2 - h_3)$

Where

h_3 = enthalpy of refrigerant at state point 3, Btu/lb.

Total heat rejected by the refrigeration system to the condenser cooling medium $(h_2 - h_3)$ = *Heat absorbed by the refrigerant in the evaporator (refrigeration effect) + heat equivalent of work input during compression.*

4. **Throttling process 3– 4:** Liquid refrigerant flows through a throttling device (e.g., an expansion valve, a capillary tube, or orifices) and its pressure is reduced to the evaporating pressure. A portion of the liquid flashes into vapor and enters the evaporator. This is the only irreversible process in the ideal cycle, usually represented by a dotted line. For a throttling process, assuming that the heat gain from the surroundings is negligible:

$h_3 = h_4$

The mass flow rate of refrigerant m_r in lb/min, is

$m_r = q_{rc} / [60 * q_{rf}]$

Cooling Capacity

Cooling capacity is measured in tons of refrigeration. A ton of refrigeration is defined as the capacity of equipment to remove heat at a rate of 12,000 Btu/hr. Vapor compression systems impose an additional heat load due to the energy required to compress low-pressure, low-temperature refrigerant gas from the evaporator and deliver it to the condenser at a higher pressure. The compressor energy input is approximately 3,000 Btu/hr per ton of refrigeration. Accordingly, normal heat rejection in a compression system approximates 15,000 Btu/hr per ton of refrigeration. Compression refrigeration systems require a cooling water circulation rate of

approximately 3 gpm per ton of refrigeration, with a 10°F temperature drop across the cooling tower.

Coefficient of Performance of Refrigeration Cycle

The coefficient of performance (COP) of refrigeration system is the ratio of the refrigerant effect to the energy supplied to compressor.

$COP_{ref} = q_{rf} / W_{in}$

Or

$COP_{ref} = (h_1 - h_4) / (h_2 - h_1)$

It is a dimensionless index used to indicate the performance of a thermodynamic cycle or thermal system. The magnitude of COP can be greater than 1.

If a heat pump is used to produce a useful heating effect, its performance denoted by COP_{hp} is:

$COP_{hp} = q_{2-3} / W_{in}$

Or

$COP_{hp} = (h_2 - h_3) / (h_2 - h_1)$

Clearly the COP of refrigeration machine is **higher** in heating mode.

Work Input to the Chiller

The compressor provides the driving force for the refrigeration cycle and is the primary consumer of electricity in a chiller. The compressor functions to increase the refrigerant temperature and pressure. Anything that increases the workload on the compressor will increase energy consumption.

Work input to the chiller is defined by equation as under:

$W \alpha \, m, \partial P$

Or

$W = k \, m \, \partial P$

Where

- W = Work input to compressor

- m = Mass flow of refrigerant

- ∂P = Press difference between evaporating (suction) and condensing (discharge) pressures of the refrigerant

- K = constant

The cooling duty and power requirements of a compressor depend primarily on the evaporating and condensing pressures. From this formula, it is evident that if the ∂P is high, the work input will also be more, and therefore to minimize the work input, the ∂P will have to be maintained minimum.

Now we must know that the refrigerant pressure of the evaporator is a function of the refrigerant temperature. The lower the temperature of the refrigerant at the compressor suction, lower will be the head pressure and less is the work input to the compressor. Similarly, the hotter the refrigerant gas leaving the condenser, the more is the electric power required to complete the compression cycle.

POCKETS OF ENERGY DRAIN

As stated, the major energy consumer in a compression refrigeration system is the **compressor**, which is designed to work at a certain condensing pressure for a given load. The term "high head pressure" refers to condenser pressure that is higher than it should be for a specific load condition.

High head pressure can be costly in two ways.

- First, it presents the danger of a system shutdown; a safety control will stop the compressor motor when the safe maximum head pressure is exceeded in the compressor.

- Second, an increase in power consumption results when a compressor operates at greater than design head pressure.

In industrial or commercial air conditioning systems, the heat is usually rejected to water. Most water contains impurities in form of dissolved carbonates, silicates and dirt that might settle in the cooling tower basin, at low-flow spots within the system, on condenser tubes and in the tower fill. Fouling is a general term that includes any kind of deposit of extraneous material that appears upon the heat transfer surface

during the lifetime of the condenser or any heat exchanger. Deposition (fouling) on the condenser tubes reduces transfer, increases the condenser head pressure, and results in higher energy costs.

Reduced heat transfer in the condenser causes the compressor to work harder, increasing the refrigerant condensing temperature and pressure in order to transfer the same amount of heat to the cooling water. Each additional 1°F in refrigerant condensing temperature requires the compressor to consume 1.5% more energy. If the deposit thickness is great enough, condenser head pressure will exceed the chiller limits and the chiller will shutdown.

Some deposits are more insulating than others and thus have a greater impact on the head pressure and energy requirements. For example, calcium carbonate scale deposits transfer heat up to 4 times better than biofilm deposits (slime). As a result, slime increases head pressure and energy requirements and will shut down a chiller much faster than "normal" scale. Condenser deposits can be a mixture of slime, scale, corrosion by-products, and other suspended solids scrubbed from the air.

Table below lists the fouling factors of various thicknesses of a calcium carbonate type of scale deposit most frequently found on condenser water tube surfaces where no water treatment or incorrect treatment is applied.

Fouling Factor of Calcium Carbonate Type of Scale

Approximate thickness of calcium carbonate type of scale, in (mm)	Fouling Factor
0.000	Clean
0.006 (0.1524)	0.0005
0.012 (0.3048)	0.0010
0.024 (0.6096)	0.0020
0.036 (0.9144)	0.0030

Most of the chillers available from various manufacturers are generally are designed for the fouling factor of 0.0005 (0.15 mm thick scale on the heat transfer surface) and rated for the power consumption of about 0.60 to 0.9 kW per ton of refrigeration (TR).

The condensing temperature increases linearly in proportion to the fouling factor. Figure -1 below illustrates the effect of condenser fouling factor on the condensing temperature of a typical water-cooled condenser.
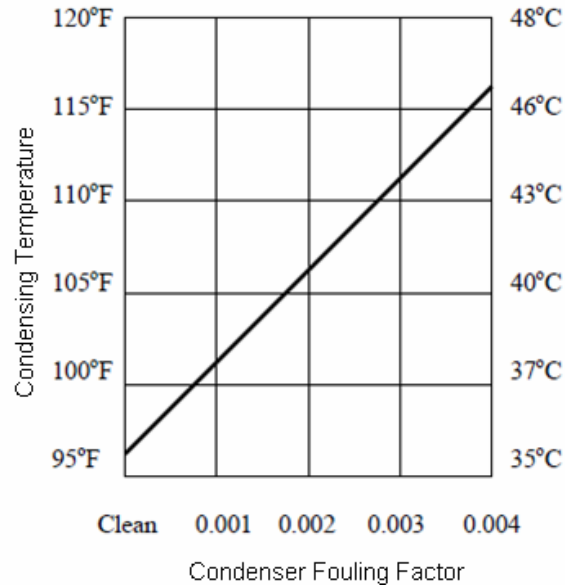
Figure -1: Effect of Scale on Condensing Temperature

An increase in condensing temperature increases the energy or compressor horsepower almost proportionally. Figure -2 shows the affect of scale (fouling factor) on compressor horsepower and energy consumption.
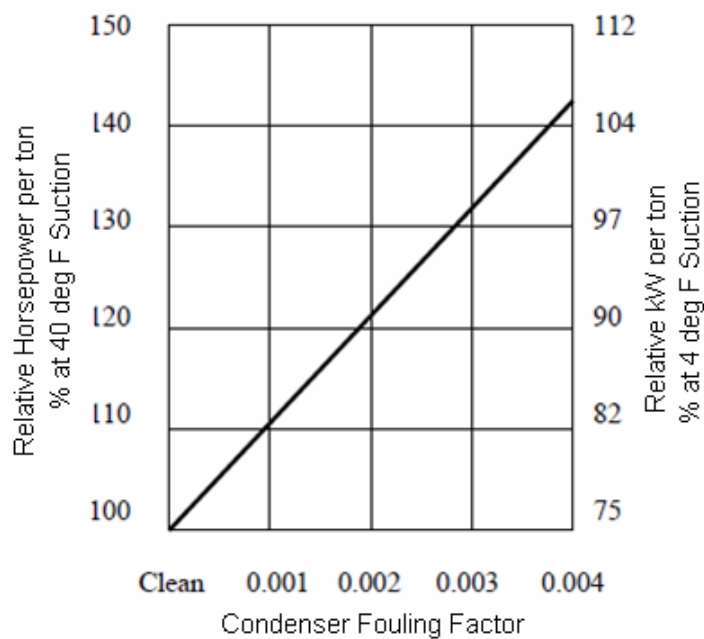
Figure -2: Effect of Scale on Compressor Horsepower

The additional energy consumption required to compensate for a calcium carbonate ($CaCO_3$) type of scale on condenser tube surfaces of a refrigeration machine is illustrated in Figure -3.
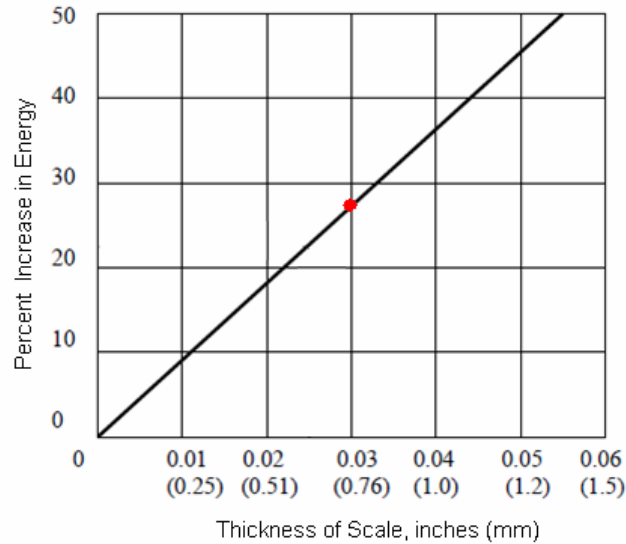

Figure – 3: Effect of Condenser Tube Scale on Energy Consumption, K = 1.0 Btu/ (h/ft^3/°F).

The graph shows that a calcium carbonate scale thickness of 0.03 inch represents an increase of 27% in electrical energy compared to the same size unit free of scale. If this scale/deposit is of an iron oxide instead of calcium carbonate, then the energy loss will be about 50% more, i.e. instead of 27% the loss will be in the order of 40%.

Cost of Scale and Deposits

The actual cost of scale is even more surprising.

Compressor performance is usually presented by manufacturers as either graphs or tables of duty and power for range of evaporating and condensing temperatures. To have the fair understanding about the loss of energy due to waterside problems, let's consider a 500 ton chiller. Based on electricity cost of $0.07 per kWh, a chiller efficiency of 0.65 kW/TR and 12 hours operation a day, the chiller will consume

500 TR x 12 hrs x 365 days x 0.65 kW/TR x $0.07= **$99645** per annum

Let's assume the same air conditioning plant operate with a scale deposit of 0.03 inches (0.0025 fouling factor) of calcium carbonate. This will increase energy requirements by 27% (refer figure – 3). The annual dollar cost will be:

500 TR x 12 hrs x 365 days x 0.65 kW/TR x $0.07 x 1.27 = **$126549** per annum

Or, the energy consumption will increase by 1265549 - 99645 = **$26904** per annum kWh.

The following table shows the potential economic impact of scale deposits on a 500 ton chiller running at full load, 12 hours per day. Actual increased energy use depends on compressor type, actual operating head pressure, operating power factor and percent operating load.

Condenser Deposit Thickness vs. Increased Electricity Cost

Deposit Thickness, inches	Fouling Factor	% Efficiency Loss	Increased Annual Electrical Cost
0	0.0000	0	$0
0.01	0.0008	9	$8968
0.02	0.0017	18	$17936
0.03	0.0025	27	$26904
0.04	0.0033	36	$35872
0.05	0.0042	45	$44840

The table provides insight to the energy loss due to fouling. For the same thickness, the increased cost associated with a biofilm deposit can be significantly greater than with scale, depending on the actual scale composition. It becomes clear that good microbiological control is vital for efficient chiller operation.

There are two things that can be done to minimize the effects of fouling.

First, since some degree of fouling is inevitable, good manufactures rate their condensers with a built–in fouling factor to assure full–rated capacity under normal operating conditions. The standard manufacturer's recommended design fouling-factor for air-conditioning chillers and condensers is 0.0005. This means that the equipment cannot tolerate deposits with a fouling factor greater than 0.0005 without the efficiency of the machine being seriously reduced.

Second, water–side fouling can be controlled with water treatment and periodic cleaning of the system. The energy losses can be controlled by implementing a proper water treatment program.

There are various means and ways to treat the water. The treatment programs are to be designed and implemented on the case-to-case basis. This is mainly because of the great variance in the quality of water from one place to another. We will discuss the cooling water problems and treatment approaches in subsequent sections.

Other Factors Influencing Head Pressure

Besides waterside fouling, there are 3 other conditions which can cause high head pressure:

1. Non-condensable gases (i.e. air) in the refrigerant;

2. Low condenser water flow rate;

3. Condenser inlet water temperature too high.

In diagnosing a high head pressure condition, all of these factors should be investigated as possible causes.

SECTION – 2   **COOLING WATER PROBLEMS**

Water related problems and treatment approaches vary greatly with the quality of water. It is seen that most of the HVAC installations rely on a simple water-softening plant irrespective of the make-up water quality. This is not a right approach. The main reason for this could be attributed to the fact that usually the air-conditioning contracting companies are neither equipped with water treatment engineers nor are their design engineers trained in handling the treatment issues. Therefore first very step to an effective treatment program is to understand the waterside problems and making sure that the air-conditioning design engineers, the O & M personnel are trained to handle these issues.

The major problems encountered in cooling systems are scale, corrosion and deposits of organic slime or algae growths. Before any effective treatment can be decided upon, it is necessary to first understand few important terms associated with water chemistry.

1) **Alkalinity:** Alkalinity is the quantity of dissolved alkaline earth minerals in the form of bicarbonates and carbonates which combine with calcium and magnesium to form calcium carbonate and magnesium carbonate. It contributes to scale formation because its presence encourages deposition of calcium carbonate, or lime scale.

2) **pH Value:** pH, the measurement of acidity or alkalinity, is one of the most important factors affecting scale formation or corrosion in a cooling system. The pH value of the water determines if the hard water will cause scale or corrosion. The pH scale is from 0 to 14. Neutral water has a pH value of 7.0. Any reading under 7.0 is acid, while a reading above 7.0 is base or alkaline. Low pH waters have a tendency to cause corrosion, while high pH waters may cause scale formation.

3) **Hardness:** Hardness is the amount of calcium, magnesium, iron, and trace amounts of other metallic elements in water. Water containing 200 p.p.m. hardness and a pH indication of 9 or above will enhance the formation of scale. To avoid scale in cooling towers, you must control hardness. The maximum p.p.m. standards for cooling towers are 100 p.p.m. for makeup water and 200 p.p.m. for bleedoff water.

4) **Conductivity and Total Dissolved Solids:** Conductivity is the measure of a solution's ability to conduct electricity. Measuring conductivity give you a good indication of the total amount of dissolved solids present. The dissolved solids in water combine to form highly insoluble mineral deposits on the heat transfer surfaces generally referred to as scale.

5) **Suspended Matter:** Suspended matter is finely divided organic and inorganic substances found in water. It is caused by clay silt and microscopic organisms, which are dispersed throughout the water, giving it a cloudy appearance. The measure of suspended matter is **"turbidity"**, which is determined by the intensity of light scattered by the suspended matter in the water.

6) **Chlorides:** Chlorides are the sum total of the dissolved chloride salts of sodium, potassium, calcium, and magnesium present in water. Chlorides do not ordinarily contribute to scale since they are very soluble. Chlorides are however corrosive when present in large volume.

7) **Saturation Index:** The saturation index of a water or Langlier Saturation Index (LSI) is a measure of the stability of the water with respect to scale formation. When LSI readings are positive they tend to be scale forming, and when they are negative they tend to be corrosive. Normally readings within 1.0 units from zero are considered stable.

SCALE

When water is heated or evaporated, insolubles are deposited on metal surfaces. These deposits usually occur on the metal in the cooling towers, evaporative condensers, or inside the pipes and tubes of the condenser water system which have a recirculation water system.

What causes scale? We can explain it in a simple formula:

$Ca(HCO_3)$ + heat = $CaCO_3$ + CO_2 + H_2O
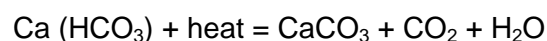
Calcium bicarbonate + heat = calcium carbonate + carbon dioxide + water

In this formula the calcium carbonate is the chief scale forming deposit found in air-conditioning systems, but magnesium carbonate and calcium sulfate can also cause some degree of scaling.

Problems

The scale deposits give rise to the following problems in cooling water systems:

a. Reduced heat transfer decreasing the heat transfer efficiency;

b. Increased pressure drop on water side;

c. Under Deposit Corrosion.

Factors

The prime causes of scale formation could be attributed to:

1. **Alkalinity:** The higher the alkalinity of a particular water, the higher the bicarbonate and/or carbonate content. As these minerals approach saturation, they tend to come out of solution.

2. **Total Hardness (calcium + Magnesium):** A higher concentration of hardness will increase the/tendency of calcium and magnesium salts to come out of solution. You will find that scale will form on heat transfer surfaces when you use water containing even a small amount of hardness.

3. **Total Dissolved Solids (TDS):** The higher the solids content, the greater the tendency to precipitate the least soluble of these solids.

4. **Temperature:** The higher the temperature, the greater the tendency to precipitate the calcium and magnesium salts because of their property of **inverse** solubility. A rising temperature decreases the solubility of calcium carbonate and calcium sulfate. This is known as reverse solubility. Sodium compounds such as table salt (sodium chloride), on the other hand, have a direct solubility. Suppose you take a glass of water 80°F and dissolve table salt into the water, soon you will saturate the water and no amount of stirring would cause any more salt to go into solution. But if you heat the water to 100°F, more salt can be dissolved into the solution. This dissolving action is known as **direct** solubility. But if you re-accomplish these steps using calcium saturates instead of table salt, you would see more solids precipitate out of the solution as the heat is increased. This action is suitably called **reverse** solubility and occurs in a water-cooled condenser cooling tower.

5. **pH:** The higher the pH value, the greater the carbonate content of the water. As you know, pH means potential hydrogen. When a hydrogen atom has lost its electron (H+), it becomes a positive hydrogen ion. When a great many of these hydrogen atoms make this change, the solution will become highly acid

and attack metals. When the hydrogen atom gains electrons, the solution will be base and have a pH value from 7.1 to 14. A base solution contains more hydroxyl ions (OH-). Scale will form when a base solution is exposed to a temperature rise, providing the hardness is 200 parts per million or higher. Notice the recommended pH for cooling towers in figure below:

pH Scale
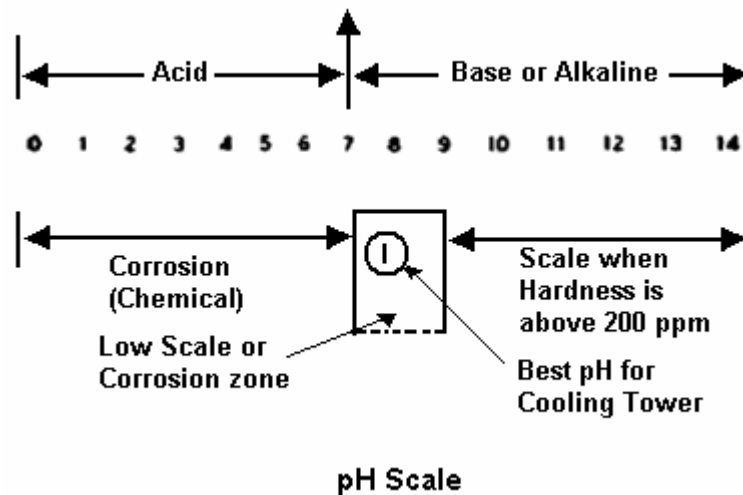
CORROSION

Next to scale, the next most important concern in open recirculation cooling water system is "corrosion". Corrosion is very difficult to prevent, but it can be controlled. Before we can control corrosion, we first must understand what causes it.

What causes corrosion?

Corrosion is a process of converting the metal into its oxide. Corrosion is a three step electrochemical reaction in which free oxygen in the water passes into a metal surface at one point (referred to as the cathode) and reacts with water and electrons, which have been liberated by the oxidation of metal at the anode portion of the reaction at another spot on the metal surface. The combination of free electrons, oxygen and water forms hydroxide ions. The hydroxide ions then combine with the metal ions, which were liberated at the anode as part of the oxidation reaction, to form an insoluble metal hydroxide. The result of this activity is the loss of metal and often the formation of a deposit. This process occurs very rapidly in heat-transfer equipment because of the elevated temperatures, corrosive gases and dissolved minerals in the water, which stimulate the corrosion process.

The effects of corrosion differ as to the type of corrosion, such as uniform, pitting, galvanic, erosion corrosion, and electrochemical. We must understand various ways of treating the system to control these types of corrosion.

Types of Corrosion

An air-conditioning system may have several types of corrosion in the water system. Many of these types are undoubtedly familiar to you.

Uniform corrosion: One of the most common types of corrosion encountered in acid environments is known as uniform corrosion. This is caused by acids, such as carbonic, which cause a uniform loss of metal throughout the condensating water system.

Pitting corrosion: Pitting corrosion is a non-uniform type, the result of a local cell action produced when a particle, flake, or bubble of gas deposited on a metal surface. The pitting is a local accelerated attack, which causes a cavity in the metal but does not affect the surrounding metal. Oxygen deficiency under such a deposit sets up an anodic action. This area keeps producing such action until the penetration finally weakens the structure and it falls, developing a pinhole leak.

Galvanic corrosion: When dissimilar metals which are capable of carrying electric current are present in a solution, galvanic corrosion occurs. This action is similar to the electroplating process used in industry to bond or plate dissimilar metals. When two metals similar to each other are joined together, there is little reaction. But the coupling of two metals from different groups causes accelerated corrosion in one of the two metals. When using large amounts of copper in a system and a few unions of steel, the steel will corrode at a rapid rate. Corrosion inhibitors reduce the corrosion rate but will not eliminate galvanic corrosion.

Erosion-corrosion: Erosion-corrosion is caused by suspended matter or air bubbles in rapidly moving water. The matter can be fine to coarse sand, depending on the velocity of the water. Usually the greatest amount of erosion-corrosion will take place at elbows and U-bends. Another place where erosion-corrosion takes place is on the impellers of centrifugal pumps.

Good filtration installations will remove grains of sand and other matter that are large enough to cause erosion-corrosion. To get rid of air tapped in a system, it is recommended that hand- or spring-operated bleed valves be installed in the highest

point of the water system. Purging the water system gets rid of the air bubbles that enter the system in the makeup water.

Electrochemical corrosion: Electrochemical corrosion occurs when a difference in electrical potential exists between two parts of a metal in contact with an electrolyte (water). The difference in potential will cause electric current to flow. The difference in potential may be set up by two dissimilar metals, by a difference in temperature or amount of oxygen, or by the concentration of the electrolyte at the two points of contact with the metal. The anode is the point at which the current flow is from the metal to the electrolyte; it is here that corrosion occurs. The cathode, which is usually not attached, is the point of current flow from the electrolyte to the metal.

Factors

Many factors affect the corrosion rates in a given cooling water system. Few important ones are:

1. **Dissolved Oxygen** - Oxygen dissolved in water is essential for the cathodic reaction to take place.

2. **Alkalinity** - Low alkalinity or acidic water promotes corrosion. More alkaline water favors the formation of the protective oxide layer film on metal.

3. **pH** – Low pH (acidic scale) promotes corrosion and high pH (alkaline) promotes scale formation.

4. **Total Dissolved Solids** - Water containing a high concentration of total dissolved solids increases potential for galvanic attack. Dissolved chlorides and sulphates are particularly corrosive.

5. **Microbial Growth** - Deposition of matter, either organic or inorganic, can cause differential aeration pitting (particularly of austenitic stainless steel) and erosion/corrosion of some alloys because of increased local turbulence.

6. **Water Velocity** – Both high and low water velocity promote corrosion. High velocity increases corrosion by transporting oxygen to the metal and carrying away the products of corrosion at a faster rate. When water velocity is low, deposition of suspended solids can establish localized corrosion cells, thereby increasing corrosion rates. 10 feet per second is recommended for carbon steel pipe.

7. **Temperature** - Every 25-30°F increase in temperature causes corrosion rates to double. Above 160°F, additional temperature increases have relatively little effect on corrosion rates in cooling water system.

Corrosion is generally more rapid in liquids with a low pH factor than in alkaline solutions. For corrosion prevention the most favorable range is with the pH from 7.5 to 9.5, but scaling becomes a problem at the higher pH range. Consequently, the pH should be held near the lower range where corrosion protection is excellent.

DEPOSIT FORMATION

Fouling is the deposition of suspended particles. The particulate matter generally accumulates at low velocity areas in the cooling water system. If cooling water is on the shell side of the heat exchanger then because of low velocity the fouling material settles on the shell side.

Open recirculating water systems provide the excellent conditions for growth of various micro-organisms. The temperature and pH of circulating water are ideal conditions for the growth of algae and various bacteria's. Also the organic matter, inorganic salts, sunlight etc. provides abundance of nutrients for the growth of these micro-organisms. The organic matter formations will plug nozzles and prevent proper distribution of water, thus causing high condensing pressures and reduced system efficiency.

The potential foulants in cooling water systems are:

a. Dust and silt;

b. Corrosion Products;

c. Sand;

d. Natural organics;

e. Microbial matter.

The following factors affect the fouling of the system:

a. Water characteristics;

b. Temperature;

c. Water velocity;

d. Microbial growth

Makeup water containing unusual turbidity or suspended matter is usually treated at the source by coagulation, clarification, and filtration so as to maintain its potability. Suspended matter and turbidity, therefore, are not common in makeup water in HVAC systems commercial or residential buildings since the makeup water usually comes from a municipal or local source, over which there is a water authority responsible for delivery of clear, potable water.

SECTION - 3   **SCALE CONTROL**

There are many methods of treating water to prevent scale. A few of these are:

1. **Adjusting pH to lower values:** Maintain the pH of the water between 7 and 9, as near 8 as possible.

2. **Bleed- off:** Regulate the amount of bleed-off water to keep the cycles of concentration within tolerance.

3. **Chemical dosage:** scale inhibitors like polyphosphates keeps scale forming compounds in solution.

4. **Physical water treatment methods** – Zeolite water softening exchanges a non-scale forming element for calcium and magnesium compounds. Other methods are dealkalizer, filtration, magnetic and de-scaling devices.

pH Adjustment

Scale forming potential is minimized in acidic environment i.e. lower pH. Acids are added to lower the pH. The types used are sulphuric, phosphoric, and sodium sulfate. They are added through solution feeders. Add only enough acid to reduce the pH (alkalinity) to the proper zone. The zone is usually 7-9 pH, preferably a pH of 8. [Caustic soda, soda ash, and sodium hydroxide can be added to water to increase the pH, when required].

The Langlier Saturation Index (LSI) and the Ryznar Saturation Index (RSI) are indexes utilized to monitor the tendency of water to form a calcium scale or promote corrosion. A positive LSI number (RSI less than 5.0) indicates a scale forming water while a negative LSI number (RSI greater than 7.0) indicates a dissolving scale, or corrosive, water. Normal practice is to maintain a slightly positive LSI number [+.2 to +.5; RSI between 5.0 and 6.0)] and add some chemical scale inhibitor to cope with the resultant slight tendency to scale.

Caution - Addition of excessive acid to the cooling water results in depressed pH values and extremely rapid corrosion of all system metals. Therefore, proper pH control is required to provide a suitable environment for both scale and corrosion inhibitors work effectively.

Controlling Cycles of Concentration

In cooling towers and evaporative condensers the water becomes harder due to evaporation. The term used to compare hardness to the circulating water to the makeup water is **cycles of concentration**. For example, 2 cycles of concentration indicate that the circulating water is twice as hard as the makeup water. If the makeup water contained 100 p.p.m., the circulating water would contain 200 p.p.m. To avoid this damaging concentration, you will find it is necessary to limit the cycles of concentration. Bleed-off is an effective method used for this purpose.

Here are the governing relationships for the makeup flow rate, the evaporation and windage losses, the bleed-off rate, and the concentration cycles in an evaporative cooling tower system:

Evaporation Loss: Evaporation loss from a cooling tower is defined as:

E = .001 (Cr) (DT)

Where

- Cr = circulation rate in gallons per minute and

- DT = temperature differential between hot and cold water in °F.

The evaporation rate amounts to approximately 1% of the recirculation rate for every 10°F temperature drop across the cooling tower.

Windage or Drift Loss: This is a relatively small amount of entrained water lost as fine droplets in the air discharge from a tower. Unlike evaporation which does not contain dissolved impurities, windage carries these impurities with it and reduces dissolved solids in the circulating water. Typical values are 0.1% to 0.3% of the circulating rate for mechanical draft towers.

Blowdown (or Bleed off): Blowdown is the process of removing a portion of concentrated recirculating water, which is obviously replaced with fresh make up water. By specifying a certain amount of bleed off we limit the cycles of concentration the system can operate at, thus controlling scale formation.

The amount of bleed off can be determined from the following equations:

% B (blowdown) + % (windage) = % E (evaporation loss) / (cycles -1)

Blowdown is critical to a successful treatment program. The preferred method of bleed off control is with the use of automated bleed off control. This includes a

contacting head water meter, dual timer, chemical pump and solenoid controlled bleed off line.

Cycles: "Cycles of concentration" (COC) is a very useful term for describing the number of times that dissolved minerals in water are allowed to concentrate. It may be determined by dividing the amount of chloride in the cooling water by the amount of chloride in the make-up.

The concentration ratio (COC) is defined as:

COC = [E / (B + D)] + 1…………. (1)

Where:

E = Evaporation rate

B = Blowdown

D = Drift

Ignoring insignificant drift loss (D), the equation can be simply put as:

COC = M / B…………….. (2)

Where:

M = Make up water equal to E + B.

COC is controlled by blowdown; the equation (2) tells us that as long as the amount of blowdown is proportional to the amount of water entering the system, the concentration ratio will remain constant irrespective of variations in the inflow water chemistry.

Example

A cooling tower operate at 450 gallons per minute recirculating rate (C) , 5 cycles of concentration (COC), 10° DT (temperature drop), and 0.1% windage loss. Calculate %age blowdown, evaporation loss and make up water requirements.

Solution

Evaporation 1% (450 gallons/minute) = 4.5 gallons/minute

Windage 0.1% (450 gallons/minute) =.45 gallons/minute

<u>%Blowdown</u>

% B (blowdown) + % (windage) = % E (evaporation loss) / (cycles -1)

%B + .1% = 1% / (5-1)

Which is %B = .25% - .1% therefore %B = .15% of the circulating rate.

%B = 0.15% (450 gallons/minute) which is 0.675 gallons of blowdown/minute.

<u>Make up Water</u>

Total make up water requirements for the system are:

Blowdown rate 0.675 gallons per minute

Evaporation 1% (450 gallons/minute) = 4.5 gallons/minute

Windage 0.1% (450 gallons/minute) =.45 gallons/minute

Total make up water = 5.625 gallons/minute

Total make up water per hour is = 60 minutes/hr (5.625 gallons per minute) = 337.5 gallons per hour.

COC vs. Blowdown

Cycles are regulated by adjusting the blowdown rate. COC is nearly the inverse of blowdown i.e. to reduce cycles of concentration; the blowdown rate is increased.

Figure below shows the relationship between cycles of concentration and make-up requirements. As you can see at about 4.5 cycles the curve starts leveling off which indicates higher cycles will not affect the quantity of makeup water drastically.
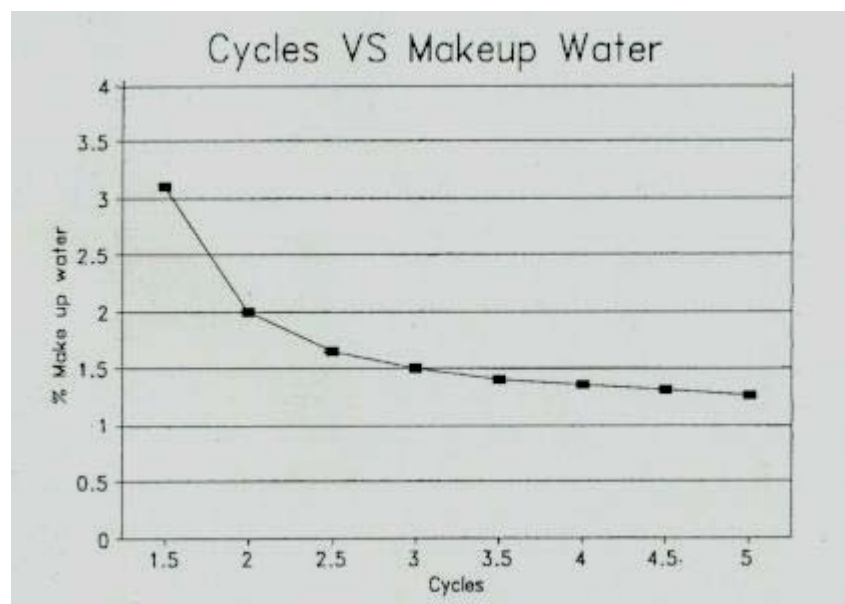
There are two key points to note when studying these curves:

1. As cycles of concentration increase, the resultant savings in makeup water become less and less pronounced. Therefore, in each case very little additional water is saved by operating above six cycles.
2. At lower evaporation rates (DT), the maximum makeup water savings occurs at lower cycles.

Chemical savings are directly proportional to water savings. Table below illustrated this point for a 10,000 gpm open recirculating system with a 10°DT.

Cycles	Makeup (gpm)	Chemical needed at 100 ppm (lbs)
1.5	300	240
2.0	200	120
4.0	133	40
5.0	125	30
10.0	111	13.3

Summarizing,

Operating system at maximum cycles of concentration gives following benefits:

1. Minimal water loss through blowdown;
2. Maximum recycling of water;
3. Minimum water consumption;
4. Minimal chemical requirement due to less water losses from the system;
5. Minimum water discharge to drain or effluent.

Chemical Dosing

The following list includes generic or family of chemicals which may be used to condition cooling water stream. The specific name of the treatment product containing the listed chemical depends on the manufacturer. Consult your chemical

supplier to formulate your dosage requirements and to establish procedures for safe chemical storage and handling.

1. **Polymers (Polyacrylate, etc)** - Disperse sludge and distort crystal structure of calcium deposits. Prevent fouling due to corrosion products. Commonly used, cost effective for calcium scale at 5 to 15 mg/l.

2. **Polymethacrylate** - Less common for calcium scale at 5 to 15 mg/l.

3. **Polymaleic** - Very effective for calcium scales at 10 to 25 mg/l, higher cost.

4. **Phosphonates** - Phosphonates are excellent calcium scale inhibitors at levels from 2 to 20 mg/l.

5. **Sodium Phosphates (NaH_2PO_4, Na_2HPO_4, Na_3PO_4, $NaPO_3$)** - Precipitates calcium as hydroxyapatite ($Ca_{10}(OH)_2(PO_4)_6$). Stream pH must be kept high for this reaction to occur.

6. **Sodium Aluminates ($NaAl_2O_4$)** - Precipitates calcium and magnesium.

7. **Chelants (EDTA, NTA)** - Control scaling by forming heat-stable soluble complexes with calcium and magnesium.

8. **Coploymers** - These products commonly incorporate two active groups, such as a sulfonate and acrylate, to provide superior performance to a single group compound at use levels at 5 to 20 mg/l, higher cost.

9. **Terpolymers** - Like the co-polymers, only incorporate three active groups to give yet better performance under severe conditions at use levels of 5 to 20 mg/l, costly.

10. **Polyphosphates** - Fairly good calcium scale control under mild conditions. Caution - Polyphosphates are of some value for scale control but must be applied cautiously, because hydrolysis of the polyphosphate results in the formation of orthophosphate ions. If this process is not properly controlled, calcium phosphate deposits may result.

11. **Tannins, starches, glucose, and lignin derivatives** - Prevent feed line deposits by coating scale crystals to produce sludge that will not readily adhere to heat exchanger surfaces.

As a general rule, common chemical scale inhibitors such as polyacrylate and phosphonate can be utilized if the Saturation Index (LSI) value of the cycled cooling

water does not exceed 2.0. Cycled cooling water SI values up to 3.5 can be obtained by use of co- and terpolymers combined with surfactants. Multiple water treatment firms have reported operation of cooling systems with newer treatment chemistries scale free at cycled LSI values from 2.5 to 3.5 without pH adjustment.

Note that the scale and corrosion can result even when chemicals are applied at the desired treatment levels if there is improper blowdown. When blowdown is excessive, scale forming minerals and treatment chemicals are also removed making the water more corrosive.and also increasing chemical costs. If blowdown is inadequate, scale forming minerals build up in the system to the point that treatment chemicals cannot overcome the tendency to form scale deposits.

It is highly recommended to use automatic conductivity blowdown controller to control TDS wherever practical. It is better to control blowdown continuously or in small frequent increments rather than infrequent long increments. This avoids wide swings in the TDS level as well as chemical levels. Manual blowdown requires too much effort to be effective and is not recommended.

Physical Water Treatment Methods

Hard water can be softened by two different methods. The first is the lime-soda process which changes calcium and magnesium compounds from soluble to insoluble forms and then removes these insolubles by sedimentation and filtration. The second and most common is Zeolite or base-exchange process. This process replaces soluble calcium and magnesium compounds with soluble sodium compounds.

Zeolite Water softeners

Ion exchange is a chemical operation by which certain minerals that are ionized or dissociated in solution are exchanged (and thus removed) for other ions that are contained in a solid exchange medium, such as a zeolite sandbed. An example is the exchange of calcium and magnesium, in solution as hardness in water, for sodium contained in a sodium zeolite bed. The zeolites used in the process of ion exchange are insoluble, granular materials. A zeolite may be classified as follows: glauconite (or green sand), precipitated synthetic, organic (carbonaceus), synthetic resin, and clay. Various zeolites are used, depending on the type of water treatment required. Most zeolites possess the property cation, or base exchange, but anion exchangers are also available and may be used when demineralization of water is required. In

the course of treating water, the capacity of the zeolite bed to exchange ions is depleted. This depletion requires the bed to be regenerated by the use of some chemical that contains the specific ion needed for the exchange. For instance, when a sodium zeolite is used to soften water by exchanging the sodium ion for the calcium and magnesium ions of hard water, the zeolite gradually becomes depleted of the sodium ion. Thus, it will not take up the calcium and magnesium ions from the water passing through the bed. The sodium ion is restored to the zeolite by uniformly distributing a salt or brine solution on top of the bed and permitting it to pass evenly down through the bed. The salt removes the calcium and magnesium taken up by the bed as soluble chlorides and restores the zeolite to its original condition. Beds may also be regenerated with acid, sodium carbonate, sodium hydroxide, or potassium permanganate, depending on the type of zeolite being used.

The zeolite process is usually used for water which has low turbidity and does not require filtration. Usually, it is NOT economically advantageous to install water softeners unless the makeup water is more than 300 or 400 mg/L hardness.

Dealkalizer

Dealkalizer units operate the same as water softeners, but use different resin bed materials and require strong caustic or acid regeneration. The makeup water is passed through a treated resin bed where the contaminants in the water are collected through a chemical exchange process. When the bed becomes saturated with contaminants, the bed is backwashed, treated with a concentrated electrolyte, rinsed, and placed back in service. For critical or continuous operations, treatment units may be dual-column units that allow switching from a saturated column to a regenerated standby column so that service is not interrupted for routine column regeneration.

The ion exchange process is to remove calcium and magnesium ions by replacing them with an equivalent amount of sodium ions. Unlike simple water softener, these are mixed bed ion-exchange unit consisting of cation and anion exchanger. The cation exchanger section removes metals, such as calcium and magnesium (hardness), and the anion exchanger section controls alkalinity and may remove bicarbonates (corrosion and embrittlement), sulfates (hard scale), chlorides (foaming), and soluble silica (hard scale).

Magnetic devices

This method involves the exposure of incoming make up water under the intense magnetic field. Magnetic field affects the suspended particles or the ions in solution and prevents the deposition of a hardened deposit. The particles will then form a mobile suspension or do not precipitate at all. Also, existing deposits of scale can be converted into solution. Vendors of magnetic water treatment devices claim that powerful magnetic fields can affect the structure of water molecules, thus eliminating the need for chemical softening agents. Only the effective hardness is claimed to be altered; no solutes (such as calcium or magnesium) are removed from the water by the process.

Tests by independent sources have not yet corroborated the claims of vendors and the readers are advised to research this further as a viable water treatment method.

Electronic De-Scaling technology

Electronic de-scaling technology makes use of induced oscillating electric fields using time-varying magnetic fields generated in the solenoid wrapped around a water pipe. Dissolved ions are then charged and collided with each other. Collisions between positive and negative ions facilitate precipitation of the ions in the pipe-work.

Electronic de-scaling technology can be used to enhance chemical-based water treatment program but caution: selection of chemicals used in corrosion inhibition and micro-biological control shall be compatible with the technology.

SECTION - 4   **CORROSION CONTROL**

In open cooling water systems, oxygen cannot be economically removed because these systems are constantly aerated. Therefore, corrosion inhibitors must be utilized. Inhibitors are substances that do not necessarily alter the environment, but do act as a barrier between the corrosive medium and the metal surface. These materials, when added to the recirculating water, form a protective barrier on the metal surface either by chemical reaction with the metal surface or by physical or chemical adsorption on the metal surface. An actively corroding metal can be rendered passive though the use of inhibitors that react in this manner.

The principle methods to prevent or minimizing corrosion include:

1. Selecting suitable materials of construction to resist corrosion

2. Adding protective film- forming chemical inhibitors that the water can distribute to all wetted parts of the system.

3. Controlling scaling and micro-biological growth

4. Protect cathodically, using sacrificial metals

5. Apply protective coatings such as paints, metal plating, tar or plastics on external surfaces

Treatment Methods

Most corrosion control strategies involve coating the metal with thin films to prevent free oxygen and water from coming into close contact with the metal surface. This breaks the reaction cell, and reduces the corrosion rates. Several major chemical treatment methods can be used to minimize corrosion problems and to assure efficient and reliable operation of cooling water systems.

Types of Corrosion Inhibitors

In general, there are four types of inhibitors: 1) anodic, 2) cathodic, 3) mixed and 4) adsorption, commonly adopted in cooling water treatment. In addition passivation technique is used for galvanized components. Working principles of common corrosion inhibitors is described below.

Anodic inhibitor

Applying anodic inhibitor enables a protective oxide / inhibitor film to cover the anodic corrosion points inside the cooling water circulation system. This method is effective

only if all points are filmed and isolated from corrosion initiator. Otherwise, severe localized corrosion may occur at the points without effective protection by protective film. Therefore, sufficient safety margin shall be applied and these shall generally be applied at high dosage levels (hundreds of mg/l). Common anodic inhibitors are chromates, nitrites, orthophosphates and silicates.

Cathodic inhibitor

Cathodic inhibitor is effective by the formation of protective inhibitor film at cathodic corrosion sites so as to prevent oxygen reduction. It is more effective than anodic inhibitor and lower dosage level is required. Therefore, it is commonly used in cooling water treatment. Common cathodic inhibitors are bicarbonates, metal cations and polyphosphates.

Mixed inhibitor

Mixed inhibitor composes of two or three types of inhibitor and majority of the proprietary corrosion inhibitor formula falls into this category. Since chemicals with different characteristics supplement their deficiency with each other, efficacy of the mixed inhibitor increases. Hence, dosage concentration can be significantly reduced, thus, lowering the operating cost and environmental impacts caused by chemicals.

Adsorption

Protective absorbed film is formed over the entire metal surface if adsorption inhibitor is used. The film helps to protect electrochemical reactions between metal and aqueous ions. Some of the organic compounds are suitable to act as adsorption inhibitors.

Passivation

In order to prevent corrosion on galvanized steel cooling towers and associated pipes, formation of a non-porous surface layer of zinc carbonate is one of the effective methods. The formation of zinc carbonate layer is called passivation, which is accomplished by controlling pH during initial operation of the cooling tower. Control of the cooling water pH in the range of 7 to 8 for 45 to 60 days usually allows passivation of surfaces. In addition to pH control, operation and moderate hardness and alkalinity levels of 100 to 300ppm as $CaCO_3$ will promote passivation.

Corrosion Control Chemicals

The following list notes some common inhibitors with pertinent comments.

1. **Chromate -** Excellent steel corrosion inhibitor, the standard against which all others are compared, banned by the USEPA for environmental reasons.

2. **Zinc -** Good supplemental inhibitor at 0.5 to 2 mg/l level, some environmental restrictions, can cause scale if improperly applied. Zinc enhances the effect of some filming agents, but its use is sometimes limited by discharge regulations that don't allow the zinc to be discharged into the wastewater.

3. **Molybdate -** Non-toxic chromate replacement, often used as tracer, controls pitting corrosion control at 4 to 8 mg/l, primary inhibitor for steel at 8 to 12 mg/l, higher levels, 35 to 250 mg/l in closed loop and severe environments, very costly material**.**

4. **Polysilicate -** Excellent steel and aluminium inhibitor at 6 to 12 mg/l, not commonly used due to formulation difficulty.

5. **Azoles -** Three specific azoles compounds, MBT, BZT, and TTZ, which are excellent yellow metal inhibitor compounds at the 2 to 8 mg/l level.

6. **Polydiol -** A proprietary organic steel corrosion inhibitor at 2 to 4 mg/l, also a dispersant.

7. **Nitrate -** Specific corrosion inhibitor for aluminum in closed loop treatments at 10 to 20 mg/l.

8. **Ortho-phosphate -** Good steel inhibitor at 4 to 12 mg/l, needs a minimum of 50 mg/l calcium present with a pH above 7.5 to be effective.

9. **Polyphosphate -** Good steel and yellow metal inhibitor at 4 to 12 mg/l, needs a minimum of 50 mg/l calcium present with a pH above 7.5 to be effective.

10. **Phosphonates -** Includes AMP, HEDP, and PBCT, which are commonly used as scale control compounds. Fair steel corrosion inhibitors when operated with pH values above 7.5 and more than 50 mg/l calcium present.

11. **Nitrite -** Excellent steel corrosion inhibitor at 500 to 700 mg/l, commonly used only in closed loops due to high level needed, attack by micro-organisms, and reaction with oxygen.

Phosphates, particularly the polyphosphates, are most commonly used in cooling water treatment. One advantage of using polyphosphates is that there is no yellow residue such as produced by chromates. This highly undesirable residue is often

deposited on buildings, automobiles, and surrounding vegetation by the wind through cooling towers or evaporative condensers, when the system is treated by chromates. Also, polyphosphate treatment reduces corrosion products (sludge and rust) known as tuberculation.

A factor limiting the use of polyphosphates in cooling water systems is the reversion of polyphosphates to orthophosphates. Orthophosphates provide less protection than polyphosphates, and orthophosphates react with the calcium content of the water and precipitate calcium phosphate. This precipitation forms deposits on heat exchanger surfaces. The reversion of polyphosphates is increased by long-time retention and high water temperatures. Bleed-off must be adjusted on the condenser water system to avoid exceeding the solubility of calcium phosphate. The ability to prevent metal loss with polyphosphate treatment is inferior to the chromate treatment. In addition, pitting is more extensive with polyphosphates.

For facilities where the cooling water system is constructed of several materials, a blended inhibitor is required to obtain satisfactory corrosion protection. For example, adding 2 mg/l of zinc to a phosphonate product at 10 mg/l reduced the corrosion rate on mild steel from 2.2 mils/yr to 0.9 mils/yr. It is common to see programs using mixtures such as molybdate-silicate-azole-polydiol, phosphonate-phosphate-azole, and molybdate-phosphonate-polydiol-azole.

Seawater application

For seawater application, nitrites and phosphates at appropriate concentrations can provide adequate protection. Organic inhibitors can also be used to provide protection where nitrites cannot be used.

Cathodic Protection

Cathodic protection (CP) is a method used to protect metal structures, pipes and equipments from corrosion. The cathodic protection can be obtained by connecting a noble metal to a less noble. In practice steel is protected by supply of electrons from less noble metal like Zinc, Aluminum and Magnesium alloys, often called sacrificial anode materials. The anode is sacrificed and eventually is used up, but the steel is protected.

Monitoring of Corrosion rate

Monitoring of corrosion rate is important to get feedback on the effectiveness of treatment. An acceptable cooling water treatment program should be able to reduce corrosion rates to the following average levels reported as mils/yr:

Rating	Rate (Mils/yr)
Poor	>5
Fair	3.5 – 5.0
Good	2.0 – 3.5
Excellent	0.0 – 2.0

The corrosion rate of mild steel for a 30-day exposure time in an open recirculating cooling water system is generally rated to be acceptable below 2.0-3.5 mils per year (mpy) and excellent if below 2.0 mpy. The corrosion rates for copper would be, perhaps, 10% of those for mild steel.

Corrosion monitoring is done by various methods but most common method is by "Test Coupons" Test coupons are generally installed in the following location

- At the outlet of hottest condenser/cooler;

- In cooling water return;

- In makeup water line.

SECTION - 5   CONTROL OF ORGANIC GROWTHS

The core of any microbiological treatment program is to feed an oxidizing biocide to kill organisms before they can settle on condenser tubes, cooling tower fill and other locations. Three general classes of chemicals are used in microbial control 1) Oxidizing biocides, 2) Non-oxidizing biocides and 3) Bio-dispersants.

Oxidizing Biocide

Oxidizing biocides are powerful chemical oxidants, which kill virtually all micro-organisms, including bacteria, algae, fungi and yeasts. Common oxidizers are chlorine, chlorine dioxide, and bromine, ozone, and organo-chlorine slow release compounds.

Chlorine

Chlorine is the most widely adopted biocide for large circulating water systems. It provides a residual biocide in the treated water and can be readily checked. It is cheap and readily available as a pure gas, as well as in the form of various liquid and solid compounds. Its effectiveness increases when it is used with other non-oxidizing biocides and biological dispersants.

Chlorine is a very strong oxidizing agent but must be carefully controlled and monitored due to effluent quality control guidelines. The killing efficiency of chlorine dramatically declines as the pH goes above 7.5. Because most cooling tower scale/corrosion treatment programs operate at an alkaline pH, chlorine chemistry might not be efficient. Chlorine demand is further affected by ammonia or amines in the water, which react irreversibly to form the much less potent chloramines.

Chlorine when used in excess will damage wood and organic fill in cooling towers and is corrosive to metals. Usually it is only used in systems large enough to justify equipment for its controlled feed. Where chlorine is used on a continuous basis, the concentration of free chlorine should be maintained at 0.3 to 0.5 mg/L to minimize the attack on materials of construction. For cleaning purposes, shock feed of up to 50 mg/L can be used, provided this high chlorine content is held for no more than 8 h and the system is thoroughly flushed and drained, to remove dead organic matter and excess chlorine. Chlorine can be dosed in the form of sodium hypochlorite.

Caution - Chlorine and hypochlorites must be applied carefully, because excessive chlorine will increase corrosion and may contribute to deterioration of cooling tower wood and reduction of heat transfer efficiency.

Chlorine dioxide

Chlorine dioxide is another strong disinfecting agent that is effective in controlling microbiological growth at <u>high pH values</u>. It is similar to free chlorine but having certain advantages:

1. Chlorine dioxide does not react with ammonia this reduces the disinfectant dose relative to chlorine.

2. Chlorine dioxide does not react with organics to the extent that chlorine or bromine does; this reduces the cooling water demand for chlorine dioxide relative to chlorine or bromine.

3. It is more effective than free chlorine at high pH values. Also, chlorine dioxide is very effective against Legionella and its relatively long half life allows chlorine residual remains in cooling tower water circuit for a relatively long period.

Chlorine dioxide is an unstable chemical that must be generated on site. Chlorine dioxide is produced by mixing the chlorinated water from a normal chlorinator and sodium chlorite solution. The reaction takes place very quickly; however, the process is more costly than simple chlorination. Chlorine dioxide is also generated electrolytically from a variety of chemicals. For cooling tower applications, the acid/sodium chlorite and acid/sodium hypochlorite/sodium chlorite generation method are typically used.

Chlorine dioxide and some of the chemicals used to generate it are hazardous.

Alternatives to Chlorine

Due to safety concerns, Sodium hypochlorite (NaOCl) has replaced gaseous chlorine at many facilities. Sodium hypochlorite is generally furnished as a solution that is highly alkaline and therefore reasonably stable. Federal specifications call for solutions having 5 and 10 percent available chlorine by weight. Shipping costs limit its use to areas where it is available locally. It is so furnished as powder under various names, such as Lobax and HTH-I5. The powder generally consists of calcium hypochlorite and soda ash, which react in water to form sodium hypochlorite.

A popular alternative is bromine which has similar killing powers to chlorine, but functions more effectively at alkaline pH. Another factor in favour of bromine is that it does not react irreversibly with ammonia or amines. The primary disadvantages of bromine vs. simple bleach are that an extra chemical is needed and feed systems are a bit more complex.

Ozone

Ozone is a powerful biocide and virus deactivant that is capable of oxidizing many organic and inorganic compounds. When reacting with another molecule, the ozone molecule is destroyed, producing carbon dioxide, water, and a partially oxidized form of the original reactant molecule. Any residual ozone will decompose and recombine as oxygen, producing no toxic or carcinogenic by-products.

The potential benefits from ozone treatment are twofold:

1. Effective antimicrobial treatment without the use of expensive chemicals
2.   Reduced blowdown since the ozone generation process precipitates out dissolved solids

The effectiveness of ozone is about 100 to 300 times more than chorine and is not significantly affected by pH. However, ozone is corrosive to some materials, and the cooling system construction materials need to be resistant to ozone attack. Application of ozone is not suitable under the following situations where excessive organic material in the water or high operating temperature has a high depletion of applied ozone:

1. High organic loading from air, water or industrial processes that would require a high chemical oxygen demand (COD) since ozone oxidizes the organics and insufficient residual may remain for the water treatment.

2. Water temperatures that exceed 110°F eliminate the effectiveness of ozone treatment since high temperatures decrease ozone residence time.

3. Make up water is hard (>500 mg/L as $CaCO_3$) or with sulphates greater than 100 ppm. Softening and / or pre-filtering of makeup water is recommended.

4. Since ozone has a short half life (usually less than 10 minutes), it readily decomposes into oxygen after oxidization. It is not recommended in large systems or systems that have long piping runs that would require long residence times to get complete coverage.

Ozone exposure for workers is also a consideration. US- OSHA has established an exposure limit of 0.1 ppm in the air over an 8-hr exposure period. Monitoring of ozone concentration is required if towers are located at ground level, adjacent to personnel.

Hydrogen Peroxide

Hydrogen peroxide (H_2O_2) is a powerful oxidizer, with its power stronger than chlorine and chlorine dioxide, but weaker than ozone. However, it can be catalyzed into hydroxyl radicals (OH-), which is more powerful than ozone, for micro-organisms control. Catalysts, such as iron, copper or other transition metals compounds can be added to hydrogen peroxide to generate hydroxyl radicals for more rigorous oxidation. This is the most powerful method to destroy micro-organisms and trace organics in water.

Hydrogen peroxide decomposes into oxygen and water readily. It is a simple and effective treatment technology when comparing with conventional water treatment chemicals and does not cause any gaseous release or chemical residue problem.

However, hydrogen peroxide is totally soluble in water, which may cause safety problems if high concentration >8% H_2O_2 by weight is used. Safety precaution in storage, delivery, handling and disposal of hydrogen peroxide shall be considered, which shall be complied with related guidelines.

Application of Oxidizing Biocide

The most effective use of oxidizing biocides is to maintain a constant level of residual in the system. Oxidizing biocides are usually maintained at a continuous level in the system. Dosage may be adjusted in response to regular testing but fully automatic control of biocide level in using reliable and durable measuring systems is desirable since overdosing can lead to increased corrosion and adversely affect the water treatment performance. Shock dosing is also applicable, which can enhance the effectiveness by faster killing action.

Since oxidizing biocide may sometimes be corrosive, corrosion inhibitors shall be added and selected to ensure compatibility.

Non-Oxidizing Biocide

Non-oxidizing biocides are organic compounds, which kill micro-organism by targeting specific element of the cell structure or its metabolic or reproductive process. Non-oxidizing biocides are not consumed as fast as the oxidizing types and

remain in the system for a significant period of time until they pass out with the blowdown. They often have the added advantage of breaking down into harmless, nontoxic chemicals after accomplishing their bacteria-killing purpose. They are effective where chlorine may not be adequate.

However, the non-oxidizing biocides are more costly and normally justified only in small systems, as a supplement to an oxidizing biocide in a large system, or when a particular problem exists in a large system and an alternative to the use of chlorine is required.

- Non-oxidizing biocides usually are organic compounds such as ammonium salts, Isothiazolinones, organo-metallics and organo-sulfur compounds.

- Quaternary ammonium salts or diamines are sometimes found to be toxic, but the low concentration application allows them to maintain in an acceptable limit for discharge.

- Isothiazolinones are biodegradable, which cause little adverse impacts to the environment.

- Glutaraldehyde is an effective and rapid-acting biocide and its reactivity prevents it from persisting to harm the environment.

- Non-oxidizing biocides such as organo-metallics, chlorophenols, organo-sulfur compounds and cationic biocides have not been adopted for use in large circulating water systems because of economics, degree of effectiveness, adverse side effects, or a combination of these reasons.

Advantages to using non-oxidizing biocides:

1. They are well suited to applications that are highly concentrated or fouled.

2. Contaminants such as ammonia, organic material, or nitrites cause a chlorine demand but do not affect a properly applied non-oxidizing biocide program.

3. They are active at low levels and are environmentally degradable, providing minimal discharge problems.

4. They will not attack organic scale inhibitors and are less corrosive than chlorine at normal dosages.

Disadvantages to using non-oxidizing biocides:

1. The cost is considerably higher.

2. They are pH sensitive.

3. Some are specific to certain microbial organisms.

4. Some are not effective against algae.

5. In order to ensure the effectiveness of non-oxidizing biocides, monitoring of chemical concentration in cooling tower systems is required.

Typically, except in air conditioning cooling systems, non-oxidizing biocides are used only as a supplement to chlorine. If, during operation, it is determined that a non-oxidizing biocide is required because of severe fouling problems, the chemical supplier should be consulted on the method of feed. Normally, the supplier will lease the storage and feed equipment for a minimal charge.

BIO - DISPERSANTS

Bio-dispersants do not kill organisms; they loosen microbial deposits, which can then be flushed away. They also expose new layers of microbial slime or algae to the attack of biocides. Bio-dispersants are an effective preventive measure because they make it difficult for micro-organisms to attach to equipment and / or pipe work surfaces to form deposits. Bio-dispersants can greatly enhance performance of biocides particularly oxidizing biocides. Possible bio-disperants include Acrylates, Ligonsulphonates, Methacrylates and Polycarboxylic acids, etc.

Biocide Dosage Rates

Biocide treatment is designed to either periodically shock the microorganisms with a relatively heavy dose of chemical, or maintain a continuous biocide residual in the circulating water. Below the lower threshold value of the biocide, the microorganisms will begin to multiply again. The recommended practices are:

1. Continuous chlorine residual systems typically maintain a residual of 0.5–1 mg/l as Cl_2.

2. Intermittent sodium hypochlorite feed systems typically dose at about 3 mg/l as Cl_2 for
   1–2 hours per day to the circulating water flow. Shock chlorination is typically done 2–4 times per day, each with duration of 20–30 minutes.

3. Continuous bromine residual systems typically maintain a residual of 0.5–1 mg/l as Br.

4. Continuous chlorine dioxide residual systems typically maintain a residual of 0.2–0.5 mg/l as ClO_2.

5. Intermittent chlorine dioxide feed systems typically dose at about 1.5 mg/l as ClO_2 for
1–2 hours per day to the circulating water flow. Shock chlorine dioxide feed is typically done 2–4 times per day, with duration of 20–30 minutes.

6. Non-oxidizing biocide are generally slug-fed (such as once a week) at high concentrations. The concentration is specific to the biocide, but is typically in the 5–30 mg/l range as product.

To stay within the chlorine discharge limits, feed rates of 3ppm chlorine or less are required, depending on the circulating water system.

Other Supplementary Methods

UV Treatment

UV disinfection, with secondary dosing using a suitable biocide, is one of the most cost-effective and efficient methods of reducing biofilms in cooling water. When used in conjunction with a secondary chemical biocide, UV works instantaneously against all water-borne microorganisms including those resistant to chlorine.

The treatment systems are very compact and can usually be easily retrofitted to existing water treatment systems. In addition, secondary dosing does not require the complex monitoring equipment necessary if biocides are used as a primary disinfectant. All these factors add up to a simple, effective treatment process that saves the operator time and money while providing reliable protection against the spread of dangerous diseases.

UV is the part of the electromagnetic spectrum between visible light and X-rays. The specific portion of the UV spectrum between 185-400nm (also known as UV-C) has a strong germicidal effect, with peak effectiveness at 265nm. At these wavelengths UV kills microorganisms by penetrating their cell membranes and damaging the DNA, making them unable to reproduce and effectively killing them.

A typical UV disinfection system consists of a UV lamp housed in a protective quartz sleeve which is mounted within a cylindrical stainless steel chamber. The water to be

treated enters at one end and passes along the entire length of the chamber before exiting at the other end.

Copper and Silver Ionization

Ionization indicates the electrolytic generation of copper and silver ions in cooling tower water. If properly managed, copper and silver ion concentrations at 20 to 30 µg/L and 10 to 15 µg/L, respectively, can be effective to kill bacteria in the systems.

The ions assist in the control of bacterial populations in the presence of a free chlorine residual of at least 0.2 mg/kg.

It should be noted that in hard water systems, silver ion concentrations is difficult to maintain due to build-up of scale on the electrodes, and the high concentration of dissolved solids precipitating the silver ions out of solution. For both hard and soft water, the ionization process is pH sensitive and it is difficult to maintain silver ion concentrations above pH 7.6. It is not recommended to adopt ionization in systems having steel or aluminium heat exchanger since deposition of the copper ion and subsequent galvanic corrosion is significant.

SECTION - 6   **TURBIDITY CONTROL**

Another problem area besides organic growth is turbid water, so let's now study turbidity.

Turbidity in water is caused by suspended matter in a finely divided state. Clay, silt, organic matter, microscopic organisms, and similar materials are contributing causes of turbidity. While the terms "turbidity" and "suspended matter" are related, they are not synonymous. Suspended matter is the amount of material in water that can be removed by filtration. Turbidity is a measurement of the optical obstruction of light that is passed through a water sample.

Turbid makeup water to cooling systems may cause plugging and overheating where solids settle out on heat exchanger surfaces. Corrosive action is increased because the deposits hinder the penetration of corrosion inhibitors.

Turbidity Treatment

Filtration is the most common method for removing suspended matter such as mud, silt and microbial matter from water by collecting the solids on a porous medium. Removing suspended matter helps the overall water management program's success by eliminating deposit-causing substances, as well as chemical treatment products to work more effectively.

There are two methods of filtration:

1. **Full-flow filtration**: Full flow filtration continuously strains the entire system flow. For example, in a 100-ton system, the flow rate would be roughly 300 GPM. A filter would be selected to accommodate the entire 300 gal/min flow rate. In this case, the filter typically is installed after the cooling tower on the discharge side of the pump. While this is the preferred method of filtration, for higher flow systems, it may be cost prohibitive.

2. **Side-stream filtration**: Here, a portion of the water is diverted through a filter for removal of dirt and suspended solids. These systems draw water from the sump, filter out sediment and return the filtered water to the tower, enabling the system to operate more efficiently with less water and chemicals. Side-stream filtration is particularly cost effective for high flow systems.

   Properly sized side-stream filtration system is critical to obtain satisfactory filter performance. A common rule-of-thumb suggests a filter size capable of

handling water at a rate equivalent to 3 to 5% of the total circulation flow rate. For example, if the total flows of a system is 1,200 gpm (a 400-ton system); a 60 gal/min side-stream system is specified. A more accurate approach is to calculate the system's total water volume and filter it once per hour. Thus, it is necessary to determine the total system water volume contained in the tower basin and wet deck, condenser water piping, condenser(s), etc., and divide that volume, in gallons, by 60min to establish the required filter flow rate, in gpm.

Both in-line filtration and side-stream filtration processes help in reducing suspended solids to an acceptable level. These filters not only reduce the potential for settling of particulates in condenser tubes and low-flow locations, but also remove microbes and particulates that would otherwise consume some of the polymers utilized for scale control.

Filtration Equipment

A number of mechanical filtration devices commonly used in cooling tower systems are:

1. **Strainers** – A strainer is a closed vessel with a cleanable screen to remove and retain foreign particles down to 25µm diameter inside cooling water. It shall only be used as pre-filtration to remove large particles in the system.

2. **Cartridge filters** – Cartridge filters utilize a pleated, porous medium as a filtering medium and can be cleanable and reusable or disposable. These have a filtration range of 0.1 micron to 100 microns. Cartridge filters are preferable for systems with contaminations less than 100 ppm that means with contamination levels less than 0.01% by weight. For concentrations that are bigger than 100ppm then a bag filter or some other method should be used.

3. **Sand filters (Permanent media filters)** – Sand filters are used for water purification. The degree of suspended solids removal in sand filters depends on the combinations and grades of the medium being used in the vessel. Typical sand filter can remove suspended contaminants down to 10µm. Specialized fine sand media filters are designed to remove suspended particles down to less than 1µm. Multimedia vessels with each layer containing medium of different size may also be used for low suspended

solids application. When the vessel has retained enough suspended solids to develop a substantial pressure drop, the unit must be backwashed either manually or automatically by reversing the direction of flow.

4. **Centrifugal-gravity separators** – Cooling water is drawn through tangential slots and accelerated into the separation chamber. Centrifugal action tosses the particles heavier than the liquid to the perimeter of the separation chamber. Efficiency of centrifugal-gravity separator depends on the gravitational mass of suspended solids; performance data indicate that separator efficiency is about 40% for particles in the range of 20µm to 40µm.

5. **Bag type filters** – Bag filters are composed of a bag of mesh or felt supported by a removable perforated metal basket, placed in a closed housing with an inlet and outlet. Filter bags can be made of many materials (cotton, nylon, polypropylene and polyester) with a range of ratings from 0.01mm to 0.85mm. Mesh bag are generally coarser, but are reusable. However, periodic replacement of filters is required to ensure the efficiency of filters.

Coagulants, flocculators, and sedimentation basins are also used but are more common to large water treatment facilities.

Selection Recommendations

The type and density of the suspended solids is a key for selecting an effective filter. Sand, corrosion products and scales are very dense whereas vegetation, microbiological biomass and oily/greasy products are very light and float readily in the water. Bacteria are very small -- actually minute -- while corrosion products such as chips are very large. Selection of the filter and its media must identify these considerations. As a rule of thumb, keep the following tips in mind:

1. If mainly sand and other dense particulates are present, a cyclone separator is ideal.

2. If the suspended solids are lightweight, then a sand filter or cartridge filter will work well.

3. For a cooling tower system operating 24 hours per day, use a side-stream filtration system that filters the entire volume of the system four to five times per day. As an alternative, 3 percent to 5 percent of the recirculation rate is

used. Using this calculation method, if the recirculation rate is 5,000 gal/min, filter 150 to 250 gal/min.

4. To conserve water and treatment chemicals, backwash filters with makeup water, not system water.

5. If oil and/or grease are present with suspended solids, use an oil water separator and then filter the separated water to remove suspended solids.

6. Dispersants often used for cooling water treatment break up suspended solids so fine that sand filters may not work very well. Media should be much finer or precoat used.

7. Filter media may harbour microbiological organisms and should be disinfected periodically.

SECTION - 7 WATER TREATMENT SYSTEM CONTROLS & MONITORING

Chemical Dosing

Water treatment chemicals shall be added to turbulent zones of cooling tower water system to achieve rapid mixing and well distribution of chemicals. Also, separate dosing point shall be used to ensure dilution of one potentially reactive chemical prior to adding the second chemical. The dosage concentration of chemicals, including inhibitors and biocides, shall be calculated based on the total quantity of water, make up water quality and bleed-off rate.

The purpose of most chemical treatment control programmes (other then certain biocides) is to maintain a constant concentration in the recirculating water at all times. In order to maintain a stable chemical concentration in cooling water, a number of application methods can be adopted, including:

  a. Shot / slug dosing;

  b. Continuous / intermittent dosing;

  c. Proportional dosing related to bleed-off volume;

  d. Proportional dosing related to make up water volume;

  e. Dosing controlled by sensor.

Shot / slug dosing

Chemicals are added to the system manually on a routine basis.   Shot / slug dosing is the most economic and effective application method, which may be adopted in small-scale cooling tower installation. However, it is not recommended because chemical concentration cannot be controlled accurately and large fluctuations in chemical levels are always found.

Continuous / intermittent dosing

Continuous / intermittent dosing makes use of mechanical devices, such as timer and pump for chemical dosing. It is the simplest type of automatic dosing system. Since chemical dosing frequency and amount is regulated by the pre-set value, fluctuation of chemical concentration inside cooling tower water is always found.

Proportional dosing related to bleed-off volume

System bleed-off can be controlled by simple timer, conductivity sensor or make up water flow. Signal from the device can also be used to initiate chemical dosing. When the conductivity of the system water reaches a pre-determined value, a timer can be actuated which allows a dosage pump to run for a period to add the requisite amount of chemicals, in relation to the make up water entered the system.

A delay timer shall be installed to prevent wasteful chemical addition during bleed-off.

Proportional dosing related to make up water volume

Proportional dosing maintains a nearly constant chemical level by dosing in proportion to a varying make up water rate. The treatment requirement is based on make up water quantity and injection rate varies as the water make up changes. Impulse water meter installed in make-up line shall be used to activate a chemical dosing pump. Proportional dosing can be applied to all cooling tower systems continuously. Such dosing is particular benefit to systems which operate under conditions with great varieties.

Dosing controlled by sensor

Dosing controlled by sensor is ideal for controlling chemical concentration in a system. Correct amount of chemical is continuously presented to the system once the dosing rate and frequency are gauged by operational parameters. Therefore, concentration of chemicals inside cooling tower water can be maintained within a designated range. pH sensor, redox probes and oxidation reduction potential (ORP) probes are commonly used to control dosing of acids and oxidizing biocides, respectively.

Bleed-off Control

For an accurate bleed-off control system, automatic control by conductivity sensor is recommended to regulate the amount of bleed-off required. Conductivity is a measure of total ionic concentration in water, hence, concentration of total dissolved solids (TDS). Bleed-off control is a critical part to ensure scale prevention in water-cooled air conditioning systems.

Bleed-off rate is related to the cycle of concentration, which shall be determined by water treatment methods being adopted. If a comprehensive water treatment programme, including both chemical and physical methods, is implemented to

control scale, corrosion and micro-biological growth effectively, bleed-off rate can be significantly reduced.

There are a number of methods to control bleed-off, including:

a. Manual control: a bleed valve is opened in response to test measurements;

b. Timer / intermittent control: a simple interval timer is set to open and close the bleed valve intermittently;

c. Continuous bleed: an orifice plate or pre-set valve is set to release water continuously;

d. Proportional control: an impulse water meter on the make up line actuates the bleed valve

e. Conductivity control: the cooling water conductivity is continuously monitored and the bleed-off valve is opened at a pre-set conductivity.

A number of points shall be considered for a bleed-off system.

a. To ensure the bleed assembly can be isolated from the system for maintenance purposes;

b. To ensure the head of the conductivity sensing probe is positioned in the main water flow, but not where air pockets can develop;

c. To place the conductivity sensing probe upstream of the bleed-off system solenoid valve;

d. To clean the conductivity sensing probe regularly;

e. To regulate valve in the bleed line so that the flow cannot exceed the make up water to the system;

f. To provide an alarm signal when solenoid valve and flow switch signals in the bleed-off line do not correspond.

Central Monitoring and Control

Water treatment monitoring can be controlled through Building Management System (BMS). It co-ordinates the entire system operation and water treatment programme.   This control strategy may have the following advantages:

   a. Accurate dosing control is assured which optimizes chemical usages;

   b. Bleed-off and chemical dosage would not occur at the same time so that wastage of chemicals on drainage can be avoided;

   c. Adjustment of water treatment programme in accordance with cooling tower system operation can be performed in the central control system;

   d. Minimal chemical handling is required to reduce the risks of the operators' health and safe;

   e. Water consumption, energy consumption, chemicals consumption are recorded accurately; and

   f. Any malfunction of water treatment equipment can be reported immediately.

Monitoring Devices

Sensors are generally used as monitoring devices in water-cooled air conditioning system. Comparison between the measuring results and the set points for specific parameter are useful to determine the control action required for normal operation. Different type of sensors to be selected is relied on the control strategy. Common types of sensors are described as follows.

Flow meter

Chemical feeding requirements are proportional to the make up water flow. Many chemical feeding systems are designed according this basis, which is the simplest automatic dosing method. Flow meters including orifices venturi, flow tubes and turbine meters can be used to suit the design.

Level sensor

Make up water supply to cooling tower sump depends on water level of cooling tower basin. Hence, chemical dosing can be controlled by monitoring of the water level. However, this dosing method is not accurate and cannot control the concentration of chemicals contained in the cooling system water precisely.

Conductivity sensor

Electrical conductivity of water relies on total ionic concentration of water, which indicates the concentration of total dissolved solids (TDS) in water. Both corrosion rate and scale formation potential for any specific systems are normally proportional to the conductivity of water. Conductivity sensor is frequently employed as chemical detection device. The sensor is usually used for bleed-off system for the control of cycles of concentration.

pH sensor

Carbon steel corrosion rate decreases with an increase in pH value, and the scale potential for most scale forming compounds increases with pH value. Also, water treatment chemicals work in specific range of pH value. Hence, pH value measurement is often the basic principle for acid dosing to maintain effective water treatment programme.

ORP probe

ORP probe is used as real time monitoring and recording of oxidation reduction potential, which can be utilized to monitor chlorine residuals in cooling tower systems. It measures the inorganic and organic particles remains in cooling water so as to facilitate chemical dosing. ORP probe shall be used together with pH sensor since ORP values vary with pH value.

Chlorine residuals sensor

Chlorine is commonly employed biocide for water-cooled air conditioning system. Continuously measuring chlorine residual analyzer is commercially available to measure either free or total chlorine residual.

Turbidity sensor

Turbidity measurement provides an indication of the amount of suspended matter in cooling water, which is useful in determining deposit potential. Therefore, it can be used for bleed-off control.

Corrosion rate sensors

Corrosion rate sensors are available in the market to provide continuous, instantaneous measurement of corrosion rates for any alloy. These sensors are

normally based on linear polarization resistance between a pair of electrodes. Corrosion coupon test method can also be used to determine corrosion rate.

Sensors for specific ions and Compounds

Sensors are commercially available to measure ion concentrations in water. Many analyzers are also available to measure either compounds or classes of compounds or classes of compounds dissolve in water.

The selection of proper location of sensors in the water-cooled air conditioning system is very important. Sensors measuring treatment chemicals shall be located at a point after the treatment is well mixed. Corrosion rate increases with increasing temperature.   Therefore, corrosion monitoring device should be installed at the outlet of the heat exchanger where water with the highest temperature is passing through. Requirement of measurement and reliability of sensor shall also be considered in selecting an appropriate device.

Control Devices

In order to achieve maximum effectiveness of water treatment programme, chemicals must be dosed into the system in an appropriate concentration periodically. Since handling of chemicals may be dangerous, it is always recommended to perform chemical dosing by means of automatic monitoring and control strategy. Chemical injection can be facilitated by different control devices.

Timer

It is a simple device allowing operator to set the operation of chemical dosing valve, hence, chemical dosing frequency, in a fix interval. Also, circulation of water during system intermittent down time can be achieved by using timer control.

Dosing pump

Dosing pump can be operated manually or automatically.   For automatic control, dosing pump activates upon receiving signal from timer or sensors. It runs for a certain period to inject chemicals into the cooling tower water circuit.

Motorized valve

Motorized valve is an essential component for automatic controlled chemical dosing and bleed-off. It will switch to open / close position upon receipt of signal from monitoring devices, such as water meter and conductivity sensor.

Occupational Safety and Health

Water treatment may involve application of relatively aggressive and toxic chemicals, which is the major concern.   All personnel involved must be fully conversant with the safe handling of the products.

a. Material safety data sheet (MSDS) and relevant recognized data sheet for chemicals used in water treatment process shall be provided by water treatment services providers and included in the operation and maintenance manual. MSDS and relevant warning / safety label shall be provided on the surface of water treatment chemical bucket. The MSDS and labels shall be properly protected against water and chemical damage.

b. Eye wash bottles or washing basin with fresh water tap shall be provided adjacent to water treatment chemicals tanks or any appropriate location for emergency use. Water treatment chemical shall be stored at an appropriate location to facilitate chemical handling.

c. Mechanical / natural ventilation shall be provided to the room entirely / partially used for water treatment chemical storage.

d. Electrical fittings and luminaries serving water treatment chemical storage area shall be weather-proof and corrosion resistant type.

e. Warning signs shall be erected to alert for operation and maintenance personnel of the potential hazard caused by cooling tower.

f. Warning signs shall also be erected to restrict the unauthorized access to chemical storage areas and cooling towers.

g. Workers exposed to hazardous substances and engaged in processes of cleaning and disinfection and water treatment shall undergo regular health surveillance with a medical practitioner. In case any worker develops respiratory, cutaneous and other symptoms when exposed to hazardous chemicals, immediate medical attention shall be sought.

Course Summary

In today's world of expensive energy and replacement costs, it is more vital than ever, for heat exchange equipment to be kept free of insulating deposits. The cooling duty and power requirements of refrigeration equipment depend primarily on the evaporating and condensing temperatures. The condenser in particular due to warm

water and in an open loop is susceptible to scale deposits that shall raise the condensing temperature of the system. Higher the condensing temperature, higher shall be the power drawn by the compressor and lower shall be the performance.

The four principal reasons for water treatment in HVAC systems is to (a) to limit corrosion, (b) to prevent the build-up of scale and sediment, and (c) to reduce the amount of bacteria, including Legionella, and other microorganisms and (d) to affect energy conservation.

The energy losses can be controlled by implementing a proper water treatment program. During normal operation, it may not be possible for the operators to understand the severity and magnitude of the problem. A routine O & M practices shall provide a clue of higher current drawn by the compressor and a drop in cooling range (differential of cooling water inlet and outlet temperature) across the condenser.

The common chemical inhibitors compounds are: Chromates, Poly-Phosphates, Zinc, Nitrates, Silicates and Sodium Meta Phosphate (SHMP).

Select your chemical treatment vendor with care. A simplest approach for HVAC system is to perform vendor evaluation on "cost to treat 1000 gallons makeup water" and highest "recommended system water cycle of concentration."