Water best management practices guidebook

Implement, improve and save

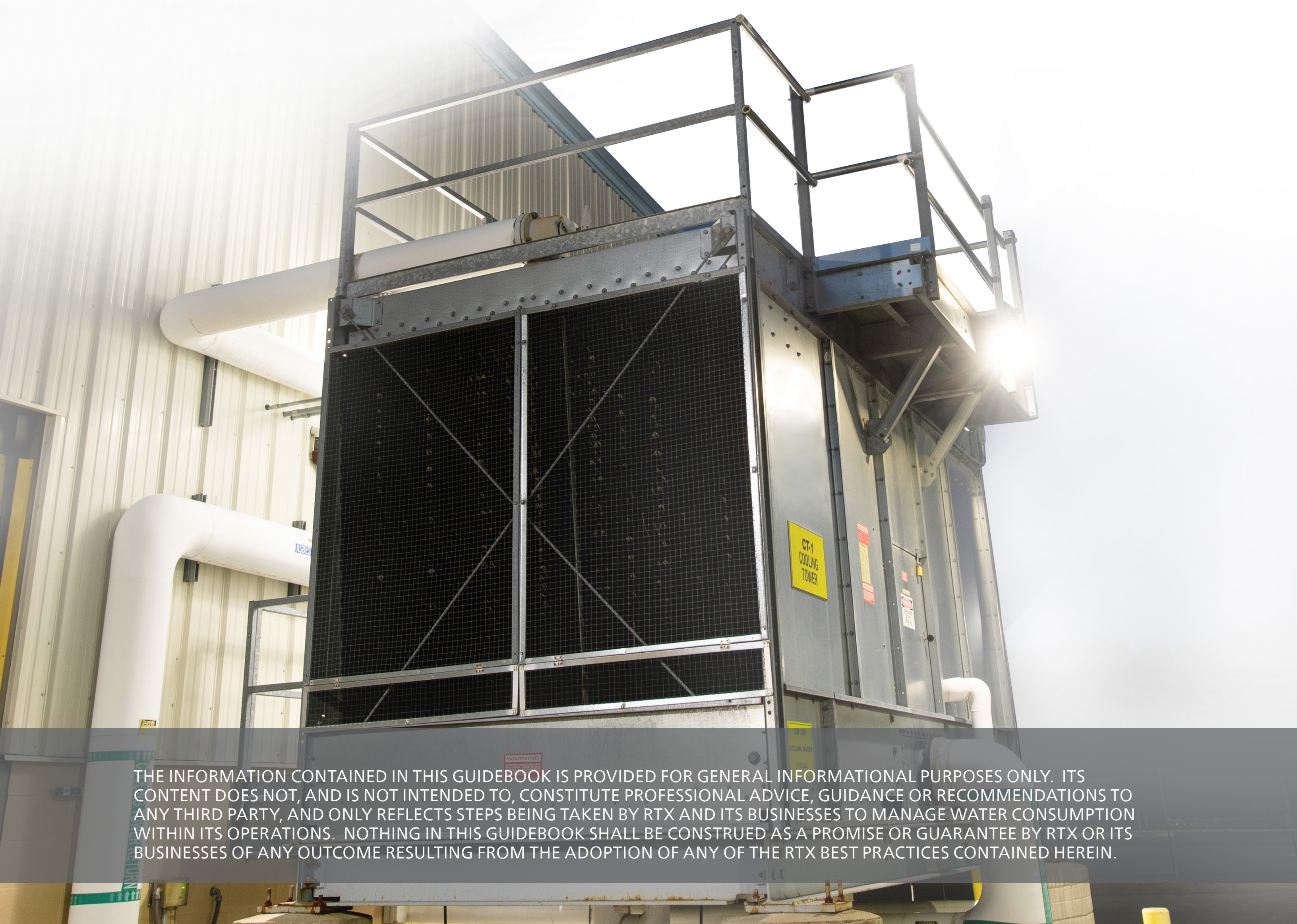


Table of contents

Appendices 58

Introduction

In 2015, we identified 10 water BMPs that we believe represent best-in-class management of water stewardship and water use.

Welcome to the RTX Water Best Management Practices guidebook. The guidebook is designed to provide practical advice on implementing water best management practices (BMPs) at RTX's facilities around the world.

The guidebook follows a simple format. For each BMP, we define the actions that must be taken at the site for a BMP to be considered fully implemented and then provide descriptions and examples of how sites might complete each action. The guidebook is not a standard and is intended to simply provide help in implementing the BMPs.

Water best management practices

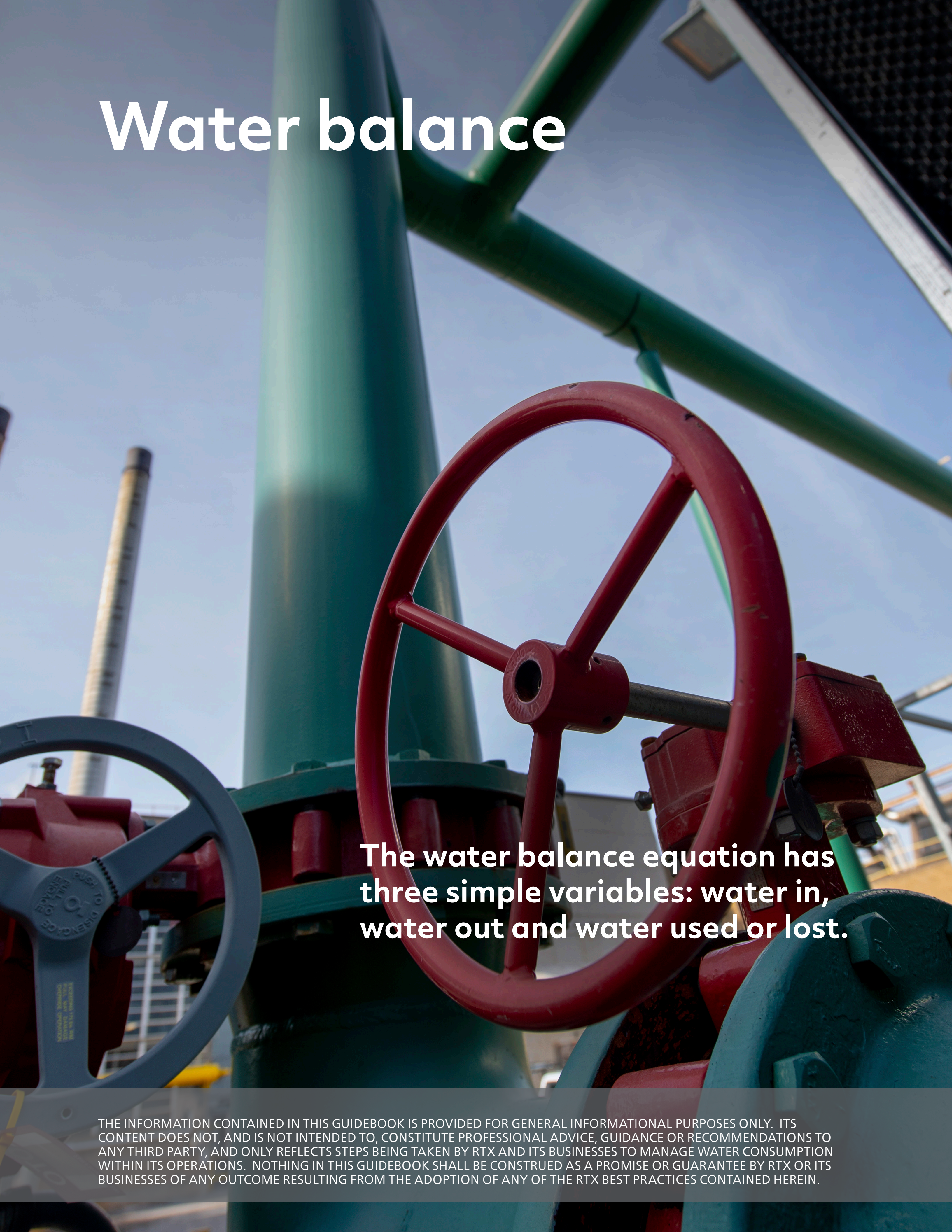
In 2015, working with our businesses and sites, we identified 10 water BMPs that we believe represent best-in-class management of water stewardship and water use at RTX facilities. The BMPs were assessed as being so important to our overall water management success that their implementation is required under the RTX 2020 factory and operations sustainability goal set. The water BMPs are:

- Water balance.
- Leak management.
- Eliminate once-through cooling.
- Cooling tower management.
- Flow meters.
- Low flow fixtures.
- Rinse tank overflow.
- Xeriscaping and irrigation.
- Recycle process wastewater.
- Rainwater harvesting.

In addition to this guidebook, for more information on these and other water best management practices, see the United States Environmental Protection Agency WaterSense Best Management Practices guidebook.[1]

1 EPA WaterSense, Best Management Practices for Commercial and Institutional Facilities. https://www.epa.gov/sites/production/files/2017-02/documents/watersense-at-work_final_508c3.pdf

Water balance



The water balance equation has three simple variables: water in, water out and water used or lost.

Water balance

An equation that is used to describe the flow of water in and out of a system:

Water in – water used = water out

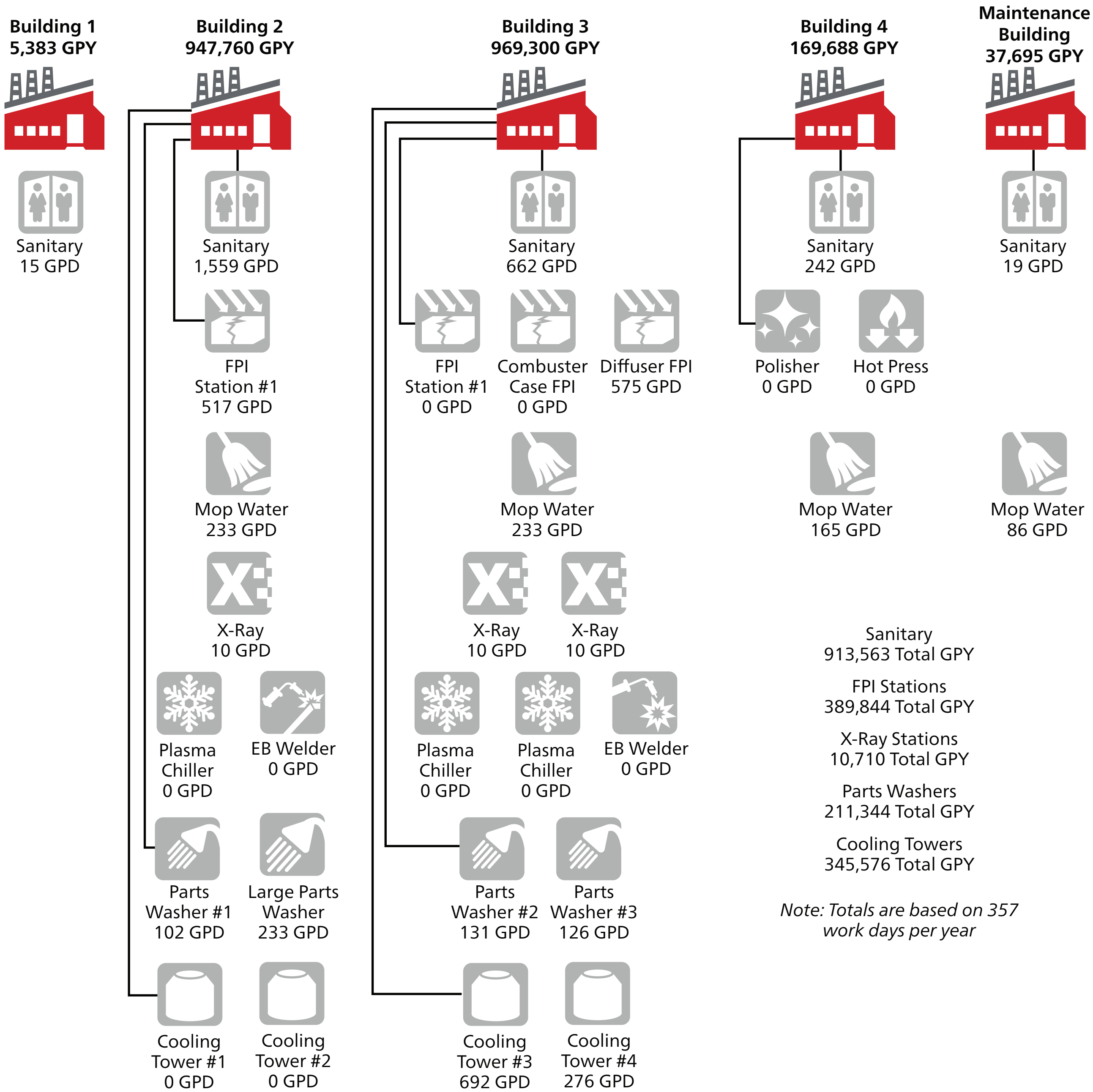
Requirements to implement the BMP

- Written identification of water sources, uses and discharges.
- Simple water balance schematic map.
- Annual review and update of water balance.

The water balance equation has three simple variables. Two of them, water in and water out, should be readily quantifiable through the use of water supply records and meters measuring the sources and amounts of water flowing into and away from the site. The difference between water in and water out is the water used or lost in site processes, including evaporation, leaks and spills. The three variables should balance arithmetically. If they don't then the water balance process requires further investigation to identify the sources of inconsistencies representing 5% or greater of the site's water supply volume. Included in the water balance is a diagram identifying locations where water enters the site, is used, and discharged.

An efficient water balance diagram should be based on a site schematic drawing or blueprint and clearly identify the sources, uses and discharge points of all water used on site, as shown on the next page. Sites should also include a companion table providing the water use in gallons for each input, process and discharge, along with the identification of discharge points, whether or not the discharge is direct (to a receiving water body), indirect (to a sanitary sewer), or discharged to air (via exhaust) or directly to land.

Water Balance Schematic



The water balance of the facility should be calculated and recorded, including the identification of each process and use of water, and reviewed annually. The example below presents a clear and useful water balance format in use by RTX's facilities.

Water Feed Sources:

SOURCE	ANNUAL USAGE (GAL)
Gas-fired 300,000 Btu/h or more	25,500,000
Onsite Well	3,000,000
TOTAL	28,500,000

Water Consumption Sources:

SOURCE	WATER USAGE (GAL)	WASTEWATER DISCHARGE (GAL)	DISCHARGE POINT	DISCHARGE TYPE	RECEIVING WATER BODY
Domestic Sewage	9,500,000	9,500,000	Manhole #1, 2, 4 and 5	Indirect Discharge	Sanitary Sewer System
Cooling Towers	8,250,000	750,000	Manhole #2 and #3 Evaporation	Indirect Discharge Air Discharge	Sanitary Sewer System Building Exhaust System
Process Wastewater:					
Washer #1	1,750,000	1,750,000	Manhole #3	Indirect Discharge	Sanitary Sewer System
Washer #2	1,250,000	1,250,000	Manhole #4	Indirect Discharge	Sanitary Sewer System
Printing Machine	3,000	3,000	Manhole #2	Indirect Discharge	Sanitary Sewer System
Water Reactor #1	2,500,000	2,500,000	Manhole #4	Indirect Discharge	Sanitary Sewer System
Water Reactor #2	1,750,000	1,750,000	Manhole #5	Indirect Discharge	Sanitary Sewer System
Water Reactor #3	1,000,000	1,000,000	Manhole #6	Indirect Discharge	Sanitary Sewer System
Labs	50,000	50,000	Manhole #2, 5 and 6	Indirect Discharge	Sanitary Sewer System
Boilers	1,500,000	434,520	Manhole #1, 3 and 4	Indirect Discharge	Sanitary Sewer System
Air Handlers	0	25,000	Roof Drains	Direct Discharge	Sanitary Sewer System
Air Compressors	0	2,000	Roof Drains Outside Gras	Direct Discharge Direct Discharge	Little River Groundwater
General Floor Washing	5,000	5,000	Manhole #2 and 6	Indirect Discharge	Sanitary Sewer System
Fire Sprinkler Testing	200,000	200,000	Manhole #1-6 Roof Drains Outside Gravel	Indirect Discharge Direct Discharge Land Application	Sanitary Sewer System Little River Groundwater
Power Washing Building	17,000	17,000	Outside Grass	Direct Discharge	Little River
Lawn Irrigation	725,000	0	Outside Grass	Land Application	Groundwater
TOTAL	28,500,000	19,236,520			

Leak management

Leak management is a very important water conservation technique.

Leak management

Leaks can occur in many forms including line, irrigation and valve. Factors that contribute to leaks include aged or poorly constructed pipelines, inadequate corrosion protection, lack of proper system maintenance, incorrect material selection for the site water infrastructure and equipment. Environmental and physical factors such as temperature, velocity, pressure, freezing and thawing also contribute to leak formation.

Requirements to implement the BMP

- Written documentation demonstrating leak management inspections.
- Annual review and log of inspections.

Indicators of a potential leak

- Unusual wet spots in landscaped areas and/or water pooling on the ground surface.
- An area that is green, moldy, soft or mossy surrounded by drier areas.
- A notable drop in water pressure/flow volume.
- A sudden problem with rusty water, dirt or air in the water supply (there are other causes for this besides a leak).
- A portion of an irrigated area suddenly turns brown/dead/dying when it used to be thriving (indicates water pressure is too low to enable irrigation heads at a distance to pop up properly).
- Heaving or cracking of paved areas.
- Sink holes or potholes.
- Uneven floor grade or leaning of a structure.
- Unexplained sudden increase in water use, consistently high water use, or water use that has been climbing at a fairly steady rate for several billing cycles.

A sudden increase in water use is an indication of a potential leak.

In addition to simply walking around the site looking for physical indications of leaks, standard practices and tools are available to help in the leak detection process:

- **Monthly review of sites water balance.** A monthly review of the site water balance variables is an effective way of identifying potential leaks. Any imbalance of ± 5% in the water balance equation warrants investigation.
- **Acoustic loggers.** Acoustic leak loggers are instruments that identify leaks using noise detection, map their location, and support the export of data to spreadsheets and analytical programs. Acoustic loggers can be purchased from $1,000 - $2,000, be rented or will be provided by consultants conducting a leak detection program.
- **In-line leak detectors.** In-line leak detectors are another way of determining if there are any leaks along the water pipes. Leak detector costs range from a few hundred to a few thousand dollars, however, a consultant is often the best resource for utilizing in-line leak detection.

Data loggers. Data loggers record data over time. These products are easy to use and are relatively inexpensive. In addition to the acoustic loggers mentioned above, there are a variety of different data loggers designed for specific types of measurement, including temperature, voltage, carbon monoxide, water, pH and more. The data loggers can retrieve data via wireless connection, Ethernet or USB. The cost of these products can range from a few hundred dollars to upwards of a few thousand.

Equipment malfunction

Equipment malfunction is one of the largest sources of water leakage in factories. These leaks typically persist for long periods of time because they do not interrupt daily factory operations. Over time, the leaked volume can become part of the site's typical monthly water use profile, making it even more difficult to identify. Some common areas where malfunctions occur are:

- Overflow valves or float valves on cooling towers, water features, testing tanks, storage tanks, etc. can malfunction in the open position allowing equipment to continuously overflow water to the sewer.
- By-pass valves can be left open following equipment maintenance, allowing a piece of equipment that is normally on a closed cooling loop to operate in a single pass mode, wasting thousands of gallons of water every day.
- Temperature control valves can fail, causing substantially more water to be passed through a piece of equipment than is necessary to cool it.
- Off/on switches or sensors can stick in the on position, running water through machinery that normally would be shut off when not in use.
- Internal parts can rust-through or separate and allow water to escape and drain from a machine that normally contains and/or re-circulates the water.
- Nozzles that are supposed to shut off can drip continuously or stick in the on position.

Wet areas above an underground pipe can be an indication of a broken pipe or joint.

An indicator of a potential leak is a heaving or cracked area of pavement.

Checking for leaks

Armed with the variety of tools described above, sites should check for leaks using five basic steps:

- Read the water meters, at minimum monthly, and identify any unexplained fluctuations in the amount of water used.
- Inspect irrigation systems for obvious above ground leaks. Extremely wet areas above an underground pipe can be an indication of a broken pipe or joint.
- Examine equipment routinely and look at exposed pipes to see if you can visually see any leaking water. Complete a Water Leak Inspection Checklist (see example on next page) monthly to identify and address all the water leaks including piping joints, toilets, showers, taps, pump seals, hose nozzles, shut-off valves, cooling towers, etc.
- Compare your water usage records with the same month of previous years. While the amount of water used will vary due to weather and processes, look for sharp increases in your consumption that could indicate a leak. These would include any unexplained variation/increase in monthly water use over 20% or deviation greater than 10% for several months.

Responsibility for leaks

The property owner and/or occupant is typically responsible for the installation, repair, maintenance and replacement of all private fittings and pipes that run from the property up to the water meter's outlet riser. If a leak is found in any of these pipes, it is the property owner and/or occupant's responsibility to have it repaired. If the stop tap malfunctions as a result of misuse by the property owner and/or occupant, the utility company will not accept responsibility for water loss or damage.

The utility company is typically responsible for the maintenance and repair of the water meter and any pipes that lead away from the water meter to the water main.

Water leak inspection checklist

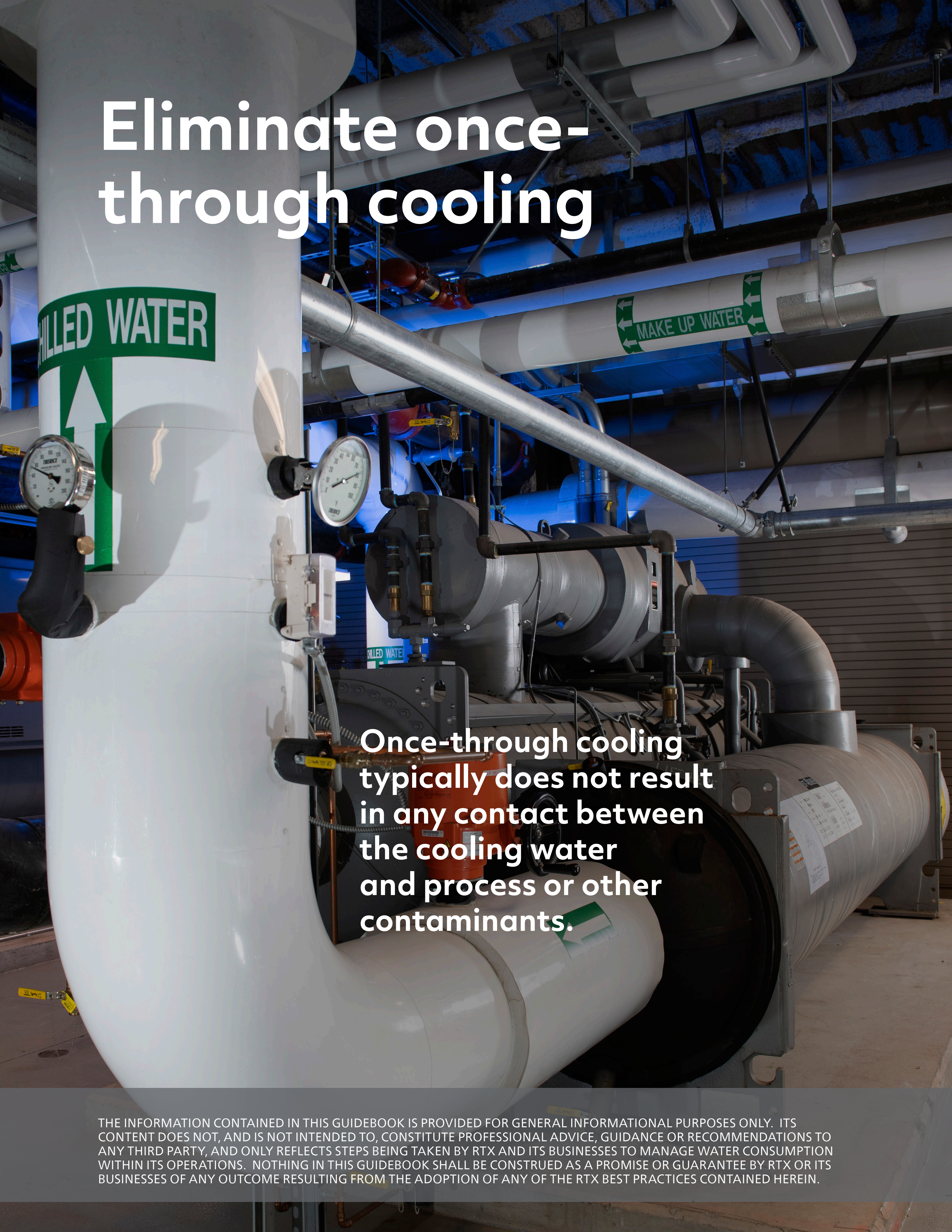
A checklist should be used monthly to document the site's water leak inspection activities and any resulting leaks or areas of concern. This checklist will provide a starting point for determining possible water management actions at your facility. Sites should modify the list as needed to make it more applicable to site conditions.

Water leak inspection checklist:

	SOURCE	YES	NO	N/A	COMMENTS
1.	Water meter reading indicates an unexplainable increase in the amount of water used at site				
Underground Leak Inspection					
2.	Unusually wet spots in landscaped areas and/or water pooling on the ground surface				
3.	An area that is green, moldy, soft, or mossy surrounded by drier conditions				
4.	A notable drop in water pressure/flow volume				
5.	A sudden problem with rusty water, dirt, or air in the water supply (there are other causes for this besides a leak)				
6.	A portion of an irrigated area is suddenly brown/dead/dying when it used to be thriving (water pressure is too low to enable distant heads to pop up properly)				
7.	Heaving or cracking of paved areas				
8.	Sink holes or potholes				
9.	Uneven floor grade or leaning of a structure				
10.	Unexplained sudden increase in water use, consistently high water use, or water use that has been climbing at a fairly steady rate for several billing cycles				
Equipment Malfunctions					
11.	Overflow valves or float valves on cooling towers, water features, testing tanks, storage tanks, etc. can malfunction in the open position allowing equipment to continuously overflow water to the sewer				
12.	By-pass valves can be left open following equipment maintenance, allowing a piece of equipment that is normally on a closed cooling loop to operate in a single pass mode, wasting thousands of gallons of water every day				
13.	Temperature control valves fail, causing substantially more water to be passed through a piece of equipment than is necessary to cool it sufficiently				

	SOURCE	YES	NO	N/A	COMMENTS
14.	Off/on switches or sensors can stick in the on position, running water through machinery that normally would be shut off when not in use				
15.	Rusting through or separation of internal parts that allow water to escape and drain from a machine that normally contains and/or re-circulates the water				
16.	Nozzles that are supposed to shut off drip continuously or stick on.				
Other					
17.	Examine equipment routinely and look at exposed pipes to see if you can visually see any leaking water				
INSPECTOR NAME					DATE

Eliminate once-through cooling



Once-through cooling typically does not result in any contact between the cooling water and process or other contaminants.

Once-through cooling

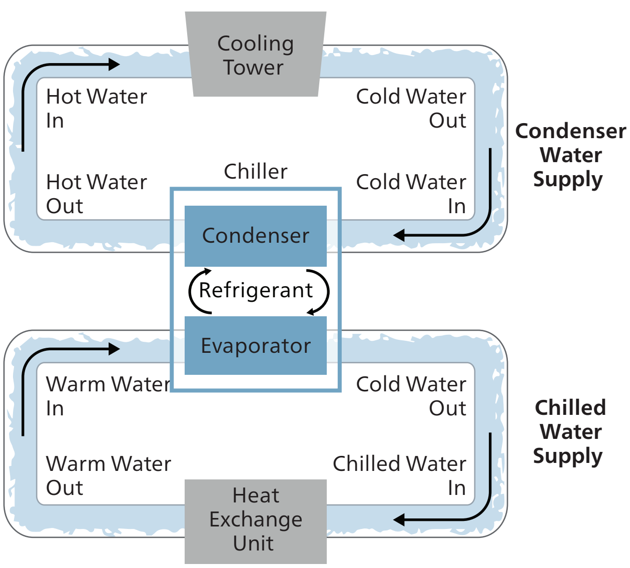
A cooling system that takes water from the local environment and uses it to absorb heat onsite before it is discharged into the atmosphere through evaporation or back into the source body. This cooling system has negative effects when the returning water is warmer than the receiving body, causing localized warming. Once-through cooling typically does not result in any contact between the cooling water and the process or other contaminants, therefore the quality of water returned to the source body should not be an issue. Discharged water should be occasionally sampled (or as required by permit) to assure that no process contamination is occurring. The presence of unanticipated contaminants should be immediately investigated and, depending on the type and amount of contaminants, the discharge of water back to the source body should cease.

Requirements to implement the BMP

- Written identification of all sources of once-through cooling in water balance schematic diagram.
- Measurement of once-through cooling water used from a predetermined baseline.
- Reduce once-through cooling by 50% of a predetermined baseline.

Alternatives to once-through cooling[1]

- **Closed-cycle cooling.** Closed-cycle cooling uses the same concept as once-through cooling, except the warmed water does not return back to the source from which it was taken. Instead, the water is cycled through a cooling tower where the heat is discharged through evaporation. Due to the water loss from evaporation, more water has to be withdrawn as "make-up" water to replace the lost water.
- **Dry cooling system.** This uses the same concept as closed-cycle cooling except that evaporative cooling is replaced by dry cooling towers, which use the ambient air to cool the water and results in no water loss through evaporation.
- **Hybrid cooling system.** Combines dry cooling and closed-cycle cooling.



Example setup of a closed-cycle cooling system to eliminate once through cooling.[2]

1 National Resource Defense Council (NRDC), Power Plant Cooling and Associated Impacts. https://www.nrdc.org/sites/default/files/power-plant-cooling-IB.pdf
2 EPA, Tackling WaterSense Mechanical Machines. https://www.epa.gov/sites/production/files/2017-01/documents/ws-commercial-webinar-slides-mechanical.pdf

Cooling tower management

A key parameter used to evaluate cooling tower operation is 'cycles of concentration.'

Cooling tower

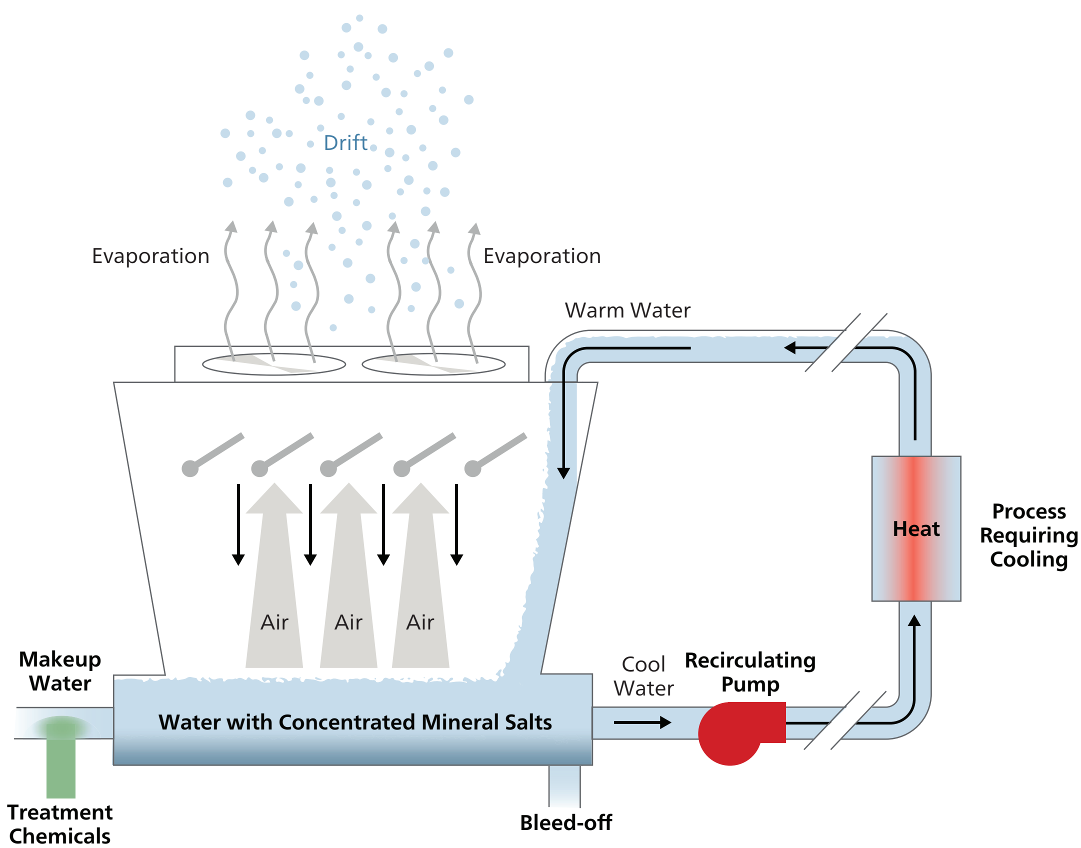
A cooling tower is a heat rejection device where the heated cooling water stream releases waste heat to the lower temperature atmosphere.

What is a cooling tower and what does it do?

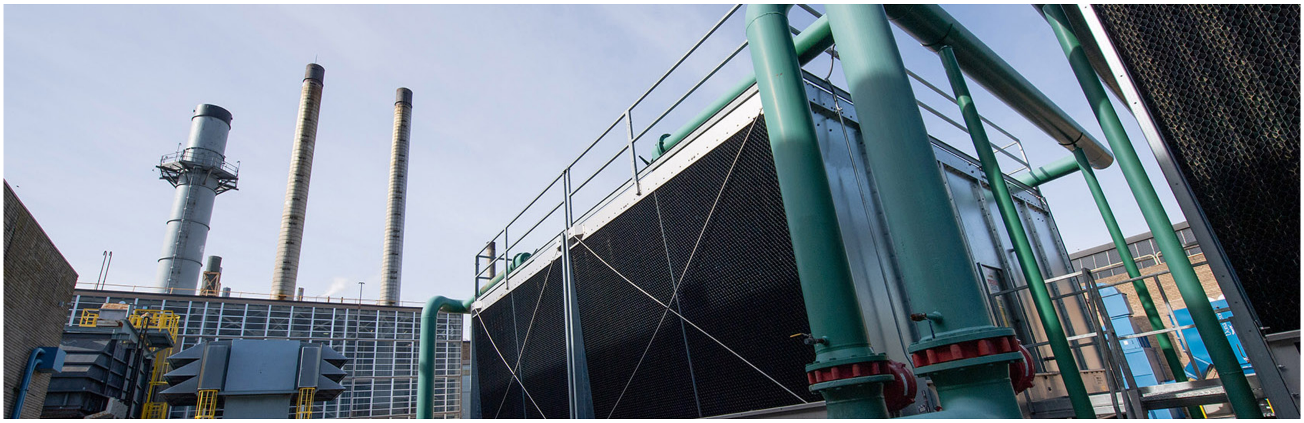
Cooling towers regulate temperature by dissipating heat from recirculating water used to cool chillers, air-conditioning equipment, or other process equipment. Heat is rejected from the tower primarily through evaporation. Therefore, by design, cooling towers consume significant amounts of water. The thermal efficiency and longevity of the cooling tower and equipment depends on the proper management of water recirculated through the tower.

Requirements to implement the BMP

- Written site cooling tower management plan including:
  - Identification of equipment.
  - Annual water use.
  - Evaporation management rates.
  - Drift.
  - Blowdown.
  - Basin leaks.
  - Water chemistry.
  - Cycles of concentration.
  - Measurement.
  - Inspection.
  - 100% of cooling tower capacity has controls installed.



Cooling tower water balance and components.



Water loss

Water leaves a cooling tower in one of four ways:

1. **Evaporation.** This is the primary function of the tower. It is the method that transfers heat from the cooling tower system to the environment.

Example:

A cooling tower circulates 200 gallons per minute (GPM) with a 10° F temperature difference

Evaporation = 0.00085 × recirculation rate (GPM) × conditioned water temperature difference

Evaporation = 0.00085 × 200 GPM × 10° F

Evaporation = 1.7 GPM (102 gallons per hour)

Assuming 2,000 hours per year at full load equivalent = 204,000 gallons per year of evaporated water from the cooling tower

2. **Blowdown or bleed-off.** Blowdown is the periodic removal of water from a cooling tower. As a result of water evaporating from the tower, the remaining tower water can develop elevated concentrations of dissolved solids (such as calcium, magnesium, chloride, and silica). As more water evaporates, the concentration of dissolved solids increases. If the concentration gets too high, the solids can come out of the solution and cause scale on the system or lead to corrosion problems. The concentration of dissolved solids is controlled by removing (blowing-down) water from the tower and replacing this water with cleaner water. Carefully monitoring and controlling the quantity of blowdown provides the most significant opportunity to conserve water in cooling tower operations. A proper water treatment program will minimize blowdown.

3. **Drift.** A small quantity of water may be carried from the tower as mist or small droplets. Drift loss is small compared to evaporation and blowdown, and is controlled with baffles and drift eliminators. Drift is generally assumed to be zero in a water balance; however quantifying the amount of drift may be a permit requirement in some countries and U.S. states.

4. **Basin leaks, basin overflows, or system leaks.** Properly operated systems should not have leaks or overflows.

The sum total of water that is lost from the tower must be replaced by make-up water:

Make-up water = evaporation + blowdown + drift + leaks

Cycles of concentration

A key parameter used to evaluate cooling tower operation is 'cycles of concentration' (sometimes referred to as cycles, concentration ratio, or COC). Cycles of concentration is typically measured using conductivity (i.e., dissolved solids). Conductivity is easy to measure and is one of the first things to cause problems in a cooling tower. This is a calculated ratio of the concentration of total dissolved solids, TDS, (or conductivity) in the blowdown water divided by the concentration in the make-up water. If the tower is operating properly, the cycles of concentration will approximately equal the volumetric ratio of water blowdown to water make-up since dissolved solids enter the system in the make-up water and exit the system in the blowdown water.

$$\frac{TDS_{blowdown}}{TDS_{make\text{-}up}} = \frac{\text{volume water}_{make\text{-}up}}{\text{volume water}_{blowdown}}$$

Therefore, from a water efficiency standpoint, you want to maximize your cycles of concentration, which will minimize your blowdown water quantity and reduce your make-up water demand. However, this can only be done within the constraints of your make-up water and cooling tower water chemistry. As cycles of concentration increase, dissolved solids increase, which can cause scale and corrosion problems unless they are carefully controlled.

Operation and maintenance options

All facilities with cooling towers should have a staff member responsible for the program who understands cooling tower water treatment chemistry and how to properly operate controllers.

Water reduction opportunities

In addition to carefully controlling blowdown, other water reduction opportunities arise from using alternate sources of make-up water. Sometimes water from other equipment within a facility can be recycled and reused for cooling tower make-up with little or no pre-treatment, including:

- Air handler condensate (water that collects when warm, moist air passes over the cooling coils in air handler units). Air handler condensate can be used as make-up water but it is quite corrosive and must be carefully accounted for in the water treatment program. Consult a water treatment specialist before using air handler condensate.
- Pretreated effluent from other processes, provided that all chemicals used are compatible with the cooling tower system.
- High-quality municipal wastewater effluent or recycled water (where available).
- Water used in a once-through cooling system.
- Improving energy efficiency in your operations will generally decrease the load on your cooling tower and also reduce water lost through evaporation.

Meter usage

Water usage meters for both makeup and blowdown water should be installed and usage should be recorded regularly. The volume of blowdown should be approximately 10 to 20% of the makeup water, but can be more or less depending on the quality of the makeup water.

If water usage is excessive when using an automated makeup water system, check the operation of the blowdown controller and makeup (float) valve. Measure the amount of water lost to evaporation. Some water utilities will provide a credit towards your sewer charges for the evaporative loss, measured as the difference between metered makeup water minus metered blowdown water.

Install automatic controls

Install a conductivity controller and a pH controller to automatically regulate blowdown and chemical additions. Controllers that automatically monitor the concentration of dissolved solids and pH and then bleed water or add chemicals as appropriate can contribute to savings in chemical and water usage, reduce the labor requirements associated with manual control and cleaning, and help avoid premature equipment failure. Operational and feed controllers should be checked regularly to ensure proper operation.

Manually-based cooling tower control systems often have more personnel and moving equipment parts than automated systems. Consequently diagnosing excessive water use in a manually based system will usually require a more extensive investigation that must also include assessment of system operator practices.

Cooling tower water treatment chemistry

Cooling tower water treatment programs are developed to control corrosion, scale, and biological growth and should be based on the incoming (makeup) water's characteristics. The objective of the program is to understand the characteristics of a healthy cooling tower and recognize the physical and chemical signs of cooling tower problems.

A proper cooling tower program customizes and optimizes overall system performance. By understanding and closely monitoring a cooling tower's chemistry you will reduce water usage and increase tower efficiency (energy/GHG reduction). While water chemistry differs for each tower, there are some water treatment axioms to remember:

1. Alkalinity and pH are proportional. As alkalinity increases, pH should also.
2. In a healthy cooling tower, total alkalinity (ppm) + total hardness (ppm) should be about < 1000 ppm. Factors influencing this number within the cooling tower:
    a. Silica concentration – must be less than 150 ppm (or precipitates out).
    b. Sulfate concentration – must be less than 100 ppm (or smells bad).
    c. Chloride concentration – must be compatible with the piping material to avoid degradation of the piping material or the creation of a brackish condition.

These axioms support the conservative maximum corrosion specifications (allowable annual pipe reduction) of:

- 1 mil (a 'milli-inch' or a 'thousandth of one inch' equal to 0.001 inches) for copper.
- 5 mil for mild steel.

For each cooling tower, establish a baseline measurement that includes measuring the volume of makeup and blowdown water and assessing the water mineral balance to understand the following parameters:

PARAMETER	UNITS*
Calcium Hardness	as CaCO3 ppm
Total Hardness	as CaCO3 ppm
Total (M) Alkalinity	as CaCO3 ppm
Conductivity	µmhos/cm

*1 ppm may also be reported as milligrams per liter (mg/l).

PARAMETER	UNITS*
Silica	as SiO2 ppm
pH	Standard Units
Total Dissolved Solids	ppm
Iron	as Fe ppm
Chlorides	as Cl ppm
Sulfate	as SO4 ppm

If makeup water comes from a single source, the makeup water only needs to be tested once; however, each tower needs its own water analyzed. These baseline measurements only need to be done initially. Once a treatment program is running smoothly, routine testing, monitoring, and inspection will provide all required data.

The chemical analysis should be conducted by an independent laboratory proficient in water testing. The resulting data will tell you a lot about how the tower is operating and if it's operating at maximum efficiency given the properties of your makeup water.

The mineral balance is a comparative mass balance on a mineral-by-mineral basis using concentration ratios. Each mineral's ratio is equal to the tower concentration divided by the makeup water concentration. The analysis will identify the dissolved materials that are most likely to precipitate out of the tower water first, specifically:

- Calcium hardness.
- Total hardness.
- Alkalinity.
- Conductivity.

The tower is in balance if the calcium hardness, total hardness, alkalinity, and conductivity concentration ratios are all approximately within + 0.5 each other. If the ratios are close to each other, but not within + 0.5 each other, the tower is probably operating okay, but also presents opportunities for optimization or better control.

Cooling tower water chemistry example

TOWER WATER (BLOWDOWN)	MAKEUP WATER	TOWER WATER (BLOW DOWN)	CONCENTRATION RATIO
Total hardness (ppm)	40	759	18.98
Total alkalinity (ppm)	12.1	91.8	7.59
Conductivity (ppm)	117	1,749	14.95
Total dissolved solids (ppm)	72	1,158	16.08
Silica (ppm)	4.9	87.3	17.82
Large pneumatic clamps (10 min each/hr)	8.1	8.1	N/A

In this example, hardness, conductivity, total dissolved solids, and silica ratios seem to be close but alkalinity seems significantly different (point of inquiry #1).

Remember, as alkalinity increases, pH should as well. In this example, the cooling tower alkalinity is higher than in the makeup water but pH remains constant, so something is depressing pH in the tower (point of inquiry #2). Only the addition of an acid can lower pH in a cooling tower.

Since the sum of the total alkalinity and total hardness in the cooling tower is less than 1000 ppm, the system is operating within acceptable parameters, but not optimally.

Notes:

- Ensure that nothing externally is getting into the cooling tower water such as process leakages and oil or acid dumps. Typically the volume of rainwater which enters the system has a negligible effect.
- Assuming no external chemical sources, the fact that the hardness, alkalinity, silica and

total dissolved solids cycles of concentration are near each other but not within + 0.5 may be an indication that automatic controls (if present) are not properly set for blowdown and chemical additions.

- When one or more of the COCs is not in balance, there may be numerous potential causes requiring further investigation.
- Less than 1 ppm of iron in the makeup water is normally not a problem. Corrosion inhibitors typically encapsulate any iron in the system. High iron oxide concentrations in chilled water systems (or condensate return in steam systems) can be an indicator that the pipes are leaching iron or corrosion control is not sufficient.

Testing program

Regularly test water quality and log results. At a minimum, use a hand-held conductivity meter to track conductivity of sump (tower) water and log results daily until an automated system can be properly installed. Monitor trends to spot deterioration in performance.

Prior to conducting periodic water quality sampling, calibrate your handheld conductivity meter to a known standard prior to use. Then take your calibrated handheld meter and compare readings to the automated controller. If readings differ clean the controller probes and recheck the calibration.

Biological testing – Biological testing should be conducted on a weekly schedule using dip slides. In a healthy cooling tower, biological plate counts should be as follows:

- Aerobic – less than 1×10^4 cfu/ml (colony forming units per milliliter).
- Anaerobic – less than 1×10^3 cfu/ml.
- Yeast – zero.
- Mold – zero.

Dip slides should be incubated for the specified time and temperature as required by the manufacturer. Check expiration dates and ensure that the agar on the dip slide is not falling off the paddle or has not shrunk.

The results should be used to determine effectiveness of biocide and adjust amounts as needed. Biocide effectiveness is a function of volume and contact time and is measured in terms of half life. A biocide half-life of nine days is excellent.

Two types of biocides are typically available. Chemical biocides are applied to cooling tower systems, usually alternating between oxidizing and non-oxidizing types. Oxidizing biocides are normally used for bulk water sterilization and non-oxidizing biocides are used for under deposit bacteria and slime control. The Cooling Tower Institute recommends continuous or semi-continuous feed of an oxidizing biocide supplemented with a non-oxidizing biocide. To ensure maximum effectiveness, it is a best practice to pre-bleed or blowdown prior to the addition of biocides to cooling tower water systems. Automatic control systems can be programmed to accomplish this.

Please note that biological testing is increasingly important in regions with warmer, sunnier climates, since those conditions are conducive to biological contaminant growth in cooling towers.

Corrosion test – Corrosion test scheduling depends on the maturity of the chemical management program. It typically consists of testing for the concentrations of corrosion inhibitor(s) as compared to the range specified by the chemical manufacturer. Most manufacturers test for phosphates, which prevent mild steel corrosion, and azoles, which prevent copper corrosion, although alternative testing proxies have been developed.

Corrosion testing should be conducted using a coupon rack, which consists of an external rack holding carefully machined small thin bars of the representative metals in your system, typically copper, mild steel

and galvanized zinc. Coupon racks should be placed in the main circulating loop and be removed and replaced every 90 days. For testing, each coupon should be sent to an independent laboratory in its original packaging, since that envelope includes the initial weight against which the coupon will be compared. Typically, the test will use ASTM Method G1-81 for its standard. The laboratory reports include initial and final weights along with annual corrosion rates in mills per year (mpy) based on the weight change.

Coupon racks should have strainers prior to the rack to remove any debris and be cleaned weekly during routine sampling rounds. The racks also require a 5 gallon per minute (gpm) flow across them to be effective. It is a best practice to meter the flow with a rotameter.

Using coupon racks to test for corrosion is a reliable indicator of corrosion but has its limitations due to the temperature and turbulence of where they are installed. An annual visual inspection is required to complement this test.

Warning signs

Corrosion problems can be indicated by various physical phenomena. If any of these items are occurring at your facility, it may be an indication that your water treatment program or testing regime needs to be evaluated. This could be a mechanical or operational issue.

- Connections at the isolation valves to various cooling units show corrosion product at the threads.
- Pinholes in some of the smallest diameter piping in supplemental air conditioning cooling requires replacement.
- Copper cooling coils have failed due to pinholes.
- Blow down on a regular basis produces a high quantity of iron oxide before the water finally runs clean.
- Rust and scale accumulates in the cooling tower pans sufficient to require periodic removal.
- Vendors and consultants can offer other pieces of equipment to assist in monitoring cooling tower water quality, including deposition monitors, sessile bacteria monitors, and corrosiveness meters. These units can be expensive and difficult to operate. Be sure to thoroughly evaluate the benefits and maintenance needs of all monitoring equipment before purchasing.

Annual maintenance

Inspections are the best way to assure that no damage is being done to important surfaces. Cooling towers should be drained and inspected annually for corrosion and scale. Equipment connected to the cooling tower system, such as heat exchangers or chillers, should also be inspected, along with the chiller tube sheet, condenser tubes, and end bell. In some cases, a borescope may be used to create a video record of the tube inspection.

One of the most effective and cost efficient methods of testing heat exchanger tubing systems is through the eddy current method, which is a non-destructive test to locate faults such as pitting, cracking, wear and erosion. Since it is up to the technician to interpret the information provided by the probe used in the method, only properly qualified technicians should be used to conduct this annual test.

Your maintenance program should include cleaning all heat exchanger surfaces. The equipment will gain efficiency and achieve energy reductions. Also include a comprehensive air handler coil maintenance program in which a qualified HVAC technician will change filters during quarterly inspections and remove any dirt, debris, or algae found on the coil(s).

Regulatory compliance

Cooling towers are operated in compliance with all environmental, health and safety legal and regulatory requirements. These typically focus on two key items:

- **Blowdown piping.** Ensure that all blowdown water is discharged in accordance with all government regulations and permit requirements. Make sure that any sanitary or storm permits allow the discharge and that the local permitting authority has approved the treatment program as required.
- **Overflow piping.** Sometimes cooling towers are equipped with basin overflows that allow treated water to exit the tower independent of the blowdown piping if the water in the tower exceeds a certain level. This piping is typically open-ended and allows treated water to be directly discharged onto the roof or the ground. In most cases, a wastewater discharge permit will be required. Make sure that all overflow piping is either eliminated or properly permitted. In some countries and U.S. states, overflow is considered a spill if the treated water reaches the ground or a storm drain. In the U.S., overflow pipes must also be noted in the Storm Water Pollution Prevention Plan (SWPPP) as a non-storm water source.

Some local Health Departments require biological additives for Legionella and other specific hazards. Check your local authority for requirements.

Each chemical source to your water treatment program must have secondary containment. The capacity of that containment should be at least 110% of the largest container stored within it. It is a best practice to never allow chemical storage amounts to exceed a two month inventory.

Water treatment vendor selection

Cooling tower chemical vendors and consultants can provide significant program support. Ask the vendors to estimate the quantities and costs of treatment chemicals, volumes of blowdown water, and expected cycles of concentration to ensure you are getting the best value. Get quotes from multiple vendors with a good reputation. Also, if possible, establish a contract with a vendor that is chemical volume independent. This type of contract effectively encourages the vendor to use the least amount of chemicals necessary to maintain water quality. Vendors should be selected based on cost to treat 1000 gallons of makeup water and the highest recommended system water cycle of concentration.

Retrofit options

Pretreatment of makeup water

The first consideration in makeup water pretreatment is to filter the incoming water to remove basic solids. Depending upon the constituents of the makeup water, significant water savings may be achieved through the pretreatment of this water. All pretreatment programs are based on reducing the constituents that would precipitate out of the makeup water first (hardness, silica or alkalinity) as tower cycles of concentrations increase. The treated water quality can then be used to determine the maximum allowable cycles of concentration necessary to keep the tower scale-free.

Water softeners should be used when the water hardness is greater than alkalinity and, alternatively, acid should be used to drop the pH when alkalinity is greater than hardness. Silica, while not typically the initial rate-determining element in the makeup water, usually becomes the limiting factor after pretreatment.

Silica's cooling tower saturation index is 150 ppm. That means if you have silica in the raw water at 10 ppm, one can only cycle it up 15 times before it reaches saturation of 150 ppm and begins to precipitate out of solution in the form of calcium silicate scale.

The following is an example of water requiring pre-treatment through use of a water softener:

	MAKEUP WATER	TOWER WATER (BLOW DOWN)	CYCLES OF CONCENTRATION (COC)
Total hardness (ppm)	40	759	18.98
Total alkalinity (ppm)	12.1	91.8	7.59
Conductivity (ppm)	117	1,749	14.95
Silica (ppm)	4.9	87.3	17.82

This example facility is currently averaging approximately 17 cycles (average of 18.98, 14.95, 16.08, and 17.82). Note that we do not include alkalinity in our average because we know the alkalinity cycles are an issue, as previously discussed in the water chemistry section.

As the cycles increase, the first mineral to help the tower reach the 1000 ppm limit (hardness plus alkalinity) is total hardness. At this point we could use an ion exchange resin water softener to partially soften the water to allow elevated cycles of concentration above 17.

After we soften the makeup water, silica will reach its saturation index at approximately 30 cycles (That's 150 / 4.88 = 30.738 and round down to be conservative). We would now use 30 cycles as our benchmark to determine how much softener to add to the incoming water.

	MAKEUP WATER	POST WATER SOFTENER	CONCENTRATION AT 30 CYCLES
Total hardness (ppm)	40	20	600
Total alkalinity (ppm)	12.1	2.1	363
Silica (ppm)	4.9	147	147

Notice that partially softening the water from 40 ppm hardness to 20 ppm still allows for total hardness plus total alkalinity to be below 1000 (600+363 = 963). This is an iterative calculation best done on a spreadsheet. Now we check our other critical pieces:

- Silica is less than 150, we based the calculation on this principle
- Chloride in the makeup is 10.3 ppm, at 30 cycles of concentration = 309 ppm (ok since less than 1000 ppm)
- Sulfate in the makeup is 1.0 ppm, at 30 cycles of concentration = 30 ppm (ok since less than 100 ppm)

As previously noted, the facility is currently averaging approximately 17 cycles but can go up to 30 cycles with a partial water softener.

This means that the facility can reduce their blowdown by over 40% (1-17/30 = 0.43).

Note that iron concentrations of over 1 ppm in the makeup water can foul these resin systems. The most effective way to keep iron fouling to a minimum is the use of a salt that contains a cleaning agent.

Acid addition example:

	MAKEUP WATER
Total hardness (ppm)	159
Total alkalinity (ppm)	303
Silica (ppm)	8.4

In this example, the first substance to help us reach the 1000 ppm limit is alkalinity. Alkalinity is typically controlled by adding acid, usually sulfuric, to the makeup water to ensure proper mixing. Note that if sulfates in the makeup water are too high, use hydrochloric acid so that calcium sulfate deposition does not occur. For safety purposes, the acid addition should be automated, using a timer or continuous pH monitoring via instrumentation. Lowering pH may require you to add a corrosion inhibitor.

Reduce system strain

Sunlight exposure should be considered when siting a tower and assessing cooling tower designs.

Side stream filtration

Cooling towers are subject to dust, pollen and other airborne contaminants. The use of side stream filters is strongly recommended. Side stream filters are comprised of a rapid sand filter or high-efficiency cartridge filter to cleanse water. These systems draw water from the sump, filter out sediments and return the filtered water to the tower. This enables the system to operate more efficiently with less water and chemicals.

Ozonation

This technology is seldom used due to the high potential of corrosion. It may be a consideration for some tower systems. A small amount of ozone acts as a powerful biocide that decreases or nearly eliminates the need to remove quantities of water from the cooling tower in order to decrease the concentration of organic and mineral solids in the system. Ozone treatment can also reduce the need for chemical additives and minimize the biofilm build up on heat exchanger surfaces. But corrosion rates WILL increase and require additional corrosion inhibitors to protect the system, thereby sometimes increasing overall chemical costs beyond what additional biocide would cost.

Cooling towers associated with chillers for air-conditioning are good candidates for ozone application, as are those with the following conditions:

- The cost of the chemical treatment program is high.
- Chemical management is burdensome.
- The handling of water treatment chemicals raises significant safety concerns.
- Current chemical water treatment is not completely effective or satisfactory.
- Water and sewer charges are high or increasing.
- Local regulations require blowdown to be treated before discharge to surface waters.

Replacement options

New cooling tower designs and improved materials can significantly reduce the water and energy requirements for cooling. When replacing a cooling tower, determine if fire protection, such as a sprinkler system is required. Placing stainless steel barriers between tower cells may result in reduced insurance rates. Since replacing a cooling tower involves significant capital costs, the facility should investigate every retrofit and operation and maintenance option available and compare their costs and benefits to a new tower.

Additional information

The proper management of cooling tower water quality can include a variety of technologies, practices and procedures. This guidebook attempts to describe the basics as found at many RTX sites, and it should be noted that outside consulting or chemical treatment vendor help are advisable for maximizing cooling tower performance. Some additional considerations include:

Water meter selection and installation guidelines

The type of meter applicable to a system is generally a function of feed water temperature and pressure. Meters should be sized according to anticipated water flows and not the size of the pipe where the meter is to be installed. Choke flow problems may occur; however, if you drop below half the size of the line, e.g., the smallest meter that can be installed is a 1-inch meter on a 2-inch diameter pipe.

SIZE	FLOWS
¾-inch	1-20 gpm
1-inch	2-50 gpm
1.5-inch	3-85 gpm

Municipal water pressure is typically delivered in the range of 65-80 psi. If this is the case, use a 1.5-inch meter for the makeup pipe if the source water is from the main municipal water supply.

Typically, blowdown is piped just after the recirculating pump and will be approximately 25 psi. If this is the case, use a 1-inch meter for blowdown.

Placement of water meters is also critical for meter accuracy. While you should check with each manufacturer's individual meter requirements, in general a water meter requires 10 to 20 pipe diameters upstream and downstream to avoid turbulent flow.

To digitally collect data, meters should have a replaceable Reid switch output for connection to a totalizer, a programmable logic controller, or other data collection device.

Couplings should be used to make a water-tight seal around the wire penetration in the water meter casing. In addition, a strain relief device should be used for the wire penetration into the meter casing.

Oxidizing and non-oxidizing biocides program notes

All water treatment vendors sell their own proprietary chemical program mixtures. This section discusses only the most common ones.

Oxidizing biocides

Oxidizing biocides like chlorine and bromine are usually applied continuously in a system and may be used in combination with non-oxidizing biocides. Non-oxidizing biocides are chemicals that kill microbes by means other than oxidation. Non-oxidizing biocides are slug fed to a system on a routine basis to establish a target concentration. Biological control programs may involve different combinations of oxidizing and non-oxidizing biocides. Every species of microbe has different resistance to each oxidizing and non-oxidizing biocide, so effective applications are largely dependent upon the native environment. The non-oxidizing biocide type should be switched when the effectiveness decreases, which is an indication that the microbes are developing a resistance.

Oxidizing biocides commonly used in cooling systems are halogens such as chlorine and bromine. Chlorine gas is used but has a safety risk when stored in bulk and is difficult to handle. Sodium hypochlorite (bleach), which contains chlorine, is most often used in large open recirculating and once-through systems. Liquid halogens (hypochlorite and liquid bromine are easier to feed and control than their solid (palletized) alternative. All liquid halogen products must have a degasification head on the chemical feed pump. All brominators must have a pressure release valve. Large systems over 40,000 gallons of tower water volume sometimes use two liquids (sodium bromide and sodium hypochlorite) fed through a static mixer to make the bromine biocide.

If you are using a chlorine or bromine halogen, please note that overfeeding halogens can become corrosive to a system. Bacteria counts that are consistently zero may be a sign of overfeeding. Chlorine is generally ineffective at a pH above 8.3, so a bromine technology is recommended.

Non-oxidizing biocides

Non-oxidizing biocides are typically added to a system at a minimum of once per week. If biological counts always increase dramatically after the addition of these products that may be an indication that the system may already have a large population of slime forming bacteria.

Notes on chemical addition

Every heat exchanger in the system should be exposed to every biocide feed, including idle equipment. Condenser water should be changed immediately on all idle chillers following biocide feeds. Failure to do so can result in biologically induced under-deposit corrosion conditions of the condenser tubes. In package units, two-way valves, and heat pump systems, feed biocides when you expect most of these units to be open.

Biocides have the potential to impact the wastewater treatment plant and the body of water to which it discharges. All biocides are toxic to fish. Some biocides are less persistent and break down rapidly in water reducing the toxicity of the compound which in turn reduces their impact on the environment when discharged. The following factors are to be considered when using biocides:

- Persistence – a biocide with low persistence should be chosen.
- Dosage – apply the proper amount of biocide. Overdosing leads to excessive discharge of the biocide to the environment.
- Chemical alternatives – do not rely solely on biocides to control bacterial growth.

In most cases, your local water permitting authority will have to approve any chemical treatment program. Obtain all approvals in writing.

There are a variety of non-oxidizing biocides for use in recirculating water systems:

TRADE NAME	ACTUAL CHEMICAL FORMULA
Glutaraldehyde	1,5 pentanedial
DBNPA	2,2-dibromo-3-nitrilopropionamide
CMIT/MIT	5-chloro-N-methylisothiazolone & N-methylisothiazolone
BIT	1,2-benzisothiazolone
Thiocarbamates	Potassium N-dimethyldithiocarbamate
Poly-Quat	Poly[oxyethylene(dimethylinimio)ethylene-(dimethylinimio)ethylene dichloride]

Controlling and testing for Legionella

A high priority for any cooling tower biological treatment program is the control of Legionella.

Legionella occur naturally in lakes and streams and can be transported through potable (municipal) water distribution lines. Outbreaks of individual cases of legionellosis have been traced to cooling towers and evaporative condensers, and potable water services, such as water heaters, showers, and faucets. The mere presence of Legionella in water or on a fixture or device is not sufficient to cause disease. For disease to develop, individuals must inhale sufficient numbers of virulent organisms to overwhelm the body's natural resistance. Variations in virulence of organisms and susceptibility of people exist.

Proper design, operation, maintenance, and housekeeping procedures that prevent amplification and dissemination of Legionella should be formulated and implemented before systems are operated. These procedures should be continued rigidly thereafter. Although using these practices will not guarantee that a system or individual component will be free of Legionella, they should reduce the chance of heavy colonization with these bacteria. Currently, the most reliable method of testing for the presence of viable Legionella in a system is by culturing for these organisms. No 'non-Legionella' surrogate tests are available, and there is currently no correlation between total bacterial counts and Legionella concentrations. The results of single tests must be interpreted cautiously as the concentration of Legionella in a water system can increase substantially over a few days. Attention should be paid to sample handling and laboratory quality control so that the number reported reflects the number present at the time of sampling.

The efficacy of a specific biocide treatment in controlling Legionella can only be determined by testing specifically for the presence of Legionella in the field under actual working conditions. Laboratory trials must not be relied on exclusively as the sole proof of the efficacy of a biocide. Biocides can be health and safety hazards and must be handled in accordance with specifications on labels and material safety data sheets.

Analytical results for Legionella screening should be completed at least quarterly to take advantage of the seasonal effects to the tower water.

Non-detectable levels of Legionella is the goal. If Legionella is detected, treatment must be administered immediately. Follow your chemical provider's directions. After treatment, re-test to confirm there is no detectable level. Non-detectable levels confirm that, at the time of testing, the Legionella counts were < 10 cfu/ml. Non-detectable levels does not mean that the tower has substantially reduced its risk. Risk reduction is achieved by a formal risk reduction program incorporating a management plan containing provisions for actions if results are positive.

Appendix A provides a cooling tower management template[1]

For more information about cooling tower management, see the United States Environmental Protection Agency WaterSense website[2]. For more information regarding Legionella go to United States Department of Labor Occupational safety and Health Administration Safety and Health Topics/ legionellosis (Legionnaires' Disease and Pontiac Fever) website[3]

1 New York Department of Health cooling tower management program and plan template

2 EPA WaterSense, Best Management Practices for Commercial and Institutional Facilities. https://www.epa.gov/sites/production/files/2017-02/documents/watersense-at-work_final_508c3.pdf

3 OSHA Safety and Health Topics/ legionellosis (Legionnaires' Disease and Pontiac Fever) https://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_7.html

Flow meters

Users should check with vendors to make sure they apply the best meter for the water flow measurement point.

Flow meter

A device that measures the flow rate of a liquid or gas moving through a pipe.

Requirements to implement the BMP

- Permanent flow meters installed that monitor 100% of the total water-in to the site, based on the water balance schematic.
- Written flow meter inspection and calibration plan consistent with vendor specifications.

Types of flow meters

There are several different types of flow meter technologies which may be applicable at RTX sites, depending on their intended use. Users should check with vendors to make sure they apply the best meter for the water flow measurement point. Common types of meters include:

Vortex shedding. Vortex shedding flow meters measure oscillation frequency in moving water and convert that into flow rate. Think of water passing over rocks in a moving river, and the vortices that appear downstream of the rock. A vortex shedding meter inserts a small fixed object into the water flowing through a pipe, and measures and converts into flow the oscillations that occur around the fixed object.

Variable area. Variable area flow meters measure flow by allowing flowing water to move a small, flexible plate suspended from the top of a horizontal pipe and then measuring the pressure changes on both sides of the plate as it moves in response to varying water flow.

Paddle wheel. Paddlewheel flowmeters use a paddlewheel inserted into the water flow, and measure the speed with which the wheel turns. The speed is then converted into a water flow value.

Turbine. Turbine flowmeters use the same principle to measure water flow as paddle wheel flowmeters. The difference is orientation of the paddles on the wheel. While paddle wheel flow meters employ a paddle wheel whose blades and axle are directly perpendicular to water flow, turbine flowmeters orient the blades and axle parallel to the flow. The resulting blade spin is measured and converted into a water flow value.

Magnetic. Magnetic flowmeters use Faraday's Law, and measure the magnetic field generated by water flowing through the pipe. Electrodes located on the walls of the pipe measure the voltage signal generated from the change in magnetic field, the meter converts these measurements into a water flow value.

Ultrasonic. Ultrasonic flowmeters rely on the Doppler effect to determine the velocity of water moving through a pipe. When no water is flowing, the sound frequencies transmitted through the pipe don't change. When water is flowing the frequency of the sound wave differs in linear relation to the rate of flow.

Differential pressure. Differential flowmeters use Bernoulli's equation to measure the flow of water in the pipe. The meter creates a flow constriction in the pipe that creates a pressure drop across the meter. The pressure drop increases as the flow increases, and the meter measures the differences in pressure on both sides of the constriction and converts those to a rate of flow.

For more on flowmeter selection visit: https://www.osti.gov/biblio/1866391/

Low-flow fixtures

Low-flow fixtures help to quickly reduce consumption and costs, yielding water savings and reduced utility bills.

Low-flow fixtures[1]

Low-flow equipment includes special types of fixtures applied to plumbing appliances that moderate the flow of water in comparison to traditional products available on the market.

Requirements to implement the BMP

- Site has installed low-flow fixtures on >75% of fixtures controlling water for sanitary purposes.

In factories and commercial buildings, major water needs include restroom activity, cooling/heating, landscaping, kitchen and other sanitation needs. Low-flow fixtures help to quickly reduce consumption and costs, yielding water savings and reducing utility bills. Low-flow technology is commonly found in faucets, aerators, toilets, urinals and showerheads.

While the costs and water savings of low-flow fixtures are individually modest, the use of low-flow fixtures can collectively save a lot of water, particularly at those RTX facilities where sanitary water is the primary source of water used.

The USEPA Green Building Manual of May 2011 provides estimates on the performance benefits from low-flow appliances:

FIXTURE	FLOW
Low-flow faucet	2.5 gallons per minute or less
Low-flow sink aerator	Reduce flow by 1.0 gallons/minute
Low-flow toilet	Reduce flow by 1.3 gallons/flush (conventionally 3.5-7.0 gallons/flush)[2]
Dual-flush toilet	0.8 or 1.6 gallons/flush
Low-flow urinal	Reduce flow to 0.1250 gallons/flush
No-flow urinal	0 gallons/flush
Showers	2.5 gallons per minute or less

In addition to water savings, low-flow fixtures also provide lower costs of water and the energy used to transport, pump and treat the water.

1 USEPA Green Building Manual, low-flow fixtures. http://greenmanual.rutgers.edu/
2 EPA WaterSense, Best Management Practices for Commercial and Institutional Facilities. https://www.epa.gov/sites/production/files/2017-02/documents/watersense-at-work_final_508c3.pdf

Rinse tank overflow

Adding new water to every rinse tank is not considered a water use best management practice.

Rinse tank[1]

A rinse tank is a process using water, acids, alkalis, and other chemical solutions to rinse dirt, oils and other impurities off the manufactured part. At RTX this process typically includes sequential rinsing using multiple water rinse tanks.

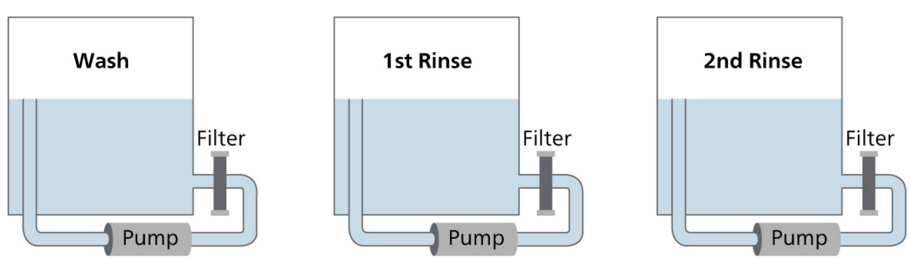
Rinse tank chemistry

In the figure below, the manufactured part that needs rinsing will be dunked into the "wash" tank to remove any impurities. This tank will contain either an alkaline detergent, acid, or other aqueous cleaning solution. The part is then transferred to the second tank, or "1st rinse." This tank will be a tank of de-ionized water where the part will be cleaned. The part is then transferred to the third tank, or "2nd rinse." The final tank contains the cleanest water because the parts are only as clean as the solution during the final rinse. Therefore, rinse tank chemistry is a really important aspect in all rinse tank operations. **Drag out** is either residue solution or left over impurities that remain on the part during consecutive rinsing. For example, a part that is rinsed in the first tank will carry some residue of that tank's solution into the next tank, tank #2 (1st rinse tank). Now expand that drag out over an hour or day of rinse tank operations. The de-ionized water that was in the 1st rinse tank is now contaminated and the concentration of the solution from the wash tank is now increasing. Therefore, when the part is transferred from the second tank to the third (1st rinse to 2nd rinse), the cleanest tank (2nd rinse tank) is now becoming contaminated and is no longer clean. This will cause the final rinsing step to be less and less effective, leaving the part to

Requirements to implement the BMP

- Written management plan that consists of:
  - Identification of equipment and process using the water in the rinse tanks.
  - Hourly/daily water consumption for the process.
  - Water quality specifications.
  - Current contaminants.
  - Estimated drag out from process to rinse tanks.
  - Process part throughput.
  - Total water used in process and tanks.
- Annual review of potential improvements to overflow.
  - Closed looping.
  - Recycling.
  - Water reduction practices.
- Site has implemented water conservation measures on >100% of total rinse tank capacity.

General rinse tank process



1 Rochester Institute of Technology. Rinsing.

contain impurities upon completion of the rinse tank operations.

In order to return the rinse tanks to their original concentrations, water, acid, alkaline detergents can be re-added to bring their concentrations back to their initial measure. However, adding new water to every rinse tank is not considered a water use best management practice. There are several options to improve the overall water use profile of rinse tanks that conserve water and maintain rinse tank chemistry:

- Lowering bath concentrations
- Increasing bath temperature to lower the solution viscosity.
- Reduce surface tension through the addition of wetting agents.
- Removal of parts slowly and allowing to drain before the next step in the rinsing.
- Use of spray rinsing and air knives.
- Installation of drainage boards after process baths to return any dragout.
- Counter current rinsing.
- Reactive rinsing.
- Flow restrictors.
- Tank agitation.
- Conductivity sensors.

While many of these options represent simple modifications to tanks or tank operations, several require further explanation:

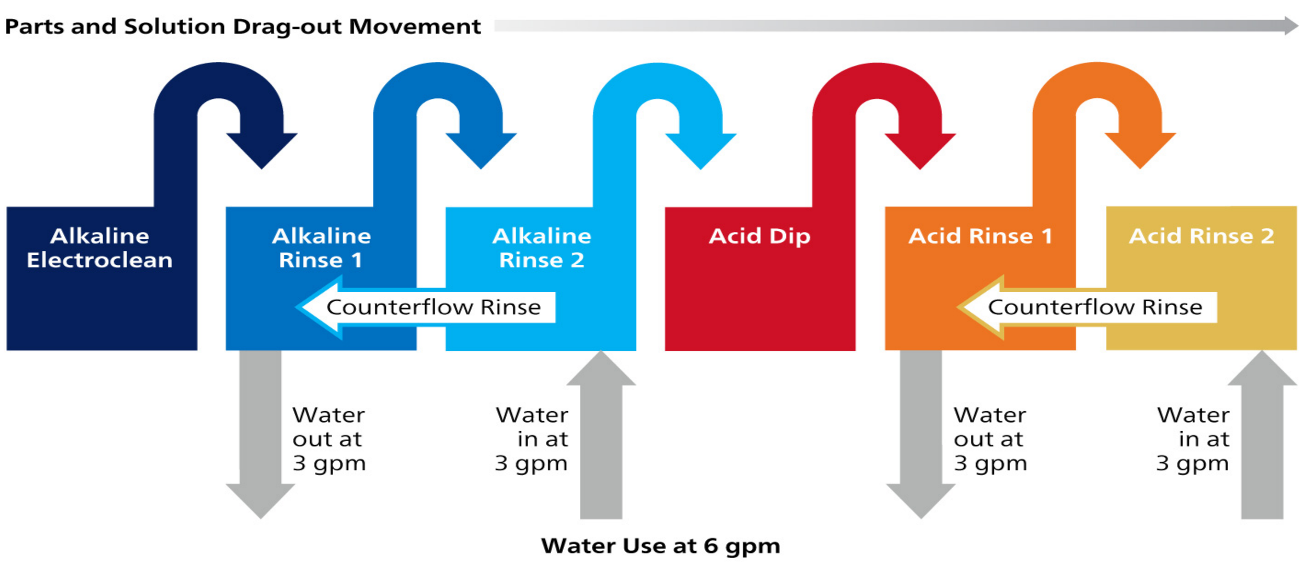
Lowering bath concentrations

Consider using condition-based testing and/or partial Drain Clean Refill- DCR. Monitor the conditions of the rinse tanks to alert when Ph levels are out of operating range. Partially drain the tanks and add replacement solution (water, acid, alkaline) to balance the Ph. This will reduce the amount of industrial waste generated and the amount of water intake.

Counter current rinsing

In counter current rinsing systems water circulates through a series of connected rinse tanks, flowing in the opposite direction of the workflow. Fresh water enters the last rinse tank, overflows to the next rinse tank and continues until it exits via the first rinse tank. This method allows the work piece to be rinsed in the least pure water first and the cleanest water last. And most importantly, it reduces the amount of clean water required. Practical experience and studies have proven that slightly contaminated overflow from the subsequent rinse is just as effective as clean water, making it a very efficient rinsing system.

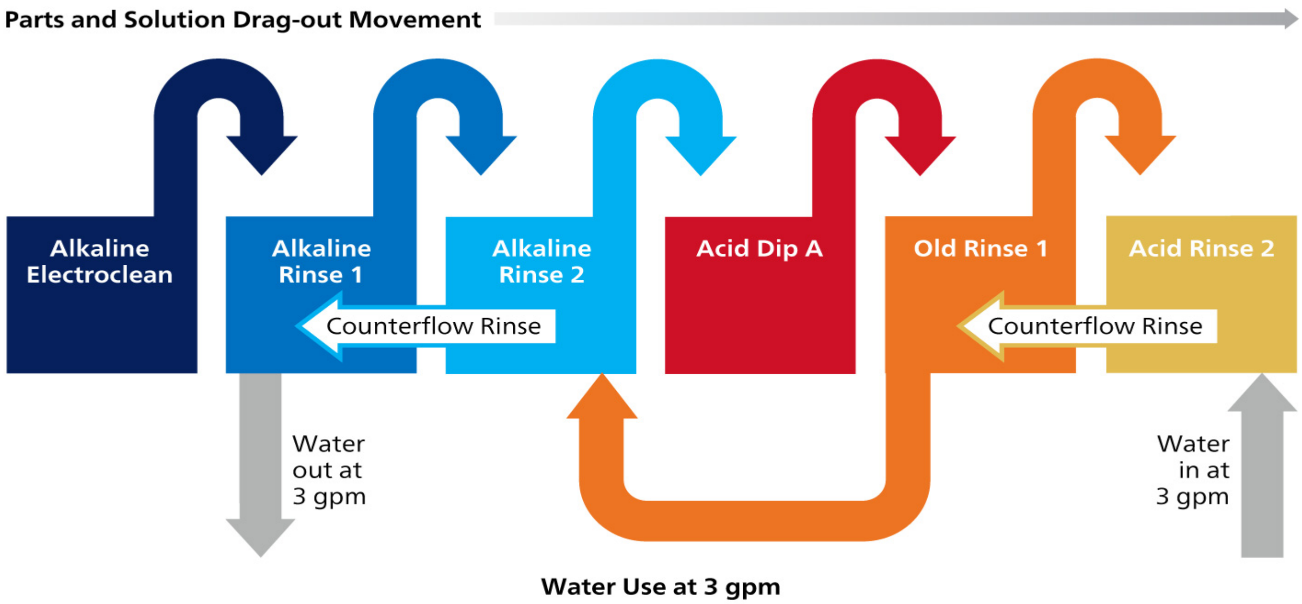
Counter Current rinse tank process



Reactive rinsing

A less common method than counterflow for reducing water use is reactive rinsing, which reuses the acid rinse as makeup water for an alkaline rinse bath. The figure demonstrates the reactive rinsing process. Acid contained in this rinse water would normally be sent to waste treatment. The purpose of reactive rinsing is to utilize the acid solution to partially neutralize the alkaline baths and reduce the need for makeup water.

Reactive Rinsing tank process



Flow restrictors

Flow restrictors limit the volume of rinse water flowing through a running rinse system. Once the optimal flow rate has been determined, these devices are used to maintain constant flow of makeup water to the system.

Tank agitation

Forced air or water is the most efficient method for creating complete mixing during rinse operations. This can be achieved by pumping either air or water into the immersion rinse tank. Air agitation can provide the best rinsing because the air bubbles create improved turbulence to remove the chemical process solution from the work piece surface.

Conductivity sensors[2]

Conductivity is the measure of ions in a solution. Measured in µS/cm (microsiemens/cm) or µmho/cm (micromhos/cm), conductivity can be correlated with total dissolved solids (TDS), which is the amount of dissolved particles in the solution (mg/L), which is also known as parts per million (ppm). Conductivity meters minimize the amount of makeup water required by triggering the addition of fresh water to rinse baths only when the conductivity in that bath reaches a certain set point. Conductivity sensors cost $1,000–$2,000 and often have a payback time of about a year. There are three different types of conductivity sensors, each of which is applicable to specific conditions:

2 Conserve water with conductivity meters: http://www.emerson.com/documents/automation/article-conserve-water-conductivity-meters-in-metal-finishing-en-68480.pdf

Two-electrode sensors. These sensors have reduced accuracy when the ion concentrations are high or substances coat and or foul the electrodes. Since the signal from the electrode is proportional to its surface area, any coating of the electrode will interfere with its accuracy. Consequently, two-electrode sensors perform best when used in clean water baths, such as reverse osmosis or deionizer soaking.

Four-electrode sensors. Unlike the two-electrode sensor, the four-electrode sensor uses counter-electrodes to compensate for coating and polarizing effects when the conductivity in the baths increases. These sensors are best used in baths with high ionic concentrations, including acid, base, and salt solutions that do not contain large amounts of suspended solids.

Toroidal. This plastic conductivity sensor contains two wrapped wires to form a toroid. An electrical signal is passed through the transmitting toroid, and the signal produces a current of flow in the solution. That flow is then calculated for conductivity at the receiving toroid. This sensor is very resistant to coating and is best used in highly concentrated ionic solutions.

Appendix B provides supporting documentation on rinse tank management

Xeriscaping and irrigation

A significant portion of the water that is consumed at our factories is used outdoors for irrigation.

Xeriscaping

Describes a philosophy that includes sound horticultural practices and common-sense approaches to landscaping, including implementation of landscape design where the intent is to minimize water use.

Requirements to implement the BMP

- Site landscaping plan includes minimal water use through drought resistant plants.
- Site uses no potable water for landscaping or irrigation.

Value of landscaping

Landscaping provides many benefits to industrial, commercial, and institutional properties. These include enhanced aesthetics, shading and climate mitigation, pleasant outdoor spaces for employees and clientele, as well as greater property value.

A significant portion of the water that is consumed is used outdoors for irrigation. For this reason, it is very important to plan and install landscapes carefully and to plan for proper maintenance. With good planning we can have attractive, colorful landscapes that are water efficient and easy to maintain.

A good design will include locally tolerant or adapted plants that are thoughtfully placed for attractive and functional landscapes and ease of maintenance. Most areas have local agricultural organizations, nurseries or landscape consultants that can provide a list of recommended low-water-use plants, specific to that region/climate in the world.

The irrigation design should segregate the site into zones based on exposure, provide the most efficient types of irrigation system components for different plant needs, and include products that minimize water waste.

A well-planned, well-installed design will avoid future maintenance problems and expense. Watering costs alone can be cut by two-thirds by installing a xeriscape instead of turf or other types of water-thirsty landscapes.

The term xeriscape comes from the Greek word xeros, meaning dry, but should not be confused with barren zero-scapes. Xeriscape describes a philosophy that includes sound horticultural practices and a common-sense approach to landscaping. The following seven

xeriscape principles serve as guidelines to successful landscaping.

1. **Good landscape planning and design**. Selecting the right size and type of plant for the location, grouping plants with similar needs together, and creating attractive, functional areas will help ensure a long-lasting and enjoyable landscape.
2. **Appropriate turf areas**. Grass lawns should be placed where they can be used and enjoyed. Wall-to-wall turf is unnecessary. Small, irregular areas may be inefficient and hard to maintain. High-foot traffic areas may be better served with hardscape instead of turf.
3. **Efficient irrigation**. Good water management practices, along with an efficient system, help maintain a healthy landscape without wasting water.
4. **Soil improvements**. Some soil may need to be aerated or amended to improve water absorption and the water-holding capacity of the soil.
5. **Use of mulches**. Organic or inorganic mulches protect the soil from being baked in direct sun; help retain water; and control weeds, dust, and mud.
6. **Use of low-water-use plants**. The wide variety of plants available provide year-round color in many forms and functions. They can create almost any look and help reduce energy costs when placed for shade and insulation.
7. **Proper maintenance of plants and irrigation systems**. The natural look of many plants is enhanced with occasional pruning, fertilizing, weeding, and pest control. Proper maintenance means less waste going to the landfills; healthy, long-lasting landscapes; and protection of your investment. Checking your irrigation system regularly can prevent costly repairs.

Proper plant selection and placement reduces water use. Low-water-use plants can be used to create a variety of looks. Many other groundcovers, flowers, shrubs, and grasses can be used instead of turf. Trees and shrubs in planters can provide shade, privacy screening, noise reduction, area definition, as well as attractive foliage, colorful flowers, and pleasant fragrances.

Low- and high-water use plants should not be planted together in the same area to avoid overwatering the low-water-use plants. High-water-use plants can be planted in low-lying areas or swales to intercept runoff from hardscape or pavement and decrease the need for supplemental watering. Group high-water-use plants together in a mini-oasis near the building for energy savings or in areas where they can be enjoyed up close, such as a courtyard. The lowest-water using plants should be placed farthest away from the building.

Proper landscape water management saves money

Potential financial impacts of landscape water management include water cost, maintenance cost, plant loss and replacement cost, and property value. Various studies show that many landscapes are over-watered by as much as 100%. Over-watering encourages excessive growth, disease, and other maintenance problems. Other common problems are shallow watering or poorly applied water. Deep, periodic watering encourages strong, healthy root systems that can better tolerate periods of drought.

There are a number of ways to conserve water used for landscape irrigation. Proper irrigation system design, installation, and maintenance are important. Be sure to hire contractors who have experience and knowledge with water management. You may wish to hire a company to provide water management training to your current staff or contractors.

Proper landscape practices checklist

- Adjust irrigation program frequency monthly. This requires effort and persistence, but results in healthier, more attractive landscapes and lower water bills.
- Automate landscape irrigation systems.
- Schedule irrigation for early morning or late evening.
- Water only as frequently as necessary. In the Phoenix area, turf should be watered no more than every third day in summer and less frequently in fall and spring. Dormant Bermuda grass needs no supplemental winter watering.
- Drip irrigation should run for two to three hours to provide deep watering. Frequency of operation should vary according to plant needs. Variables to consider include temperature, solar exposure, rainfall, soil conditions, plant type and maturity, density of plantings, number and placement of emitters, and emitter application rate. Use the watering guide in your local newspaper or the watering recommendations using the ET rate found on the Internet at http://ag.arizona.edu/azmet.
- Segregate valves by plant needs and exposure. For example: water turf and seasonal flowers separately. Solar exposure is more significant to water needs than temperature. The north side of a building has the least sun exposure.
- Place enough drip emitters around the root zone (at the canopy edge) of trees to encourage roots to spread farther from the trunk.

- Add or move drip emitters as plants mature. Cap emitters if no longer needed.
- Install rain or moisture sensors to reduce scheduling requirements.
- Decrease or eliminate turf areas. Keep only those that are used for active recreation. Myoporum uses only 1/10 the amount of water required for turf. Groundcovers reduce maintenance requirements, too.
- Landscape with drought-tolerant xeriscape plants.
- Use mulches, such as decomposed granite, around plants to help retain moisture.
- Keep turf at the proper height. Grass that is too short uses more water. Keep at ¾ to 1 inch for warm season grass, 1½ to 2 inches for cool season grass.
- Dethatch or aerate lawns annually to improve water infiltration.
- Remove weeds that compete with desired plants for water.
- Follow the principles of xeriscape to ensure a long-lasting, water and energy efficient landscape.
- Only prune as needed. Heavily sheared spheres and cubes are less healthy and much more wasteful of resources than plants with a natural form.
- Explore the opportunity to use recycled process water or harvested rainwater for irrigation.

Irrigation system tune-up checklist

1. Identify equipment

- Make an irrigation system map that shows the location of all water lines, sprinklers, bubblers, emitters, and valves.

2. Check for leaks

- Turn off all water and read the meter. After 15 minutes, read it again. If the meter hand has moved, you may have a leak inside or outside the building.
- Leaks outdoors can often be located by looking for overly green or muddy areas, but sometimes they are undetectable without special equipment.

3. Check controllers

- Make sure that all valves are turning on. If the controller has a battery backup, check the charge on the battery.
- Replace electro-mechanical clocks with electronic models.
- Make a list of where all of the stations water. Place the list in the controller box.

4. Irrigation system

- Repair or replace broken or missing sprinkler heads, bubblers, and drip emitters.
- Check seals between the neck and base of the sprinkler heads. Water will squirt out of the base if worn. Make sure all heads pop up all the way and fully retract when water is turned off.
- Check for sprinkler spray blocked by weeds or grass. If the spray is blocked, lower the mowing height or raise the sprinkler level.
- Make sure sprinklers are vertical and flush with soil grade. Soil should be tightly compacted around the sprinklers.
- Check for low system pressure. Water will stream out of the sprinkler instead of forming a spray. Consult an irrigation supplier for advice.
- Clean or replace clogged nozzles. Clean the sprinkler's trash screen, if it has one.
- Check the rotation and direction of spray. Adjust the radius and arc to avoid spraying sidewalks and buildings.

5. Irrigation scheduling

- Water at night or in the early morning. Between 2 a.m. and 6 a.m. is best.
- Do not water turf more than once every three days. Sandy soils and hybrid (Tiff) Bermuda grass may need to be watered more often.
- If water runoff is a problem, irrigate two or three times per night at 1/2 to 1/3 the normal watering times, respectively. Wait an hour between watering.
- Change the watering schedule about once a month according to prevailing conditions. Use ET as a guide.

Backflow prevention devices must be installed in compliance with local ordinances.

Proper maintenance protects landscape investment

The irrigation/pruning connection

Irrigation affects pruning and vice versa. When landscape plants are given excessive water, they grow much more rapidly. More plant growth means more pruning, increasing maintenance time and expense. This is a good example of why water management is one of the most important components of your maintenance program. Not only can water management save a great deal of money on water budgets, but it also saves on maintenance, overall plant health and landscape longevity.

Pruning can also affect how much water landscape plants use. Poor pruning removes shade protection on the branches, trunks, and roots. It also removes leaves, buds, and stored energy, which are needed for healthy growth. Removing too many branches also increases susceptibility to pests, slows growth, undermines health, and stimulates excessive sprouting. Plant stress, higher temperature, open wounds, and excessive sprouting can cause a plant to require more water than normal.

Recycle process wastewater

Wastewater can be reused (reclaimed) and utilized at the generating site or by others located off-site.

Process wastewater

Wastewater is water that has been contaminated by human induced activities such as industrial processes, domestic uses, commercial or agricultural activities, surface runoff, and storm water.

With wastewater comes wastewater treatment. This is a process to take contaminated water and clean it to defined governmental standards. The standard wastewater treatment process is:

1. **Preliminary treatment.** Removal of large solids that can clog the wastewater treatment process.
2. **Primary treatment.** Placement of water into a large settling tank that allows smaller solids to settle to the bottom and be removed while fats and grease rise to the top and are siphoned off.
3. **Secondary treatment.** Aerobic bacteria convert organic contaminants into suspended solids that then settle out in the large secondary settling tank.
4. **Tertiary treatment.** Nutrient (nitrogen and phosphorous) removal.
5. **Disinfection.** Treat wastewater to kill bacteria and other organisms.
6. **Treatment and removal of sludge**.

Requirements to implement the BMP

- Documented water recycling/closed loop analysis.
- Identified generators and potential users of wastewater; water use volume, temperature and quality requirements; current contaminants; assessment of potential treatment technologies; regulatory/permit impact review.
- Potential closed looping or recycling projects updated to ERS.
- Greater than 75% of manufacturing process water is supplied by recycled water sources (internal or external).

Wastewater can be reused (reclaimed) and utilized at the generating site or by others located off-site. Wastewater treatment effluent can often be used for site processes that do not require high quality/purified water, including:

- Cooling towers.
- Cooling water.
- Toilets.
- Wash down water.
- Process water.
- Landscaping and agriculture.
- Air emission scrubbers.

Several processes are available to treat and reclaim water for reuse, and the applicability of each depends on the water quality requirements of the process requiring the water:

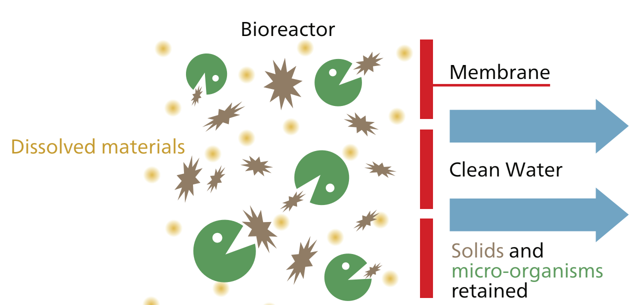
1. **Dissolved air floatation.** Utilizes small air bubbles to separate and trap coarse impurities and allow them to float on the surface where they can be skimmed off and removed.

2. **Granular activated carbon.** Activated charcoal attracts dissolved organic materials where bacteria break down the organics. These filters also contain catalytic properties that help remove chlorinated species.

3. **Softening.** Water hardness is defined as magnesium and calcium ions dissolved in the water. Cation-exchange filters remove the dissolved ionic cations present in the water.

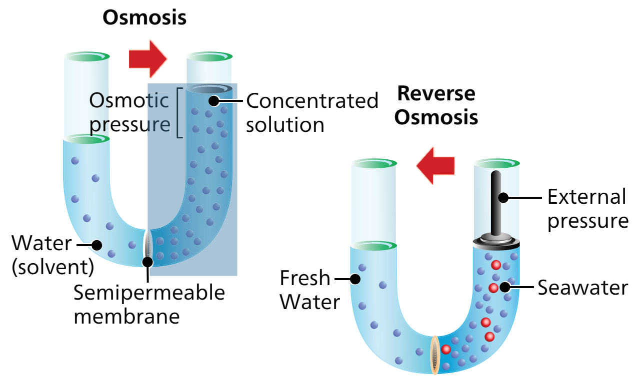
4. **Disinfection.** This process kills and controls bacterial colonies in the water. Chlorine, ultraviolet, and ozone are all used for disinfection purposes.

5. **Membrane bioreactor.** This technology utilizes the biological treatment from wastewater treatment processes in combination with a membrane filtration to prevent the biological organisms from ending up in the effluent. This process is widely used for municipal and industrial wastewater treatment.

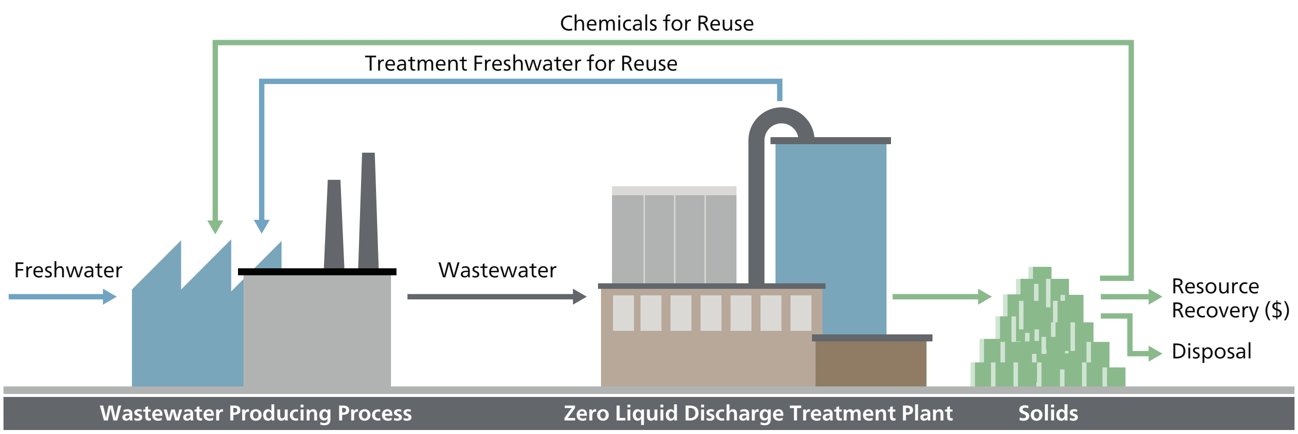


6. **Ultra-filtration.** A semi-permeable membrane separates the water effluent from the larger molecular mass contaminants in the wastewater.

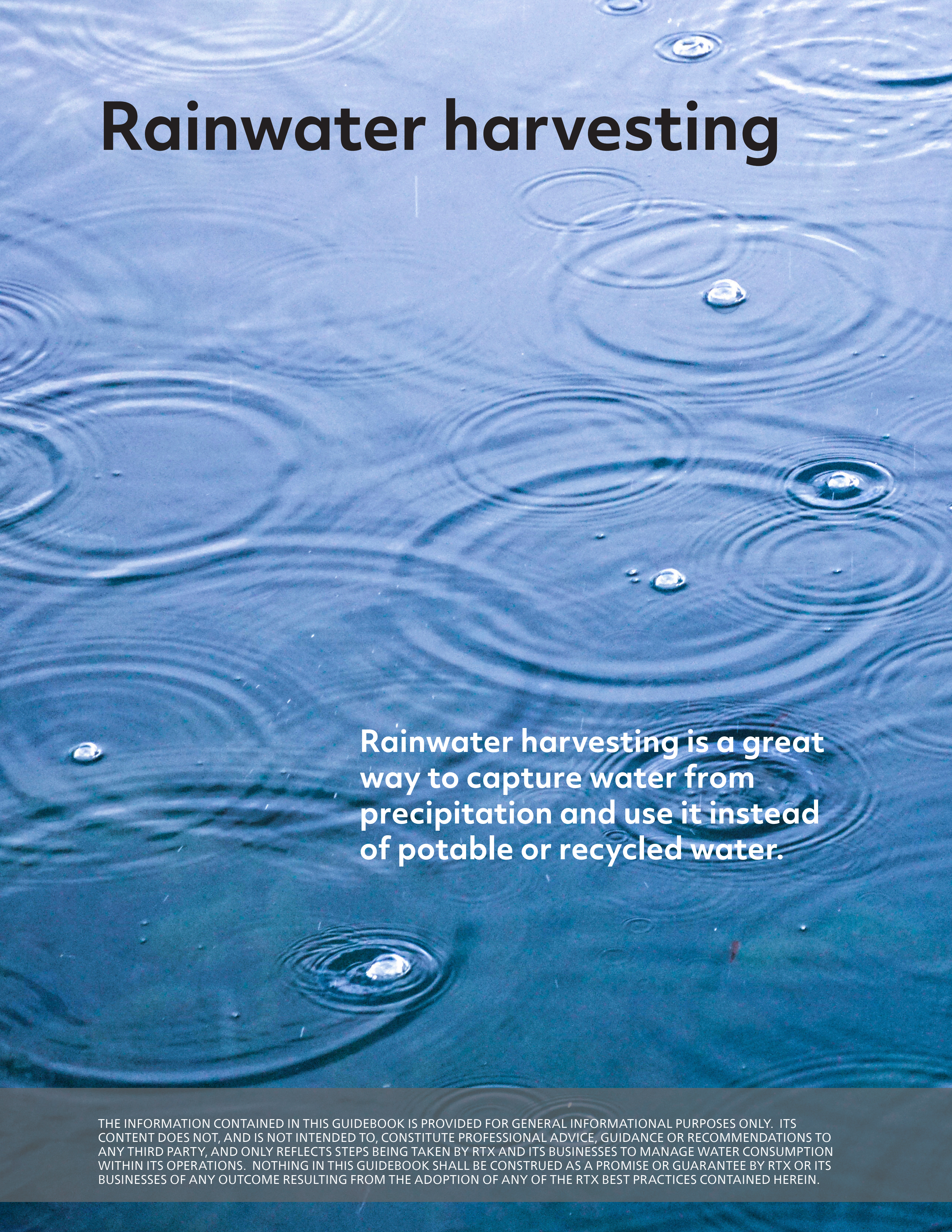
7. **Reverse osmosis.** This process isolates the ions in the water. Reverse osmosis works by water passing through a semi-permeable membrane in the direction opposite to normal osmosis when hydrostatic pressure is applied that is greater than the osmotic pressure.



8. **Evaporation for zero discharge.** Utilizes the process of filtration to separate solids. Evaporation then isolates any dissolved compounds in the wastewater. The precipitate crystals are then dewatered and all reclaimed water returns to the process.



Appendix C provides supporting documentation on closed-loop water recycling.



Rainwater harvesting

Rainwater harvesting is a great way to capture water from precipitation and use it instead of potable or recycled water.

Rainwater harvesting

The capture and reuse of rain and snow for use as industrial process water, sanitary water and irrigation purposes.

Requirements to implement the BMP

- Site has evaluated rainwater harvesting as a potential source of site water.
- Installation of rainwater harvesting on > 75% of site roof area, or > 75% of site water use supplied from rainwater reclamation.

Rainwater harvesting is a great way to capture water from precipitation and use it instead of potable or recycled water provided by off-site suppliers. While often beneficial, in areas with limited rain or snowfall, rainwater harvesting may be prohibited to allow all precipitation to replenish surface and groundwater sources[1]. In addition, older facilities may experience issues with elevated concentrations of copper or zinc in the rainwater picked up from building equipment and materials. This can pose significant compliance issues when trying to reuse it elsewhere.

For example, in the United States various prohibitions or limitations to rainwater harvesting can be found:

- **Arizona.** Regulated through the Department of Water Resources; city or town may establish money to fund rainwater harvesting systems; check county for local incentives.
- **Arkansas.** Rainwater harvesting is allowed for a non-potable purpose if the harvested rainwater is:
  1. Designed by a professional engineer licensed in Arkansas;
  2. Is designed with appropriate cross-connection safeguards; and
  3. Complies with Arkansas plumbing code.
- **California.** Authorizes residential, commercial and governmental landowners to install, maintain, and operate rain barrel systems and rainwater capture systems for specified purposes, provided that the systems comply with specified requirements. A landscape contractor working within the classification of his or her license would be authorized to enter into a prime contract for the construction of a rainwater capture system if the system is used exclusively for landscape irrigation.
- **Colorado.** Commercial facility rainwater harvesting is prohibited.
- **Nevada.** Regulated at the municipality level.
- **Oklahoma.** Encouraged through state legislation: Water for 2060 Act.
- **Oregon.** Rainwater harvesting can only be done on roof top surfaces.
- **Texas.** Each municipality and county is encouraged to promote rainwater harvesting at residential, commercial, and industrial facilities through incentives such as the provision at a discount of rain barrels or rebates for water storage facilities.
- **Utah.** Allows rainwater harvesting up to 2,500 gallons.

RTX's facilities in the U.S. and other countries of operation should check on any local rainwater harvesting regulations before considering any rainwater harvesting project.

1 Legislation on rainwater harvesting from http://www.ncsl.org/research/environment-and-natural-resources/rainwaterharvesting.aspx#az & https://www.energy.gov/eere/femp/rainwater-harvesting-regulations-map

System maintenance

If you've installed a rainwater harvesting system, USEPA recommends system maintenance in keeping with the following schedule[2].

FIXTURE	FLOW
Keep gutters and downspouts free of leaves and other debris	O: Twice a year
Inspect and clean pre-screening, inlet filtration devices, and first flush diverters	O: Four times a year
Inspect and clean storage tank lids, paying special attention to vents and screens on inflow and outflow spigots. Check mosquito screens and patch holes or gaps immediately	O: Once a year
Inspect condition of overflow pipes, overflow filter path, and/or secondary runoff reduction practices	O: Once a year
Inspect tank for sediment buildup	I: Every third year
Clear overhanging vegetation and trees over roof surface	I: Every third year
Check integrity of backflow preventer (unless required more frequently by state or local regulations)	I: Every third year
Inspect structural integrity of tank, pump, pipe, and electrical system	I: Every third year
Replace damaged or defective system components	I: Every third year
Key: O = Owner; I = qualified third party Inspector	

Rainwater harvesting tank.

2 A full and complete guide to rainwater harvesting information, cost, codes and procedures, is available from the USEPA at: https://www.epa.gov/sites/production/files/2015-11/documents/rainharvesting.pdf

Conclusion

Since 2006, RTX has a made series of formal commitments that our factories and operations will be exemplary stewards in our use of water and other natural resources. This commitment has been met through the hard work of thousands of employees across our enterprise, and whose expertise directly contributed to the development of RTX's water best management practices. While not an exclusive list of everything that can be done, the BMPs have been invaluable as we continue to improve our use of water and remain a good neighbor in the over 100 watersheds in which our facilities are located.

Our commitment and assignment

"RTX will not be satisfied until its workplace is safe from hazards, its employees are injury free, its products and services are safe, and its commitment to and record in protecting the natural environment are unmatched. RTX will make environment, health and safety (EH&S) an integral component of all business processes that impact the products, services and operations of RTX."

RTX Corporate Policy Manual, Section 23

Appendices

Appendix A: Cooling tower management program

Section 1. Facility information

This section includes a description of the facility's information.

1.1 Cooling tower location. Provide information on the cooling tower location.

Owner name	
Point of contact name	
Point of contact phone	
Street address	
Building name (if applicable)	
City, town, or village	
County	
Latitude-longitude (if applicable)	

1.2 Developer of maintenance plan (company). Provide information on the developer of the maintenance plan.

Company name	
Point of contact name	
Point of contact title	
Point of contact phone (office)	
Point of contact phone (mobile)	
Email address	
Street address	
City, state, ZIP code	

1.3 Effective date of maintenance plan. Record the date the maintenance plan goes into effect.

Date	

1.4 Cooling tower information. The following information is typically available from the design drawings, operation information and/or on the tower itself the date the maintenance plan goes into effect.

Manufacturer of cooling tower	
Model number of cooling tower	
Serial number of cooling tower	
State registration number if applicable	
Year commissioned	
Thermal cooling capacity of cooling tower	
Cooling tower type (e.g. cooling tower, evaporative cooler, evaporative condenser, etc.)	
Description of the process from which heat is being removed	
Water source (e.g., municipal water company, onsite)	
Water disposal method (sanitary sewer company, onsite disposal, discharge by permit to the environment, etc.)	

1.5 Additional narrative. Add any additional narrative that may be used to augment the information that was recorded in Section 1.1 above.

Additional narrative	

Section 2. Process description

This section includes the mechanical and quantitative description of the cooling tower process.

2.1 Tower system description. Provide a description of the tower system.

Tower type and design	
Configuration	
Purpose	
Component the tower is attached to	
Operational period type (e.g. seasonal, year long, as needed, etc.)	
Typical operational season (start date to end date)	
Number of days per week tower is used	
Number of weeks per year the tower is used	
Total system water volume (both basin and the water that is contained in the piping)	
Cooling capacity (Tons, BTU/hr, etc.)	
Circulation rate (either from basin to the spray deck or from basin and to the heat exchanger and to the spray deck, gpm)	
Filtration used (yes/no)	

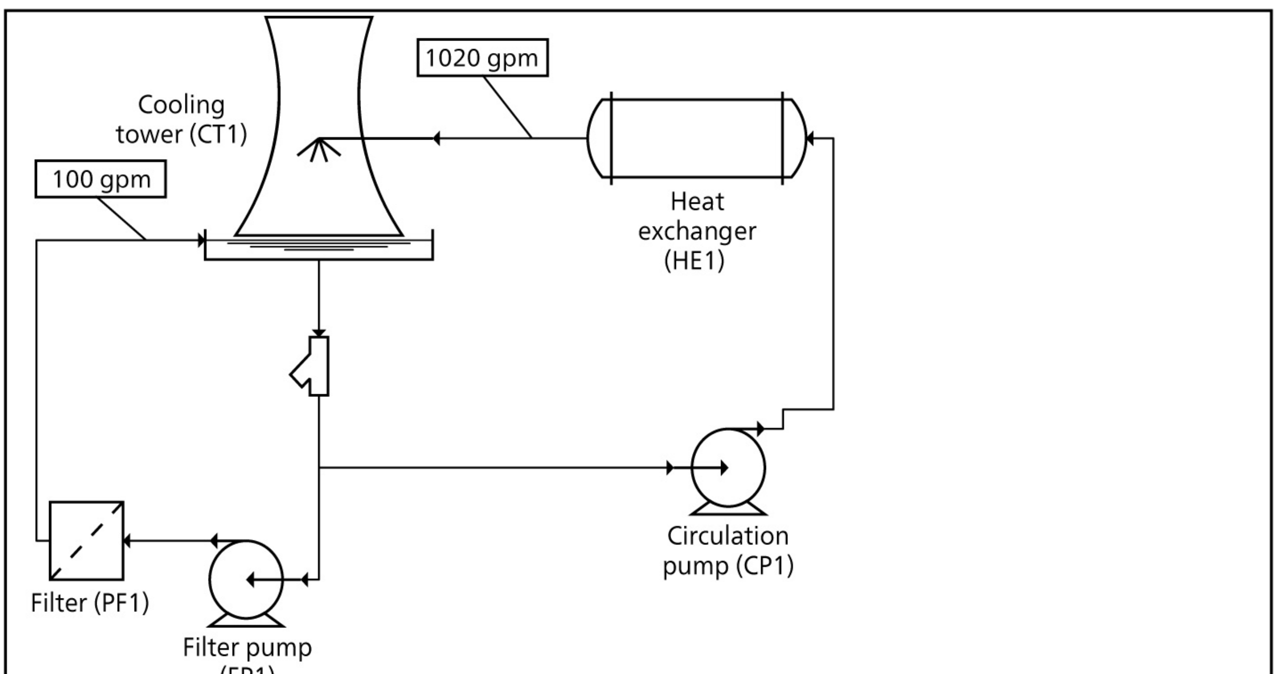
2.1.1 Filter information. If used.

Filter flow rate	
Filter manufacturer	
Filter model	
Filter pump model	
Filter pump maximum flow rate	
Filter pump power (single or three phase)	
Filter pump flow rate determined by flow controller or uncontrolled	
Filter cleaning method (e.g. backwash, cartridge cleaning, bag replacement, etc.)	
Pressure drop at which filter should be backwashed/cleaned etc.	

2.2 Process Schematic.

2.2 Process Schematic. Provide a schematic that contains sufficient information to provide a means of understanding the entire process and its mechanical components.

Process Schematic Example



ITEM	QTY.	PART NO.	DESCRIPTION
FP1	1	TRW-5682	Filter pump
PF1	1	AquaMax-1020	Filter
CP1	1	TRW-6582	Circulation pump
CT1	1	AquaCool-102	100 ton cooling tower
HE1	1	ProCess-562	Shell and tube heat exchanger

2.3 Heat source description. Provide descriptions of: a) the source of the heat that is removed by the cooling tower; and b) how the loss of cooling equipment will be addressed by backup processes or methods.

List source of the heat removed by cooling tower	
Describe how the loss of cooling equipment will be addressed by backup processes or methods	

2.4 Control elements. Designate the location and function of the control locations (or elements) that are used to maintain the operating variables of a cooling tower. Use the table below as the location for these data.

Control Element Designation Examples

CONTROL ELEMENT	CONTROL SENSOR	PURPOSE
Bleed valve located on the bottom of the basin piping	Conductivity sensor located in control room. Solenoid valve is opened by signal from central control system	Allow water containing excessively high dissolved solids concentrations to be removed from the system to be replaced by fresh water.
Sand filter	Turbidity sensor used during maintenance visits	The sand filter is operated continuously on a circulation to filtration ratio that is typically checked manually and should be re-checked periodically to ensure water turbidity is maintained.
Biocide pumps (halogen)	Oxidation-Reduction Potential (ORP) sensor located in mechanical control room	On-line disinfection is maintained using ORP as the process variable to ensure there is adequate disinfectant maintained in the system.
Biocide pumps (non-halogen)	Periodic dip slide tests performed for feedback data	Bacteria counts are used as a means of measuring the effectiveness of the biocide process.
pH chemical feed pump	pH sensor located in mechanical control room	The pH of the water is used to protect the cooling tower components from corrosion. The pH of the water is maintained by the addition of an appropriate solution.
Antiscalant/corrosion inhibitor chemical feed pump	Chemical testing performed during periodic maintenance visits	The chemical feed pump dosing is adjusted based on test data during site visits.

Section 3. Personnel roles and responsibilities

This section includes the information of the of the personnel involved in the maintenance and operation of a cooling tower and the specific actions/activities to be performed by those personnel.

3.1 Personnel. Record the information of the personnel involved in the maintenance and operation of a cooling tower.

MAINTENANCE PROGRAM ADMINISTRATOR	
Name	
Title	
Employer or company	
Address	
Phone number	
Email address	

LICENSED PESTICIDE APPLICATOR	
Name	
State pesticide applicator license number if applicable	
Employer or company	
Address	
Phone number	
Email address	

MAINTENANCE PERSONNEL (PROVIDE INFORMATION FOR EACH INDIVIDUAL)	
Name	
Title	
Employer or company	
Address	
Phone number	
Email address	

MAINTENANCE PROGRAM VALIDATOR	
Name	
Title	
Employer or company	
Address	
Phone number	
Email address	

Section 4. Program validation

Program validation should be performed by an individual who has management responsibilities for the proper implementation of the maintenance program and plan to ensure all required activities are being properly executed. This section should identify the items to be examined and the frequency of the review.

The program validation procedure is performed by reviewing the data and maintenance logs to ensure: 1) the maintenance program is being executed as documented; 2) the maintenance program is effective at reaching its goals; and 3) deficiencies or unneeded components of the maintenance program are identified for correction in future revisions of the plan.

ITEM EXAMINED	PURPOSE	FREQUENCY

Section 5. Treatment program validation

A treatment program consists of the implementation of chemicals, testing/sampling systems and administration equipment. The following sections specify appropriate information. For example:

- Chemical(s) used for corrosion control.
- Chemical(s) used for microbiological control.
- Chemical(s) used for pH adjustment/maintenance.
- Chemical(s) used for dispersants/penetrants.
- Chemical(s) used for antiscalants.

The information included in these sections should corroborate the process information in Section 2.4.

5.1 Program chemistry. Provide information on program corrosion inhibitors, biocides/disinfectants, and dispersants/detergents.

5.1.1 Corrosion inhibitors

PRODUCT	MANUFACTURER	STATE REGISTRATION NUMBER	SETPOINT RANGE

5.1.2 Biocides/disinfectants

PRODUCT	MANUFACTURER	STATE REGISTRATION NUMBER	SETPOINT RANGE

5.1.3 Dispersants/detergents

PRODUCT	MANUFACTURER	STATE REGISTRATION NUMBER	SETPOINT RANGE

5.2 Program materials – Provide a list of those items and materials that are used in the water treatment program execution.

Item 1	
Item 2	
Item 3	

5.3 Program testing/sampling devices. Provide information on program chemical testing and bacterial culture devices.

5.3.1 Dispersants/detergents

PRODUCT/INSTRUMENT	MANUFACTURER	CHEMICAL TESTED	MODEL NUMBER

5.3.2 Program bacterial culture devices (e.g. dipslides)

PRODUCT/INSTRUMENT	MANUFACTURER	CHEMICAL TESTED	MODEL NUMBER

5.4 Program administration equipment. The program and plan administration requires measuring water parameters such as conductivity, pH, oxidation-reduction potential (ORP) and other items vital to maintain the chemistry of the system.

5.4.1 Data generation/sampling and control. Input the data generation/sampling and control equipment used to maintain the chemistry levels required by the program and plan.

MODEL	QUANTITY MEASURED	SENSOR MANUFACTURER	CONTROLLER
	Conductivity		
	ORP		
	pH		

5.4.2 Control elements. Process variables may be maintained by electronic feedback loop or manual adjustment based on a test result. The following table captures the data that specify how variables are controlled.

QUANTITY CONTROLLED	ELEMENT	MANUFACTURER	MODEL
Conductivity	Bleed valve		
ORP	Chemical feed pump		
Anti-scalant/corrosion inhibitor	Chemical feed pump		
pH	Chemical feed pump		

Section 6. Onsite monitoring procedures

Onsite monitoring is required to maintain the automated process monitoring and control systems, to check the effectiveness of the current set points and to adjust (if necessary) the open-loop control systems.

6.1 Monitoring schedule. List the monitoring schedule.

OPERATING VARIABLE	MONITORING ACTIVITY	FREQUENCY PERFORMED

6.2 Monitoring methods and procedures. Document the variables or parameters that are monitored and the procedure used to obtain process data. This section must be consistent with the information in Section 5.4.1.

MONITORED VARIABLE	PROCEDURE
Cooling tower water conductivity measurement	
Cooling tower influent temperature	
Cooling tower effluent temperature	
Disinfectant test procedure	
pH test procedure	
Cooling tower bacteria sampling protocol	
Cooling tower Legionella sampling protocol	
Disinfectants	
Corrosion inhibitor/antiscaling agent	
pH adjustment chemical	
Pump operation validation	

6.3 Monitoring response protocols. List the responses to the results that are a result of the cooling tower measurements.

VARIABLE	ACCEPTABLE RANGE OR LIMITING VALUE PROCEDURE TO ADDRESS OUT-OF-SPECIFICATION VALUES
Conductivity	
pH	
Biocide	
Bacteria	
Legionella	
Temperature	
Air flow rate	

6.4 Monitoring log. Include the cooling tower monitoring sheets. The log must be consistent with the Maintenance Program and Plan that is developed by the cooling tower operator. The log sheets are therefore customized to the specifications of the program and plan.

Monitoring sheets	

Section 7. Onsite maintenance operations

Document the maintenance procedures that are required to be performed as a matter of routine operation of the cooling tower. Examples of routine procedures include calibration and cleaning of conductivity, pH and ORP probes, cleaning of the basin to maintain proper flow of water, water strainer cleaning and more.

PROCEDURE NAME	DESCRIPTION OF METHOD
Sensor calibration	
Basin cleaning	
Filling chemical feed reservoirs	
Additional regular maintenance	

Section 8. Cooling tower operation procedures

8.1 Season startup procedure. Outline the tower startup procedure and specify all chemicals and/or cleaning agents used during the startup process.

Startup procedure	

8.2 Season shutdown procedure. Outline the tower shutdown procedure and specify any and all chemicals and/or materials used for tower shutdown procedures.

Shutdown procedure	

8.3 Non-load operation/procedure. Outline any and all differences in the operational procedure for running a cooling tower without any heat load.

Non-load operation/ procedure	

8.4 Temporary shutdown and startup for maintenance operations. Outline the shutdown and startup procedures that are associated with short term (temporary) conditions that are often associated with maintenance operations.

Temporary shutdown and startup for maintenance operations procedure	

8.5 Cooling tower cleaning procedure. Describe procedure.

Cleaning procedure	

8.6 Cooling tower online disinfection procedure. Describe procedure.

Online disinfection procedure	

8.7 Cooling tower emergency online disinfection procedure. Describe procedure.

Online emergency disinfection procedure	

8.8 Cooling tower emergency disinfection procedure. Describe procedure.

Online disinfection procedure	

8.9 Commissioning guidelines for new cooling tower systems. List guidelines.

List commissioning guidelines	

8.10 Contingency cooling for planned or unplanned tower interruptions.
Describe contingency.

Describe interruptions contingency	

8.11 Contingency response plan, system interruptions. Describe contingency.

Describe interruptions contingency	

8.12 Contingency response plan, system interruptions. Describe contingency.

Describe maintenance and disinfection procedures	

8.13 Circulation procedure for off line/idle. Describe procedure.

Describe off line/idle procedures	

Section 9. Biological sampling plan

The following outline lists the minimum required sampling that must be performed to satisfy the requirements of Section 4-1.4.

Frequency of Routine Biological Sampling:

- Bacteriological culture sampling.
  - Not to exceed 30 days.
- Legionella culture sampling.
  - Within two weeks after the tower startup.
  - Weekly sampling while operational.

Biological Sampling Required Due to Operational Issues or Epidemiological Concerns:

- Legionella culture sampling and analysis.
  - Power failure of sufficient duration to allow for the growth of bacteria.
  - Loss of biocide treatment of sufficient duration to allow for the growth of bacteria.
  - Failure of conductivity control, or any other control methods, to maintain proper cycles of concentration.
  - Determination by the State Department of Health or the local health department that one or more cases of legionellosis is or may be associate with the cooling tower.
  - Any other conditions specified by the Department or local health department.

Follow the link here for more additional information from OSHA regarding Legionella https://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_7.html

Section 10. Maintenance, culture and disinfection reports

In this section, the service reports should be filed in chronological order. This section should not include responses to bacteriological or Legionella testing procedures.

10.1 Microbiological testing reports

10.1.1 Bacteria

Bacteria report	

10.1.2 Legionella

Legionella report	

10.2 Inspection reports

Inspection report	

10.3 Cooling tower cleaning reports

Cleaning report	

10.4 Online disinfection/decontamination reports

Disinfection/decontamination report	

10.5 Maintenance reports

Legionella report	

10.5.1 Routine

Routine report	

10.5.2 Remedial

Remedial report	

10.6 Annual inspection reports

Annual report	

Section 11. Chemical supply log

Document records of restocking chemicals as a means of tracking the amount of material used for proper management of the water quality of the tower water. The tables shown below are examples of what should be documented for each product used in the maintenance program.

11.1 Resupply log for biocide. Insert the biocide resupply log.

ITEM	RESUPPLY DATE	QUANTITY

11.2 Resupply log for corrosion inhibitor. Insert the biocide resupply log.

ITEM	RESUPPLY DATE	QUANTITY

11.3 Resupply log for anti-scalant agent. Insert the biocide resupply log.

ITEM	RESUPPLY DATE	QUANTITY

11.4 Other materials that may be Used for cooling tower maintenance and operation. Add any additional materials that may be used for cooling tower maintenance and operation.

Additional materials	

Section 12. Cut sheets for program equipment

Include the equipment that is used for executing the program and the specific model identified on the document.

Cut sheets	

Appendix B: Rinse tank management

Intent

It is an RTX goal to reduce freshwater intake. Several manufacturing processes including acid etching, alkaline cleaning, electroplating and fluorescent penetrant inspection require large amounts of freshwater to clean or rinse parts. This guidance document was prepared to assist in determining whether process improvements to rinse tank operations are practical. Factors to consider include available space, level of production, water quality standards, process chemistry, local regulations and economics.

Applicability

The water guidance document recommends that sites in stressed or scarce regions investigate water conservation in process rinse water tanks. Each facility will determine applicability and practicality of using these methods at their site.

Requirements

The Site EH&S Management Committee and EH&S Water Programs Manager are responsible for reviewing the opportunities and presenting their recommendation to the General Manager.

- Establish the goals for the water conservation projects and the criteria that will be used to evaluate the systems proposed.
  - Evaluate current consumption in relation to RTX's goals.
  - Determine consumption sources that could be reduced.
- Identify the equipment or processes that use water in rinse tanks. This is needed to determine the size of the conservation equipment. For each process:
  - Determine hourly/daily water consumption for each process.
  - Identify the contaminants present in the rinse water.
  - Identify the water quality specification for the rinse water.
  - Estimate the amount of dragout from each of the process tanks into the rinse tank and any steps taken to reduce the dragout (e.g.; extended time to drain parts, using compressed air to remove process solution, stagnant rinse tanks, etc.).
  - Record the amount of throughput in the process tank and associated rinse tanks.
- Based on the preceding data, the operations can implement one of the following measures:
  1. Close-loop recycle the rinse water as described in the RTX EHS Water Guidance Document: Closed-Looping or Process Wastewater Recycling (Appendix C)
  2. Reduce the volume of rinse water using technologies listed below.
- Prior to implementing the 2nd measure, contact equipment suppliers and consultants to determine if the volume of rinse water used in the process can be reduced. If yes, evaluate using the following strategies either alone or in combination:
  - **Counter Current Rinsing.** In counter current rinsing systems water circulates through a series of connected rinse tanks, flowing in the opposite direction of the workflow. Fresh water enters the last rinse tank, overflows to the next rinse tank and continues until it exits via the first rinse tank. This method allows the work piece to be rinsed in the least pure water first and the cleanest water

last. Most importantly, it reduces the amount of clean water required. Practical experience and studies have proven that slightly contaminated overflow from the subsequent rinse is just as effective as clean water, making it a very efficient rinsing system.

  - **Conductivity Controls.** Conductivity meters minimize the use of makeup water by monitoring the rinse water bath and only allowing fresh water when the conductivity reaches a certain set point. The set point depends on the chemical being rinsed and the desired cleanliness of the work piece.
  - **Flow Restrictors.** Flow restrictors limit the volume of rinse water flowing through a running rinse system. Once the optimal flow rate has been determined, these devices are used to maintain constant flow of makeup water to the system.
  - **Tank Agitation.** DO NOT USE COMPRESSED AIR FOR TANK AGITATION!* Forced air or water is the most efficient method for creating complete mixing during rinse operations. This can be achieved by pumping either air or water into the immersion rinse tank. Air agitation can provide the best rinsing because the air bubbles create improved turbulence to remove the chemical process solution from the work piece surface.

- Obtain quotations from vendors for the desired retention and treatment infrastructure.
- Evaluate data and proposals to determine if the proposed system will achieve the specified goals.
- Coordinate a Change Management review and summarize the results for Site EH&S Management Committee review.
- Follow respective business unit requirements for permitting changes or requests .
- Document project details as required by business operations.
- Upon General Manager's approval, coordinate the purchase and installation of the system(s) with Facilities and Services.

Training

Employees, depending upon their job classifications, shall be trained to understand requirements of this Guidance Document. Emphasis should be made regarding the proper operation of the control system(s) installed, acceptable water quality and supervisor' permission is required prior to adding water to the tank (i.e., bypassing the control system(s)).

Inspections and audits

Each operation shall have a program of inspections and audits in place that effectively monitors the control system(s) implemented.

* Tank agitation or "Sparging" is an inappropriate use of compressed air. See Energy Best Management Practices Guidebook, Compressed Air, Eliminate inappropriate uses of compressed air.

Appendix C: RTX's EHS water guidance document: closed-looping or process wastewater recycling

Intent

It is an RTX goal to reduce the volume of water consumed and decrease the volume of industrial process wastewater discharged to the sanitary sewer or the environment. To achieve these goals, wastewater from several manufacturing processes can be chemically or mechanical treated to remove contaminants such that the water can be reused in the same or a different process.

This document was prepared to assist in the determination of the practicality of reducing the volume of water consumed and discharged by closed looping and/or recycling wastewater from operations such as cleaning, etching and fluorescent penetrant inspections to other operations.

Applicability

This guidance document applies to all RTX business units and operations worldwide including those joint ventures, partnerships or other business arrangements where RTX holds a majority ownership interest, majority voting control, or where RTX, by contract, has agreed to manage the operation.

Each facility will determine applicability and practicality of closed looping or recycling process wastewater for each process.

Requirements

The Site EH&S Management Committee and EH&S Water Programs Manager are responsible for reviewing the opportunities and presenting the business case to the General Manager.

- Identify the equipment or processes that are potential candidates for closed looping or recycling process water uses.
  - List generators of wastewater.
  - List potential users of recycled water.
- Evaluate the process requirements to determine if close looping or process wastewater recycling is viable.
  - Identify water flow and temperature requirements.
  - Identify the contaminates of concern that may be present in the wastewater.
  - Identify where the wastewater may be reused.
  - Identify the specific water quality requirements.
- Complete an engineering assessment of suitable process wastewater treatment technologies to achieve the desired water quality.
- Confirm that proposed wastewater treatment technology does not conflict with any existing air regulations or hazardous waste processing requirements.
- Obtain quotations from vendors for the desired system.
- Coordinate a Change Management review and summarize the results for Site EH&S Management Committee review.

- Document project details as required by business operations.
- Coordinate with Facilities and Services to purchase and install the system.

Training

Employees shall receive initial and periodic training appropriate to their job responsibilities in the management of water use and wastewater management.

Inspections and audits

Each operation shall have a program of inspections and audits in place that effectively reviews all facets of water pollution prevention. The trending information gathered from these findings shall be used in the overall annual program evaluation.

Documents and records

Implementation details of closed loop process cooling applications and process wastewater recycling projects should be documented as required by business operation.

THE INFORMATION CONTAINED IN THIS GUIDEBOOK IS PROVIDED FOR GENERAL INFORMATIONAL PURPOSES ONLY. ITS CONTENT DOES NOT, AND IS NOT INTENDED TO, CONSTITUTE PROFESSIONAL ADVICE, GUIDANCE OR RECOMMENDATIONS TO ANY THIRD PARTY, AND ONLY REFLECTS STEPS BEING TAKEN BY RTX AND ITS BUSINESSES TO MANAGE WATER CONSUMPTION WITHIN ITS OPERATIONS. NOTHING IN THIS GUIDEBOOK SHALL BE CONSTRUED AS A PROMISE OR GUARANTEE BY RTX OR ITS BUSINESSES OF ANY OUTCOME RESULTING FROM THE ADOPTION OF ANY OF THE RTX BEST PRACTICES CONTAINED HEREIN.

RTX
1000 Wilson Blvd.
Arlington, VA 22209
781-522-3000

Join the conversation

www.rtx.com

ECX 4535828 (08/23)