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Subject: Industrial Consumptive Cooling Process and Water Conditioning Technology Efficiencies

City of Guelph  
1 September 2015

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CITY OF GUELPH

INDUSTRIAL CONSUMPTIVE COOLING PROCESS AND WATER CONDITIONING TECHNOLOGY EFFICIENCIES

C3 WATER INC.
1 September 2015

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1.0 INTRODUCTION

The 2015 Water Efficiency Strategy Update will identify a set of preferred program alternatives, associated water savings, program implementation forecasts, and supporting program resources required to achieve the water demand reduction of the 2014 Water Supply Master Plan. As part of the strategy scope, a series of technical memos are being prepared on technology and policy areas of opportunity, as identified through ongoing program operation, industry best practice research, and common areas of customer/stakeholder inquiry. The objective of this report is to outline potential efficiency options related to industrial cooling processes.

2.0 INDUSTRIAL CONSUMPTIVE COOLING EFFICIENCIES

2.1 Definition

An industrial cooling system removes heat from a process or piece of equipment by transferring it to another medium, often water and sometimes air. For water-based cooling systems, the heated water can simply be discharged down the drain as a once-through cooling system, or it can be cooled and reused as a recirculating cooling system. There are two types of recirculating systems, open and closed. The types of water-based cooling systems are described below:

- Once-through cooling system, Figure 1: This is the most water-intensive industrial cooling method wherein the cooling water contacts and lowers the temperature of a heat source and then is discharged to drain. Once-through cooling is prohibited by Guelph’s municipal sewer use bylaws 13791 (1991) and 15202 (1996).

  ![Figure 1: Once-through cooling system – cooling water absorbs heat and is then discharged to waste](image)

- Open recirculating system, Figure 2: Cooling is achieved via use of a cooling tower. After the cooling water picks up heat from the process or equipment, it is sprayed over fill (structured panels with a large surface area) inside the cooling tower where heat is transferred from the cooling water via both a direct energy (sensible heat) exchange between the water and the air and through the evaporation (latent heat) of a portion of the cooling water.

- Closed recirculating system, Figure 3: Cooling is achieved via use of an evaporative condenser. After the cooling liquid picks up heat from the process or equipment it passes through a heat exchanger which itself is cooled by water or air. As with open systems, water lost through evaporation must be replaced.
Figure 3: Open recirculating system where 1) water travels from the cooling tower to the heat exchanger 2) is recirculated back to the cooling tower that 3) promotes evaporation with air to cool the water and 4) uses blowdown to remove some of the water’s impurities.

Figure 2: Using the water to cool, and then using a subsequent heat exchanger to cool the water.
2.2 Description

Cooling towers and evaporative condensers function by evaporating water. They are effective for cooling because they take advantage of water’s high enthalpy of evaporation, which refers to the large amount of heat required to change water from liquid phase to gaseous phase. The amount of water evaporated is related to how much heat is being removed from the system. A rule of thumb for evaporation loss is 6.8 litres per hour of evaporation per ton of cooling (Conservation Mechanical Systems Inc.). Evaporation accounts for the greatest water loss during the operation of a cooling tower or evaporative condenser.

Water can also be lost from the cooling system through splash-out and drift. Drift is the term used for water that is physically removed from the system by the force of air moving through the tower. A rule of thumb for splash/drift loss in a new system is “0.008 percent of recirculating water” (Conservation Mechanical Systems Inc.). Splash-out and drift losses account for the second greatest water loss during the operation of a cooling tower or evaporative condenser.

As stated above, cooling towers and evaporative condensers function by evaporating water. However, the evaporation process increases the concentration of dissolved solids (minerals) in the remaining cooling water. If the concentration becomes too high it can foul or damage the cooling system (scale formation, corrosion, biological growth, etc.) and reduce the efficiency and lifecycle of the system. To help prevent the concentration of suspended and dissolved solids from becoming too high, a portion of the recirculated cooling water (which is high in dissolved solids) is purposely discharged as blowdown and replaced with fresh water. In some cases the blowdown contains not only a high level of dissolved solids but also a high level of toxic materials such as biocides and corrosion inhibitors.

Blowdown is qualified by the term “cycles of concentration”. The cycles of concentration for a system can be calculated as the ratio of the concentration of dissolved solids in the recirculated water to the concentration in the incoming makeup water. For example, if the mineral content in the recirculated water is four times as great as the mineral content in the makeup water, the cycles of concentration for that system would be 4.0. Blowdown accounts for the third greatest water loss during the operation of a cooling tower or evaporative condenser.

The volume of water evaporated by a cooling tower or evaporative condenser is directly related to the amount of heat being removed by the system. The volume of water lost through splash-out and drift is directly related to the system design and maintenance. The volume of water lost through blowdown, however, can be reduced by increasing the cycles of concentration through proper water treatment, or conditioning, of the water.

Operating at higher cycles of concentration requires a lower volume of makeup water. However, the volume of water savings decreases as the level of cycles of concentration increase. For example, increasing cycles of concentration from 5 to 8 will decrease the volume of makeup demand by only about 15 percent as much as increasing the cycles of concentration from 2 to 5 (Figure 4).
2.3 Water Efficiency Options

There are several methods for minimizing the volume of makeup water required, such as:

- **Use of Soft Water Makeup**: Calcium and magnesium are typically the two primary scale formers in a cooling system. Softening the makeup water will remove these ions and enable the cooling tower to run at higher cycles of concentration, thus reducing the volume of blowdown and makeup water required. Soft water, however, is not only corrosive but the cost of producing the soft water (salt, energy, and regeneration water costs) may make using 100 percent soft water makeup uneconomical for a cooling tower. As such, it may be beneficial to use a blend of hard water and soft water as makeup. The most economical balance for the blend would need to be calculated on a case-by-case basis.

- **Acid Feed**: Adding acid to the recirculated water will increase the solubility of calcium and magnesium and allow for higher cycles of concentration to be achieved. Many facilities, however, have acid-handling safety concerns that make them hesitant to use this alternative.

- **Use of Reverse Osmosis Concentrate**: Reverse osmosis concentrate (or reject water) may be blended with potable water for cooling tower makeup. If the water is softened prior to the reverse osmosis process, the concentrate will also be soft water. Reverse osmosis concentrate is often high in alkalinity and care should be taken to avoid mixing it with hard well water as high alkalinity in addition to hardness can result in the formation of scale on heat exchange surfaces.

- **Use of Recycled Wastewater**: Some wastewaters are suitable to use as cooling tower makeup without any extra treatment such as non-contact once-through cooling water. However, since there are often impurities in alternate sources of makeup water that can cause scale build-up, corrosion, and/or microbiological growth in the cooling system, it is important to use the correct form(s) of water treatment. If the quality of the recycled wastewater is variable, it is important to routinely monitor water quality and adjust treatment accordingly. An engineering and

![Bleed vs Cycles](image)

**Figure 4**: Operating a cooling tower with high cycles reduces the water use from bleed rate (**Harfst 2008**).
economic analysis should be completed to determine both the feasibility and potential cost savings associated with using recycled wastewater.

- **Use of Rainwater** – Although unpredictable as a source of water, rainwater can be a viable source of makeup water. Approximately 25 litres of rainwater can be recovered per inch (25 mm) of precipitation per square metre of collection surface. Rainwater from the facility’s roof is directed to a storage tank and then pumped to the cooling tower when needed as makeup water. While rainwater is relatively pure, it may require some treatment (e.g., addition of biocide to reduce microbial growth) or filtering to remove oil and other contaminants prior to use as makeup water.

- **Use of Condensate** – The operation of air conditioning equipment often produces large quantities of cold, nearly distilled condensate from the air handler cooling coils. Because this condensate does not contain the dissolved mineral impurities present in potable water, it will enable the cooling system to operate at higher cycles of concentration.

- **Use of Conductivity Meter** – If the conductivity of the recirculated water is below design parameters, the system will use more water than necessary; if the conductivity is above design parameters, there is an increased risk of scale and corrosion. Having a properly functioning conductivity meter will help keep the system running at the proper conductivity, thereby minimizing blowdown and the volume of makeup water required.

- **Fixing Leaks** – Leaks are uncontrolled water losses that could be considered another form of blowdown. If the system has a properly functioning conductivity meter installed, the volume of water lost through a small leak would be offset by an equal reduction in the volume of blowdown. Leaks start to become a real problem, however, when the rate of leakage exceeds the required blowdown rate and the cycles of concentration or conductivity cannot be maintained. If a cooling system’s blowdown is lower than expected but the system cannot maintain the set conductivity, then there may be excessive leakage in the system.

- **Conversion to Air for Cooling Purposes** – In some cases, it is possible to switch from water cooling to air cooling and remove wasting of water from cooling applications altogether. Factors to consider in switching from water to air include energy efficiency and performance (Alliances for Water Efficiency). Equipment that falls into the air cooling category include air compressors, vacuum pumps, ice machines, refrigeration condensers, hydraulic equipment, and x-ray processing equipment (Alliances for Water Efficiency).

### 2.4 Current Municipal Practice

Some municipalities offer financial rebates to customers that reduce the volume of makeup water used by their cooling towers or evaporative condensers. Because the volume of water savings will vary from system to system and from day to day, it is not possible to accurately predict the level of savings that can be achieved by a system. As such, some communities (including Guelph) offer these types of rebates through their Capacity Buy-Back programs. Other communities that currently offer (or have previously offered) Capacity Buy-Back program include: Region of Peel, City of Toronto, and York Region.

The Region of Waterloo has considered targeting facilities with cooling towers (identified through the use of aerial photos) to offer them cooling system water audits at low or no cost (Region of Waterloo 2013).
The water rates of most municipalities, including Guelph, include both water and wastewater fees. In 2015 Guelph customers paid a water rate of $1.52 and a wastewater rate of $1.66 for every cubic meter of water they received from the City (plus additional fixed fees). This type of billing structure is based on the idea that a significant portion of the water received by a customer is subsequently returned to the City as wastewater that must be treated and discharged back into the environment. In some cases a portion of the water received by a customer is not returned to the City as wastewater, e.g., water used for irrigation or water that is evaporated, and thus there are no related wastewater collection or treatment costs. Some municipalities, e.g., Toronto, offer a sewer surcharge exemption (i.e., a reduction of some or all of the wastewater portion of the water bill) to customers that can prove they do not discharge all of the water they receive into the sanitary sewer. Guelph does not currently offer customers a sewer surcharge exemption, so a customer that reduces their cooling water demand will also reduce their water bill by $3.18 per cubic meter (e.g., $1.52 per cubic meter water and $1.66 per cubic meter for wastewater). Should the City adopt a sewer surcharge exemption in the future, the financial benefit to customers reducing their cooling water demand would be reduced from $3.18 to only $1.52 per cubic meter of savings.

2.5 Benefits and Barriers Associated with Improved Industrial Cooling Efficiency

There are benefits and barriers to implementing water efficient industrial cooling, as presented in Table 2-1.

Table 2-1: Summary of benefits and barriers associated industrial cooling efficiency.

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Barriers</th>
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<tr>
<td>Water savings and lower water costs for industrial customers.</td>
<td>Inertia of industrial customers to evaluate the efficiency of their cooling systems.</td>
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<tr>
<td>Lower municipal peak water demands, which result in increased water capacity as well as lower operational costs related to energy and chemical demands.</td>
<td>Complexity of treatment processes – lack of trained on-site personnel.</td>
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<td>Potential to lower capital costs related to avoided, downsized, or deferred infrastructure.</td>
<td>Potentially high costs associated with using alternative water sources for makeup water and pre-conditioning. Potentially high energy costs in air cooling.</td>
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<td>Potential sharing of efficiency improvement costs if City rebates are provided.</td>
<td>Overall cost of cooling system versus potential cost savings from reduced makeup water may sway customers to ‘err on the side of caution’ regarding the volume of makeup water used (e.g. decide to use more water to avoid scaling and biological fouling).</td>
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3.0 CASE STUDIES

Capital Regional District (British Columbia): between 2007 and 2014, the CRD offered rebates of up to $5,000 as incentives for businesses to replace their once-through water-cooled equipment with non-water-cooled equipment. A total of 200 units were replaced as part of this program with an estimated total annual savings of 745,000 cubic meters of water. The program was cancelled at the end of 2014.

San Antonio Water System (San Antonio, Texas): Audit-based program evaluates commercial, industrial and institutional cooling tower and cooling water systems at no cost. Costs savings related to reduced water usage and sewer charges, reduced corrosion, reduced fouling, and reduced chemical costs are identified. Improvements may be eligible for up to 100 percent of the cost of implementation under the San Antonio Water System Commercial Custom Rebate program (San Antonio Water System).

Denver Water (Colorado): Cooling Tower Performance Rebate Program pays customers $18.50 for every 1,000 gallons (3.78 cubic metres) of water saved below their average consumption over the previous 3 years. Customers can receive 50 percent of project costs up to $40,000. Projects must save a minimum of 50,000 gallons (190 cubic metres) per year to qualify. Sub-meters must be installed on makeup water and blowdown water (Denver Water).

Los Angeles Department of Water and Power (California): Program offers rebates for cooling tower conductivity controllers ($625 per unit), pH/conductivity controllers ($3,000 per unit), and air-cooled ice machines ($1,000 per unit) (Los Angeles Department of Water and Power).

United States Department of Energy: Program offers online guidance on cooling tower management (Best Management Practice #10: Cooling Tower Management) as part of its federal energy management program (United States Department of Energy).

Leadership in Energy and Environmental Design is a worldwide third party certification program. To qualify for Water Efficiency certification (5 points), cooling towers and evaporative condensers for air conditioning systems, such as chilled water systems, must:

- achieve a minimum of 5 cycles of concentration under normal conditions or 4 cycles of concentration if the makeup water hardness exceeds 200 milligrams per litre (11.7 grains per gallon)
- be equipped with makeup and blowdown meters, conductivity controllers and overflow alarms as well as efficient drift eliminators that reduce drift loss to less than, or equal to, 0.001 percent of recirculating water in a counter-flow tower or 0.005 percent in a cross-flow tower use no more than 2.3 gallons (8.7 litres) per ton hour or 2.5 litres per kilowatt hour of potable water for cooling tower or evaporative condenser make-up.

El Dorado Hills, California: offered a $900 rebate to customers installing a conductivity meter, a $450 rebate to customers agreeing to supply and install a water meter on their cooling tower, and a $300 rebate to customers agreeing to read the new meter each month for a 24-month period and send the meter readings to the City (California Urban Water Conservation Council).
Contra Costa Water District: offers rebate of 50 percent of cost of conductivity meter up to $500 (Contra Costa Water District).

4.0 KEY CONSIDERATIONS

There are a number of ways to reduce the volume of makeup water required for cooling towers and evaporative condensers, including properly treating the recirculation water to maximize the cycles of concentration. For example, to qualify for Leadership in Energy and Environmental Design points a cooling tower must operate at a minimum of 5 cycles of concentration (or a minimum of 4 cycles of concentration if the hardness of the makeup water supply is greater than 11.7 grains).

Operating at higher cycles of concentration can reduce the volume of makeup water required (though the savings above a cycles of concentration value of 5 is minimal), it can also increase the potential for scaling and/or fouling which will reduce the effectiveness and efficiency of the system. The installation of a conductivity meter can help maintain the proper cycles of concentration for the cooling system to maximize water savings and minimize the potential for scaling or fouling (Aherne).

The volume of makeup water can also be reduced by lowering the concentration of dissolved minerals in the makeup water supply to the cooling system by blending soft water or air-handling condensate in with the raw potable water supply.

It is also sometimes possible to augment or replace the potable water supply of the cooling system with an alternative supply, such as rainwater, recycled wastewater, or reverse osmosis concentrate. When using or adding alternative water supplies it is important to monitor and treat the chemistry of the recirculation water to minimize the potential for scaling or fouling. A cost-effectiveness evaluation should be done on a case-by-case basis.

Some municipal programs offer rebates to industrial customers that reduce their potable water demands. The rebate level can be based on the volume of water saved (e.g., Capacity Buyback Program) or the cost of implementation to achieve the savings or simply a pre-set value. Some programs require a minimum volume of savings to qualify for a rebate. Some programs offer rebates up to 100 percent towards the installation of a conductivity meter on the cooling system.

Guelph currently provides financial incentives to non-residential customers reducing water demands through the City’s Industrial/Commercial/Institutional Capacity Buyback program. Capacity Buyback programs are considered equitable to customers because the size of the financial incentive is directly related to the magnitude of water savings achieved and maintained by the customer. Providing an incentive based on water savings versus the use of a particular process or piece of equipment helps reduce any liability that might fall to the City if the process or equipment does not meet the customer's expectations. Capacity Buyback programs also allow the greatest level of freedom to the customer to tailor their water savings efforts to meet their specific needs and expectations.
5.0 REFERENCES


