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WHITE PAPER
Water Quality Management for the Plastics Industry

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Introduction:

Water is called the "universal solvent" because it will dissolve to some degree anything that it comes in contact with. Maintaining good water quality will ensure clean heat exchangers, corrosion free piping and equipment surfaces. This will prolong the plant equipment's life and maximize a plant's productivity.

PART I:
A Brief Discussion About Water:

When a glass of water is first poured it appears to be colourless and, depending on the water source, clear and free of suspended solids. However, appearances can be deceiving. Water contains various concentrations of dissolved minerals, salts, metals and gases.

Some of the more prevalent naturally occurring impurities in water may include:

Impurity	Anions	Cations	Dissolved Gases
Acidity		H^+	
Alkalinity	CO_3^{--}, HCO_3^-, OH^-		
Sulphates	SO_4^{--},		
Gases			O_2, CO_2
Hardness		Ca^{++}, Mg^{++}	
Iron		Fe^{++}, Fe^{+++}	
Copper		Cu^{++},	
Lead		Pb^{++}	
Salt	Cl^-	Na^+	

In addition, water may also carry impurities that you can see. These may include suspended rust (iron oxide), air-borne matter (silica based), product fines (such as PVC dust) and microbiological matter (MB).

Microbiological matter is often undetectable to the eye and unless sterilized, it will be present in all water. If allowed to grow, it can form slime & algae masses in any systems which are very visible and can foul heat exchangers and any small orifices and water passages in piping or in molds.

Sources of Water:

Excluding salt water, the fresh water sources today have these characteristics:

1) Run-off Water: These waters originate from rainwater run-off into streams and lakes and are usually very soft in hardness and low pH. Run-off water doesn't have the contact time to dissolve mineral scale, and the lack of hardness tends to make it more corrosive than other waters. Its purity leads to high cycles of concentrations in cooling water systems and efficient use of water and chemicals.

2) Lake Water (Great Lakes and St Lawrence River): Lake water is a combination of spring-fed, run-off rain water and water from river sources and result in water of moderate hardness and alkalinity levels. This makes for good cycles of concentrations and good water and chemical use. Softening is not normally necessary for cooling tower systems with a proper chemical program, and when not sending cooling tower water to areas of high temperature.

3) Well Water: Well water is usually very hard and alkaline. When used as cooling tower make-up water the cooling system must run with limited cycles of concentrations resulting in high water and chemical use the water is treated by softening or pH modification through the addition of acid.

Basic Terminology:

In order to get a good understanding of chemical water treatment, it is necessary to define some basic terminology for water properties and the effects of each on the performance of industrial water systems:

1) pH: A numerical value between 1 and 14 which represents the chemical balance between acidity and alkalinity in water. One represents the most acidic condition, 7 is a neutral water and 14 the most alkaline. City water sources normally vary in pH between 6.8 and 8. Great Lakes and St. Lawrence River water pH levels are 7.5 – 7.8 which makes the water slightly corrosive and practically non-scaling under most temperatures.

2) Temperature: Temperatures in these articles are expressed in degrees Fahrenheit. Temperature is one of the most important factors affecting the one of the most common problems in water systems - the formation of hardness scale. Scale formation (Lime) preferentially occurs on hot heat exchanger surfaces. Higher temperatures will also increase the rate of corrosion.

3) Scale / Corrosion Index: Scaling and corrosion exist in a balance that can be affected by pH, temperature, alkalinity, total suspended solids and total hardness. A common method of expressing this balance is in terms of a Langelier Saturation Index (LSI), a mathematical relationship that applies the above factors mathematically to generate positive and negative numbers between +4 and -4 with negative numbers referring to corrosive waters and positive numbers referring to scaling waters. For example St Lawrence and Great Lakes water have a slightly positive LSI and can easily be treated chemically in closed systems. When used in cooling systems the LSI increases as impurities build up. Chemical management programs normally keep the LSI below +3 before any problems of scaling occur. However, if water temperatures rise above 120˚F the LSI will increase beyond +3 and scaling will occur.

4) Corrosion: Corrosion is a chemical or electro-chemical degradation process of metal surfaces. The purer the water, the more corrosive the water becomes. (more negative on LSI). For example deionised water is the most corrosive, followed by reverse osmosis water, softened water, city water, and finally cooling tower water. In general, corrosion will decrease as the pH increases and becomes more alkaline. Iron for example, will show minimal corrosion at a pH of 8.3 and above in untreated waters.

5) Impurity Concentration: In this article, the concentration of impurities is expressed in terms of parts per million (ppm). Higher concentrations of impurities in combination with other factors of temperature, flow, pH and alkalinity will combine to cause problems of deposition of suspended solids, microbiological fouling and scale formation

6) Total Hardness: Total hardness is expressed in terms of ppm of Ca^{++} and Mg^{++}. Under positive LSI conditions (high pH, alkalinity, temperature, total dissolved solids) these cations will combine with carbonate and bicarbonate alkalinity to form scale on the hottest heat transfer surfaces on any water system.

7) Scale Formation: Scale formation occurs in direct proportion to temperature and will reduce heat transfer in areas where it is needed most – molds, high temperature hydraulic oil exchangers, TCU's and barrel heat exchangers. Scale formation can be prevented by limiting the hardness in cooling water systems to below 400-500 ppm with controlled bleed-off (unless softening is available), and chemically with scale inhibitors and dispersants.

8) Suspended Solids: Airborne dirt and dust can be drawn into a tower and cause problems of deposition and fouling, especially in heat exchangers.

Corrosion products and microbiological growth from the water system can also combine and settle in areas of low flow. Tower systems concentrate the city water impurities through evaporation, and suspended solids levels must be limited by controlled bleed-off. Filtration, strainers (alarmed for pressure-loss) and chemical dispersants are used for controlling suspended solids.

9) Deposition: Deposition is the natural result of over-concentrating suspended solids and tends to occur on hot heat transfer surfaces and in areas of low flow, especially in areas changing flow. Deposition will reduce both flow and heat transfer. Cooling tower systems are especially prone to deposition due to the continuous additions of air-borne particulate by the washing of air with cooling tower water. Deposition of suspended solids can be controlled by dispersants, bleed off, and filtration.

Types of Industrial Water Systems:

Many types of water systems exist. We will categorize these types as being either open or closed.

1) Open Loop Systems: Dynamic systems that require a continuous addition of water to make-up for losses due to evaporation and bleed-off. The best example is a cooling tower system. Such a system relies on evaporation for cooling. With evaporation, all impurities (anions and cations) remain behind and concentrate several times. The amount of solids in the water can be limited by bleeding off the dirty water. Clean city water is than required to make-up for losses. For this reason, open systems are contaminated with much higher concentration of hardness, alkalinity and suspended solids. Moreover, due to their contact with air, open systems are prone to MB growth.

2) Closed Loop Systems: No evaporation occurs and apart from some controlled water losses when molds are changed no make-up water is required. In this case, the chemistry of this water is identical to city water. Therefore, unlike open systems, impurities in closed systems will not normally concentrate unless corrosion is active and adding suspended iron to the system.

Chemical Water Treatment Techniques:

There are a number of water treatment companies that provide chemicals and services to organizations with industrial processes and heating. Generally, most companies have representatives calling regularly on plants to test their water, calibrate any plant testing equipment and provide training. Some companies provide full service contracts to supply the chemicals, manage and be responsible for the chemical feed equipment. Additional services include laboratory analysis, on-site scale and corrosion studies & equipment inspection.

Chemical Treatment System provides proportional chemical feed and bleed-off to make-up.

1) Closed Systems – Chilled and Hot Water Heating Systems: Closed systems do not have the evaporation process that increases the impurity levels that are found in open cooling water systems. For this reason, the LSI in closed water systems will remain below scaling levels, even under higher temperatures. This is the preferred water system for mold cooling.

Chemical treatment of a closed system is normally required only when the system loses water such as during mold changes. Once the system is treated, the chemical corrosion inhibitors should remain unchanged unless the system loses water. Testing is therefore only required once every two weeks or after system water losses such as mold changes. If required, chemicals can be shot fed directly to the system either directly in the reservoir or in a chemical pot feeder.

2) Open Cooling Systems – Cooling Towers: Chemicals are best fed continuously in proportion to make-up and will vary according to the actual load on the system. A contact meter, on the city water make-up, controls the chemical feed of scale and corrosion inhibitors. As the system works harder, more water is evaporated; more make-up water is required which feeds more chemicals.

Berg Fibreglass Cooling Tower

System bleed-off is a way of de-concentrating dirty tower water. The amount of bleed-off should also vary in proportion to the load in system. This will keep the chemical levels constant in the system. Conductivity is a measurement of the amount of total dissolved solids in a system. As the load and evaporation increases, the water becomes saturated with impurities which will increase the water conductivity. A probe continuously monitors the conductivity of the water. As water evaporates the conductivity rises above a pre-set level and a bleed-off solenoid valve will open to discharge a controlled amount of cooling tower water to sewer.

The prevention of MB growth in a cooling system is handled by biocides. These products are to be shot-fed to a system for maximum impact and fed on an alternating basis with the second dissimilar biocide. Hand feeding is commonly done directly in tower reservoir. However, many plants now use timer biocide pump systems to avoid plant personnel from being in direct contact with the chemicals.

Tests for scale and corrosion, chemical levels, conductivity, MB counts and daily records of make-up water readings will ensure good control over a cooling water treatment. Some plants have their personnel perform daily tests to react instantly to problems. Other plants take advantage of full-service water treatment packages.

Here are a few important formulae used in Cooling Tower systems:

$$E = 0.001 \times R.R \times \Delta T \times F$$

Where: E = Rate of evaporation
R.R = Recirculation rate
ΔT = Temp rise across the tower
F = Sensible heat loss factor (usually 0.85)

$$\text{Cycles of concentration} = \frac{\text{Concentration of impurities in cooling tower water}}{\text{Concentration of impurities in city water}}$$

$$\text{Bleed-off rate} = \frac{\text{Rate of Evaporation}}{(\text{Cycles of concentration} - 1)}$$

In general, cycles of concentration in a cooling tower system for Great Lakes and the St-Lawrence River are kept around 3.5, assuming the suspended solids do not exceed 50 ppm. This controlled approach by bleed-off and chemical treatment will minimize water use and maximize chemical efficiency.

Conclusion:

No matter what type of chilling system a plant is equipped with, open or closed, understanding the water in an industrial system and applying appropriate chemical water treatment is absolutely necessary. Your plant's productivity and the life of your equipment depend on it.

Part II: Water Quality Management for the Plastics Industry

Introduction:

Types of Water Sources:

1) Medium Hardness Water – Great Lakes/St. Lawrence River Water: Water from these sources are moderately hard, approximately 120 – 140 ppm and have a pH of 7.6 – 7.8. Corrosion inhibitors are required for iron and copper, and scale inhibitors are necessary when used in cooling tower water systems. Treated water from these sources is ideal for closed water systems (chilled water) mold cooling applications and can be heated in extruder barrels or temperature control units without forming scale deposits.

This water provides very economical make-up water for cooling tower systems. When properly treated cycles of concentrations can run up to 3-4 making it very practical for cooling water cooled chillers, air compressors and hydraulic heat exchangers. However, at 3-4 cycles of concentrations scaling will occur when in contact with hot heat transfer surfaces. This is common in hot extruder screw and barrel heat exchangers and mold temperature control units. Chilled water (closed system water) is recommended for these applications.

2) Low Hardness Water – Interior Lakes/Run-off Water: Hardness levels vary from 30 to 80 ppm, and pH levels of 7.2 to 7.6 are common. Like medium hardness water low hardness water is also ideal for closed water systems when treated with corrosion inhibitors, and scale formation will not occur when heated.

In tower water systems low hardness make-up water allows for up to six cycles of concentrations making for even more economical use and reduced chemical costs than medium hardness waters. Low hardness tower water is less susceptible to scale formation when heated than medium hardness water, however chilled water (closed system water) is recommended for hot extruder screw and barrel heat exchangers and mold temperature control units.

3) High Hardness Water – Well Water: Well water is used when low or medium hardness water is unavailable. The high hardness makes well water only appropriate for closed water applications under the guidance of a water treatment specialist. Some well waters may also contain corrosive contaminants such as high levels of chlorides and sulphates, both of which can make even chemical treatment difficult.

Well water can be used as tower water make-up but only with an aggressive chemical or chemical/softening programmes. Any well water application requires regular, daily testing and monitoring of equipment and chemical levels as per your water treatment company's recommendations. Any equipment breakdown or chemical program upset will cause rapid scaling in all heat transfer equipment. The result – costly repairs and expensive downtime.

Glycol Systems:

Glycol is commonly used with water in chillers to provide freeze protection. The percentage of glycol depends on the coldest temperature that the glycol reaches during operation. In a chiller this temperature is normally the saturated suction temperature in the evaporator, and normally this temperature is 10°F below the chiller set point temperature.

With this fact in mind, since water freezes at 32°F we only use glycol when the chiller set point is below 42°F, or if we are cooling a coil that is exposed to winter outside air. Some glycol products contain a corrosion inhibitor however glycol should not be used only for this purpose. Use corrosion inhibitors from a chemical company to supplement the glycol to be certain about preventing corrosion.

Glycol is also a heat retardant rather than being good at transferring heat. Its presence also adds viscosity to the cooling fluid requiring higher hp pumps and higher flow rates to do the same as a pure water system. Therefore it is only to be used for freeze protection.

There are generally two glycols that are used – propylene glycol, a food-grade and non-toxic glycol and ethylene glycol which although is toxic to humans and requires special handling and spill containment practices, is much less expensive and therefore more commonly used.

Glycol at concentrations above 1-2% is toxic to bacteria. At low concentrations (0.1-1%) glycol is a nutrient for bacteria, and the by-product of the bacterial process is very acidic. Therefore, anytime you drain a glycol system you must do a thorough system flushing and immediately treat with a corrosion inhibitor. In some cases a chemical cleaning is a necessary part of the flushing to ensure that you have completely removed all traces of glycol. Please consult your water treatment company.

Water Quality And System Design:

For most types of plastics the molds require cool water temperatures to minimize part cycle times and maximize productivity. Since the required temperatures for these molds cannot be reliably maintained with cooling towers during warm weather, and since the mold passages are small and easily fouled most plastics plants dedicate a chiller to the molds and plastic processing sections of extruders and use tower water for the shell and tube heat exchangers for hydraulic cooling, chiller condensers, air compressors, extruder feed throats and gear boxes. The exchangers in this equipment are usually shell and tube that are easily acid washed if cleaning is necessary. The spaces between the tubes are more forgiving to fouling than the small 1/16" spaces found in plate and frame exchangers and in small mold passages.

Double Y Strainer for large particle filtration provides protection to water circulation equipment against plugged strainers and filters with no downtime.

Smart plant water system design uses mechanical (chiller) cooling only as needed, and maximizes the energy savings found when using water cooled equipment whenever possible. Tower water (ambient) cooling costs a fraction of the operating expense of a chiller, and a fraction of the equipment capital cost on a $ per ton basis. For this reason many plants select water-cooled chillers, air compressors and air dryers to put onto a cooling tower and dedicate a chiller for only cool water applications.

There are other cases where tower water is a good choice for temperature control units, barrel and screw cooling. The required temperature set points for these may be between 140 - 180°F and as we discussed in the previous article the high concentration of calcium in the tower water will cause scale formation where tower water directly contacts the heaters and hot heat exchange surfaces. Precipitated scale will also migrate downstream to foul molds and other process equipment.

Stainless Steel Fine Particle Strainer with Auto-Flush captures sediment in the clean process water.

If your plant has medium hard make-up plant water, or if only very clean water can be tolerated in your molds and processing equipment, and your exchangers can be adequately cooled with tower water there are solutions available if you do not have a spare chiller available.

1) Softening: Softening uses a sodium zeolite resin that can be regenerated by brine to remove all calcium hardness from the make-up water. This will eliminate any hardness scale formation when the tower water contacts hot heat transfer surfaces, however the softened water changes its balance from being scaling water to corrosive water. The solution is to install a small valved by-pass around the softener and maintain just enough hardness in the water (approximately 80-100 ppm) to remove the corrosiveness and low enough in concentration to not precipitate when heated. This is a relatively low cost solution however be cautioned that thorough monitoring by the plant on a daily basis must be performed in order to correct any softener upsets, maintain the salt brine tank and balance the blend between the hard, by-pass make-up water with the 100% softened make-up water. Failure at any time can result in totally scaling up your system.

2) Clean Water Tower Systems: Safe, reliable and worry-free plant operation can be assured by converting your tower system to a Clean Water Tower System. Here an efficient plate and frame exchanger is installed in the tower system with standard 85°F/95°F water providing the cooling on one side of the exchanger and a closed loop process water system operates on the other side. The process equipment sees a minor increase in temperature (most exchangers can be sized to a 3 - 5°F difference between the inlet tower water temperature and the outlet process water temperature), and the cooling water system becomes a standard closed loop system that can tolerate high hardness without scaling.

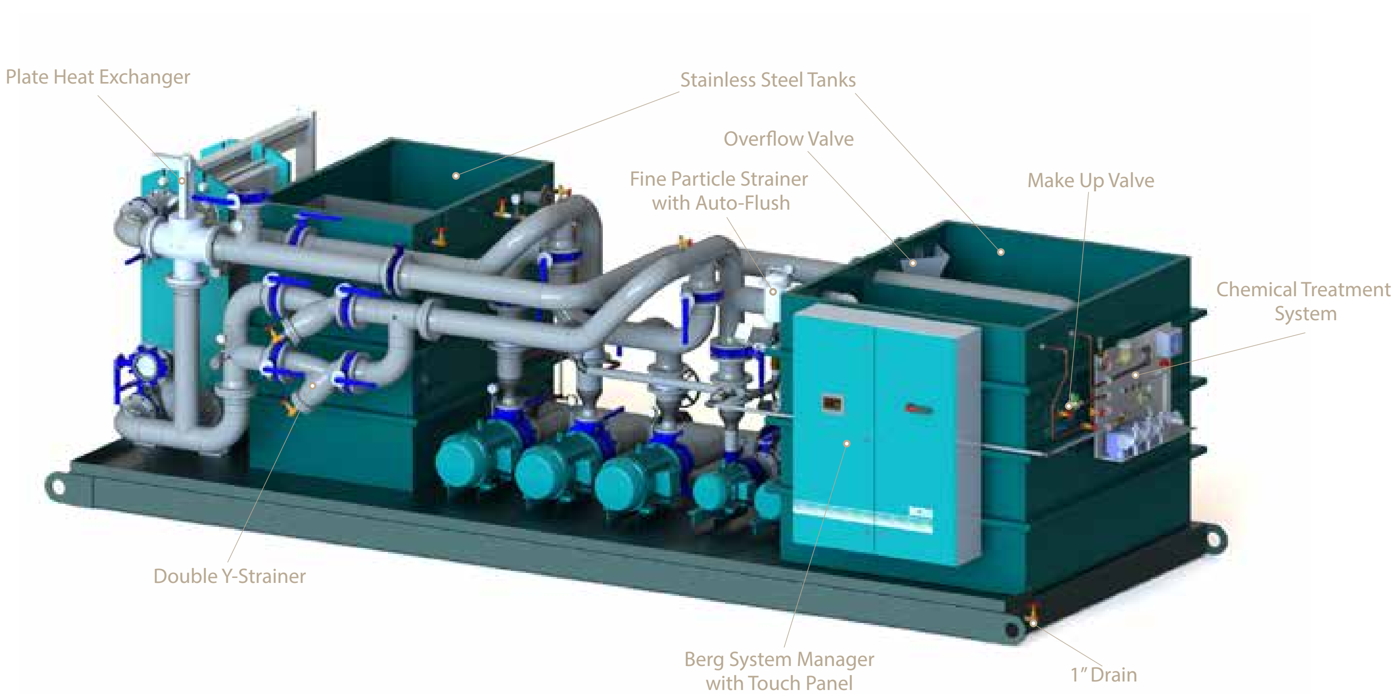
The difference between this water and tower water from the same source is that there will be no make-up to replenish the scaling process, the hardness level is a fraction of the tower water hardness, there is no contact with the air so there is

Berg Cooling Tower Pump Tank System

none of the particulate present to cause fouling or deposition, and the water treatment is a simple, add as required process assuming that the system stays tight (apart from periodic mold changes). A large system with two separate tanks is shown below. Tank baffles are not required but were added in this application to provide extra strength to the two large tanks.

In small applications less than 150 tons the two tanks can be brought together with only three pumps necessary (one process pump, one tower pump and one standby pump). In other cases, if the tower tank is large enough, or if it can be modified a heat exchanger can be added to the tankset and the baffled tower tank can be converted to two separate tanks with a full baffle from the bottom to the top of the tank. Some additional valves and piping changes then can retain the operation of a standby pump and use the two tanks to create a Clean Water Tower Tankset.

3) Other Solutions: Reverse osmosis, deionized water processes and other forms of water conditioning can remove hardness and other unwanted contaminants. There is usually a high cost to buy, install, and operate this equipment. Some of you may also encounter the non-chemical devices that claim to eliminate all chemical treatment, remove existing



Berg Clean Water Tower System ensures safe, reliable, worry-free operation.

scale, and run without the need to do daily plant tests. Many come with testimonials and references that are hard to trace, and may sound very convincing. It has been the author's experience that when things sound too good to be true they probably are, and we urge caution and consultation before you decide to try.

Conclusion:

We hope that this paper provides a basic understanding of water quality management. We cannot understate the importance of working together with a reputable and high quality water treatment company representative to enable you to achieve your goal of maximum productivity, long equipment life and efficient plant equipment operating expense.

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