Better Plants
U.S. DEPARTMENT OF ENERGY

Industrial Water Systems
Virtual Training

Session 2
Tuesday – June 23rd, 2026
10 am – 12:30 pm

U.S. DEPARTMENT OF
ENERGY

Water Virtual Training Agenda

- **Week 1 (June 16th) – Introduction to Industrial Water Assessment**
- **Week 2 (June 23rd) – Understanding System Level Water use**
- **Week 3 (June 30th) – True Cost of Water**
- **Week 4 (July 7th) – Plant Water Profiler Working Session**
- **Week 5 (July 14th) – Identifying Water Savings Opportunity**
- **Week 6 (July 21th) – Virtual Water Treasure Hunt**
- **Week 7 (July 28th) – Estimating Water Savings Opportunities**
- **Week 8 (Aug 4th) – Industrial Water System VINPLT Wrap-up Presentations**

Agenda – Session Two

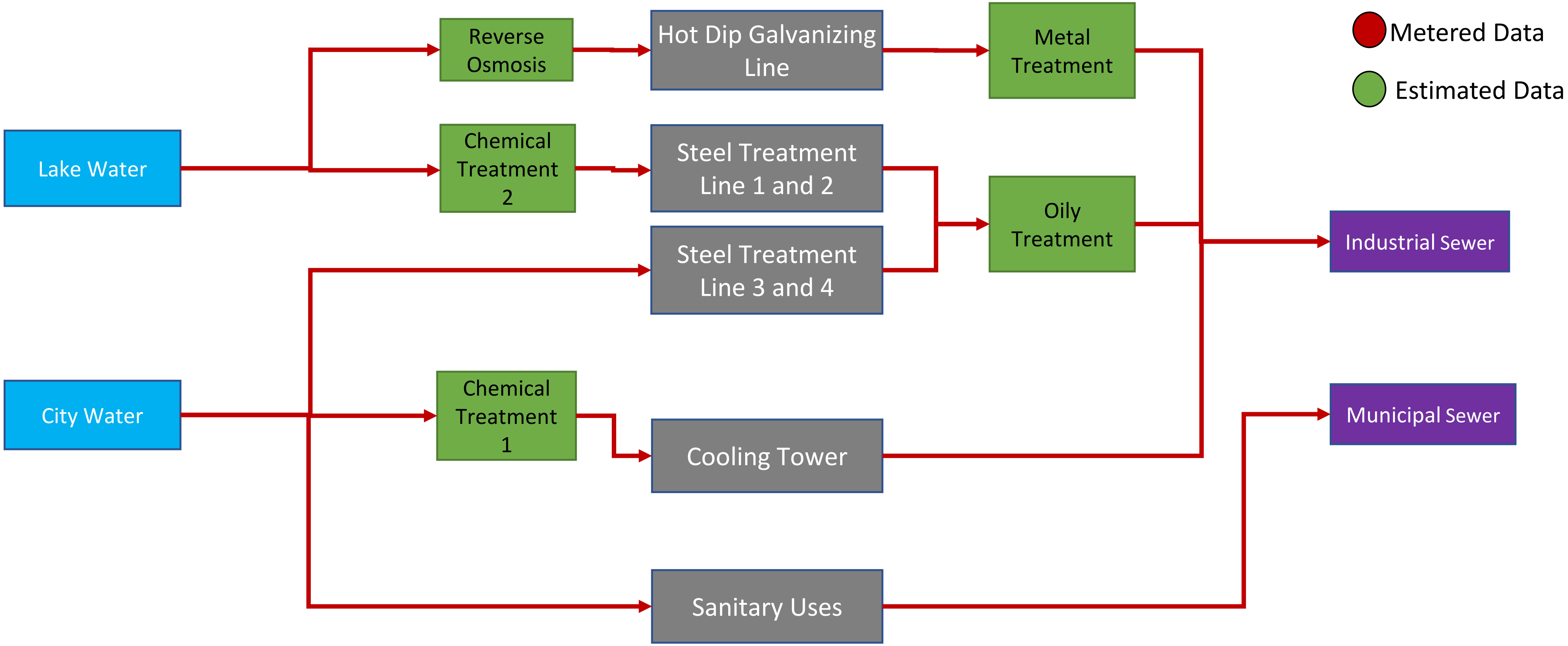
- Today's Content:
  - Day 1 Review
  - Comments on homework
  - Data Collection for baseline
    - Facility level data
    - Systems level data
  - Diagnostic equipment
- Kahoot Quiz Game
- Q&A

Better Buildings is an initiative of the U.S. Department of Energy

Session 1 – Review

- Overview of Industrial Water Use and Water Risks
- Industrial Water Assessment
  - Step 1 - Water Baselining
  - Step 2 - True Cost of Water
  - Step 3 - Identifying water savings opportunities
- Water Baselining
  - Plant Water Flow diagram
  - Data Collection

Example Facility – Water Flow Diagram



Some common comments on the homework

- Water Treatment vs Wastewater Treatment
- Encouraged to use MEASUR software
- Blowdown from cooling tower and boiler should be added to flow – they can be significant
- Avoid including systems without a makeup water to simplify the diagram
- Systems with similar intake and discharge can be combined if it makes data collection easier
- Process with non-similar intake and discharge (additional water treatment) needs to be considered separately
- If you do not have access to an industrial facility, you can use similar approach for your office buildings as well

Data Confidentiality and homework assignments

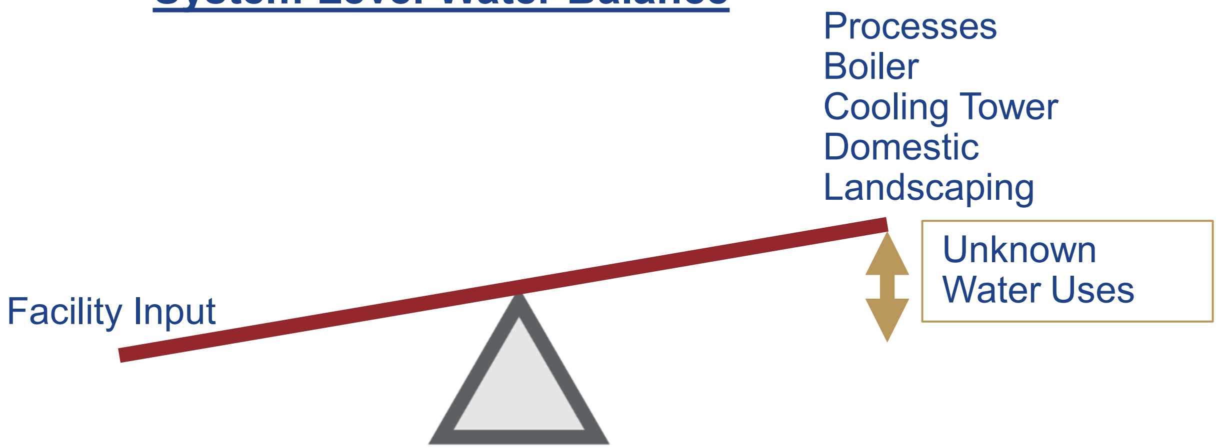
- Option 1: I am fine sharing the information submitted as part of the homework publicly – Ideal; the data from the facility will help others learn
- Option 2: I am fine sharing the information submitted as part of the homework only to participants of this workshop – We will discuss the homework during the sessions but remove it from any publicly available information
- Option 3: The data is completely confidential, and the homework information is only for workshop hosts – homework will to be discussed offline in private calls.

Water Baseline

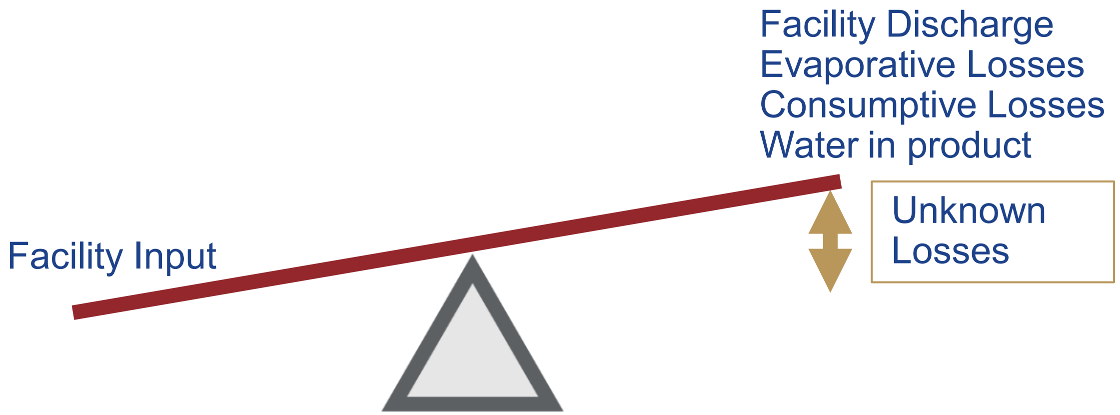
For water baseline and to perform water balance we need

- Facility Level Water Data
- System Level Water Data

System Level Water Balance



Facility Level Water Balance



Water Baseline - Data Collection

The information required to complete the water baseline can come from the following

- Metering (ideal)
- Engineering estimates (when metering is not feasible)

The **Water Balance** activity can also be used to determine the water flow when appropriate

Determining flow from Metering

Permanent Metering

- Using facility meters, submeters and utility bills (most reliable data)

Short-Term Monitoring

- Data logging for few weeks (estimates depend on how well the monitoring period represents annual operation)

Instantaneous Measurements

- Spot measurements using hand-held devices (estimates may have high uncertainty)

Facility Level Data Collection

Facility Water Intake

- Municipal City Water:
  - Potable, Non-Potable
- Surface water:
  - River, Lake, Pond
- Ground water
  - Wells

Facility Wastewater Discharge

- Municipal Sewer:
  - Domestic, Industrial Sewer
- Surface discharge:
  - River, Lake, Pond
- Third Party Disposal
  - Wastewater shipped offsite
- Onsite Disposal
  - Irrigation

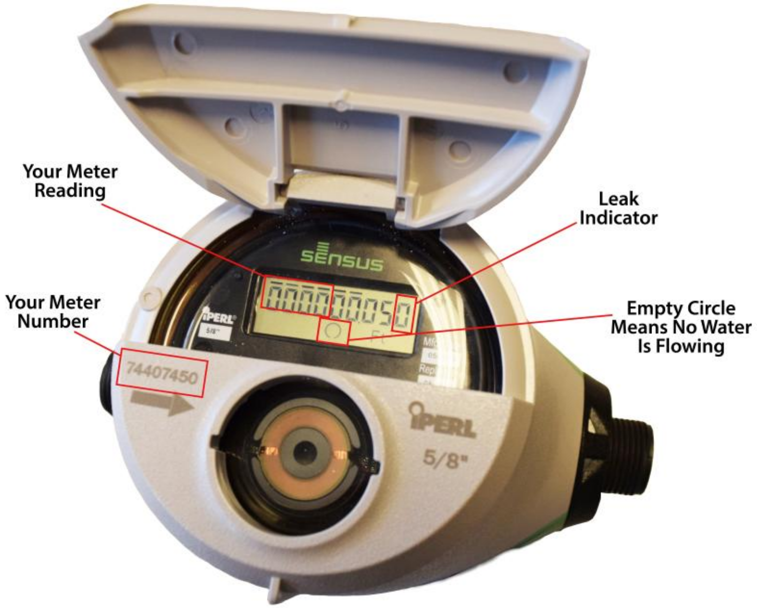
Collecting Facility Level Water Data

- Utility Meter
  - Municipal City Water and Sewer
  - Municipal City Water: Potable, Non-Potable

- Onsite Metering
  - Surface water: River, Lake, Pond
  - Ground water: Wells
  - Third Party Disposal
    - Wastewater shipped offsite
  - Onsite Disposal
    - Irrigation

Displacement Water Meter

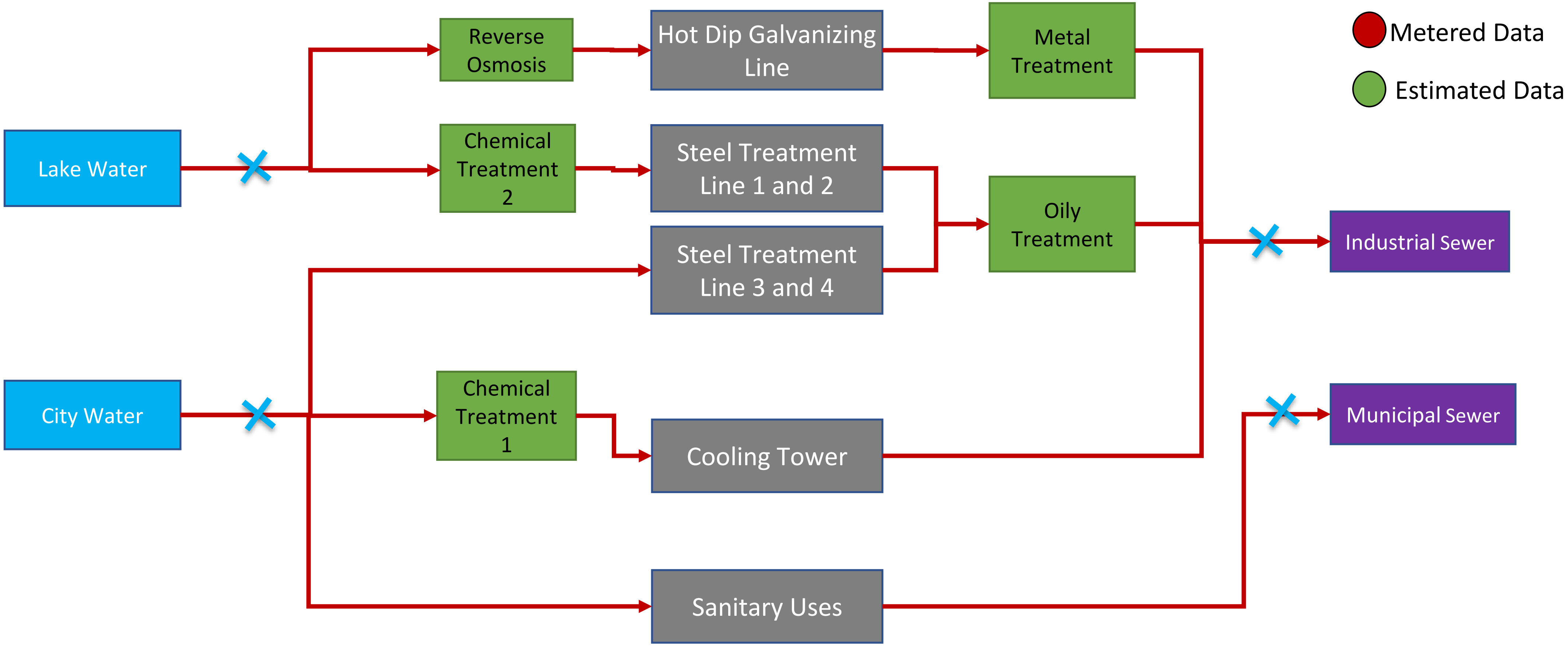
Courtesy: Neptune



Electromagnetic Water Meter

Courtesy: KUB and Sensus

Facility Level Water Data



Water Using Systems

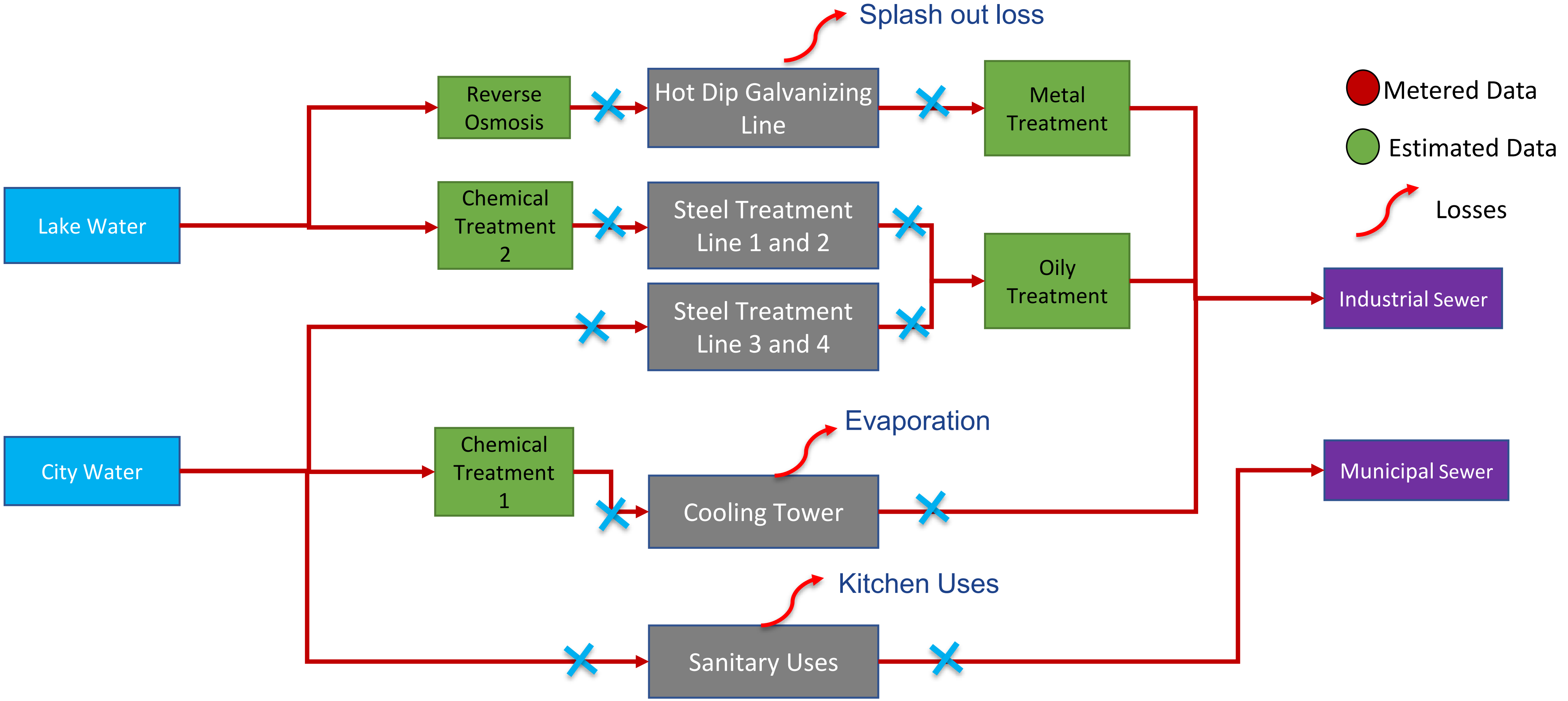
- Cooling Uses
  - Direct and Indirect
- Boiler System
- Process Water Use
  - Cleaning
  - Product treatment
  - Dilute chemicals
  - Transport material
  - Water as product
- Domestic Use
- Landscaping

Contact Cooling of Steel coils in Hot Rolling

Water used in the dilution of chemicals

Cooling tower showing water loss through evaporation

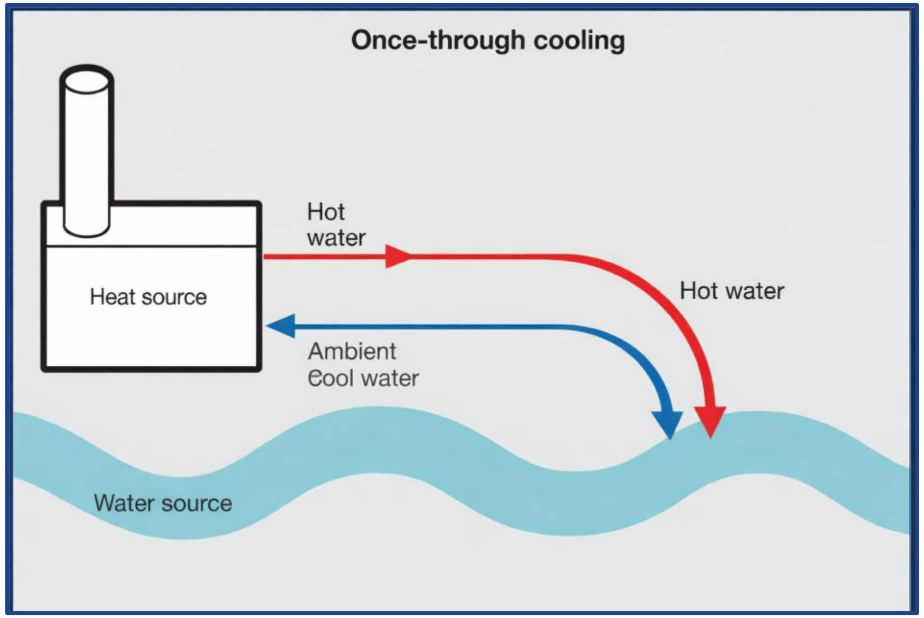
System Level Water Data



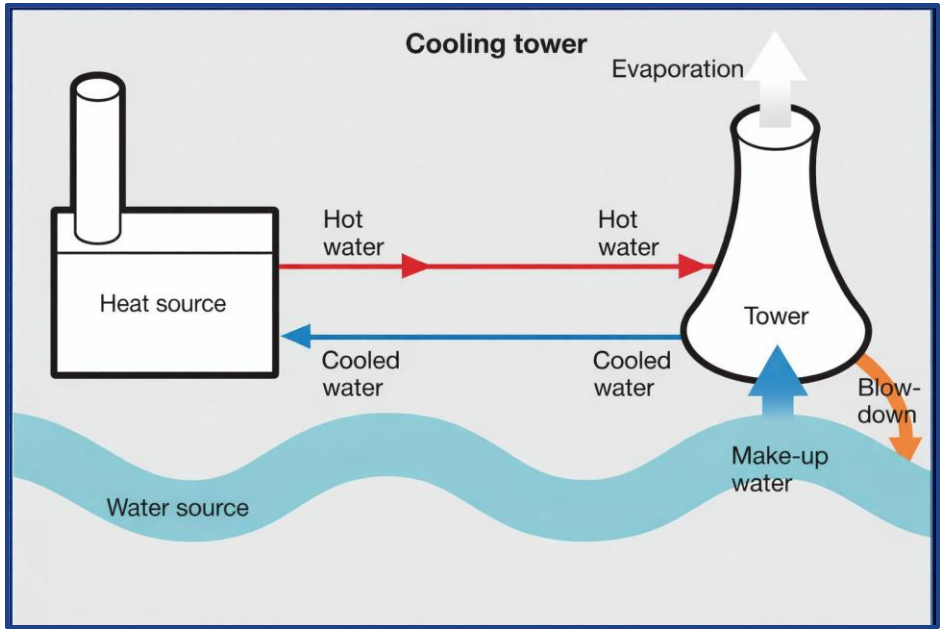
Cooling Water Uses - Overview

- **Contact (Direct) or Non-Contact (indirect) :** Depending on if water comes in contact with any raw material or product.

- **Closed or Open loop:** Depending on the recirculated system in place



Open Loop Cooling system – Once through cooling



Closed Loop Cooling System with Cooling Tower

Source: Wartsila, Efficient use and consumption of water in power generation

Direct and Indirect Cooling Uses Water Users

Indirect or non-contact water does not touch any raw material, intermediate product, waste product, or finished product. They are typically part of a closed loop system.

Most relevant and typically seen in cooling applications

Direct Cooling

- Product cooling by contact (plastic extrusion, metal surface cooling)
- Effluent picks up contaminates from the product/raw material and needs to be treated

Indirect Cooling

- Cooling done via a heat exchangers and cooling tower or once through indirect cooling system (furnace cooling)
- Effluent stream is typically contaminant free and requires no/minimum treatment before being reused

Cooling Tower System – Typical Use

A cooling tower is a heat rejection device brings air and water in contact with each other in order to reduce the water's temperature

- Cooling Tower connected to electric chiller can be used to provide chilled water for process or HVAC needs

- Cooling Tower can be used as a stand-alone device to provide cooling water to process

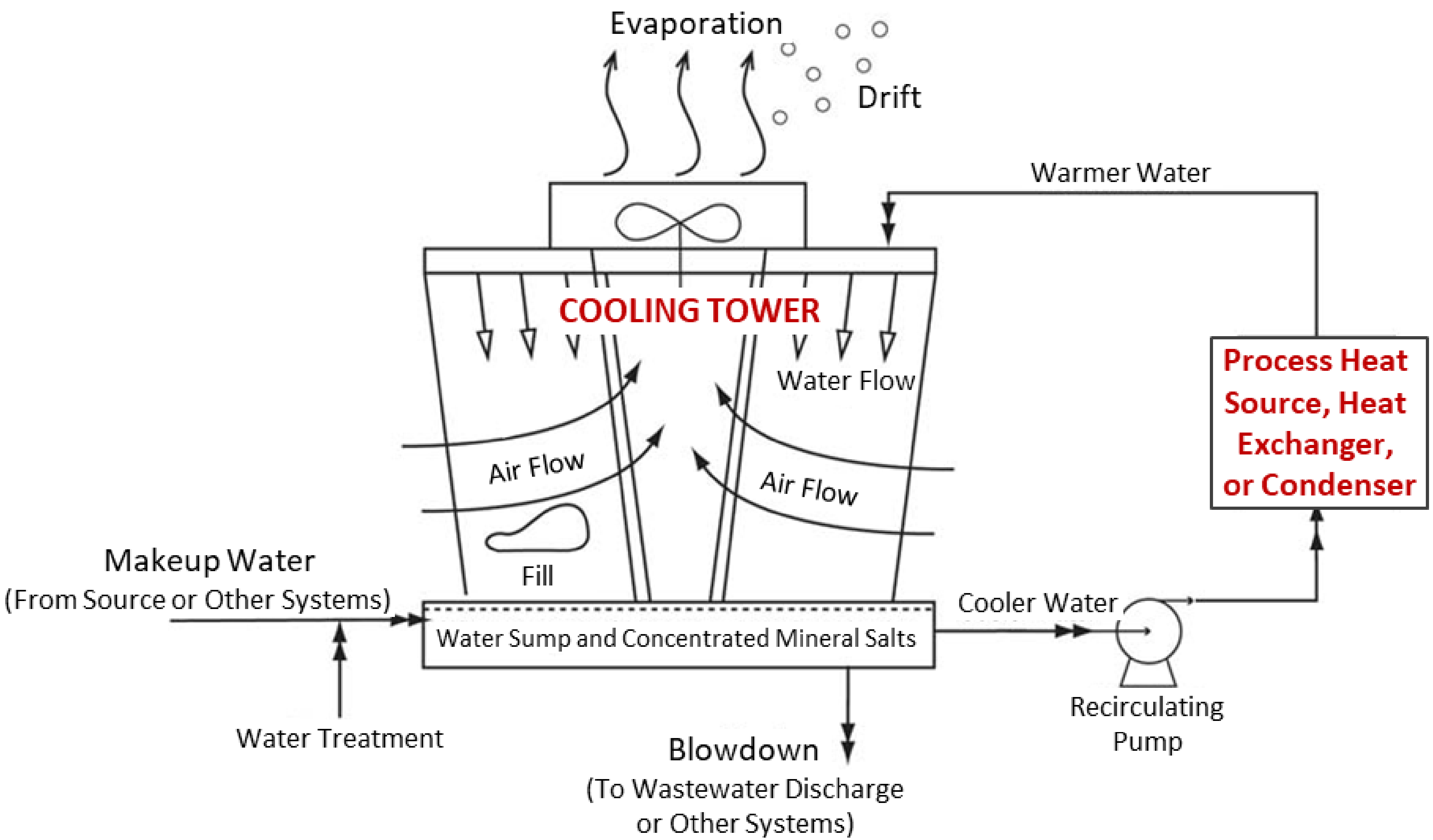
Some typical processes served by cooling towers

- Indirect cooling of process equipment and product
- Cooling of Electronics and Mechanical Equipment
- Building HVAC

Cooling and Condensing System

Major Components

- Cooling Tower
- Pumps
- Cooling Loads
  - Process Heat
  - Heat Exchangers
  - Chiller



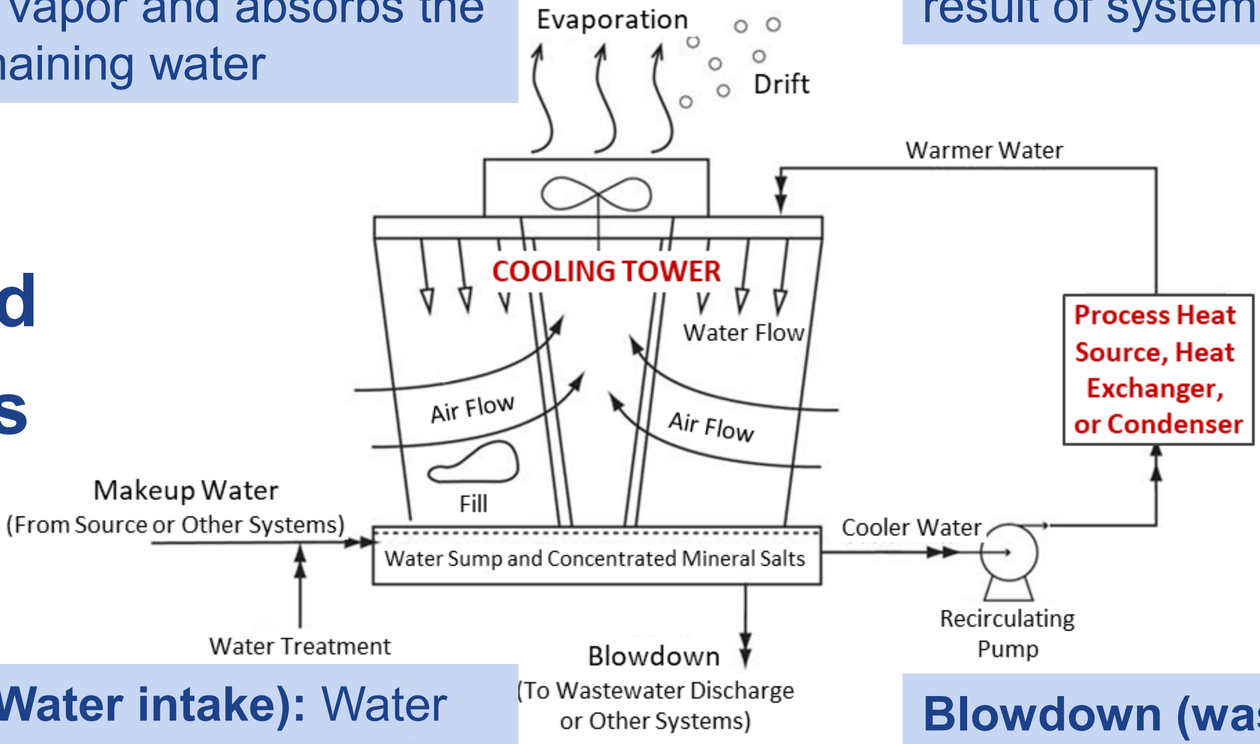
Water is often used as the working fluid or for heat rejection in a process cooling system.

Cooling and Condensing System

Evaporated water (consumption): Portion of the recirculating water that converts to water vapor and absorbs the heat from the remaining water

Cooling tower drift (unaccounted loss): Escape of water droplets from the cooling tower structure as a result of system air flow and wind-effect air flow.

Understand water flows



Recirculated water (gross water use): primary water stream that continuously flows through the system

Make-up water (Water intake): Water supply needed to replace all losses due to evaporation, leaks, or discharge in boiler or cooling systems.

Blowdown (wastewater discharge): Water discharged from a cooling tower to remove high mineral content system water, impurities, and sediment.

Cooling Tower - Estimating Water use

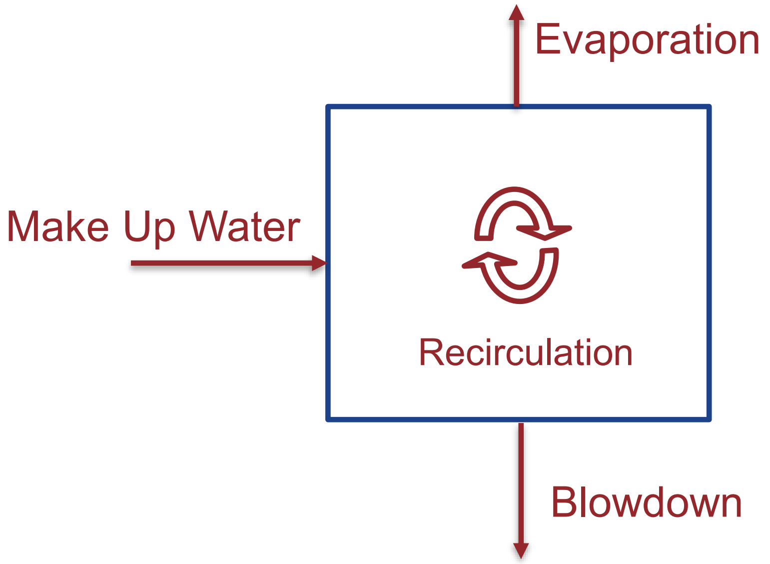
Losses

Make Up Water = Evaporation + Blowdown

Intake

Discharge

Cycles of Concentration = $\frac{Make\ Up\ (GPM)}{Blowdown\ (GPM)} = \frac{Conductivity\ of\ Blowdown}{Conductivity\ of\ Make\ Up}$



One can determine the intake, discharge and loss in a system if

- If cycles/conductivity and makeup are known
- If cycles/ conductivity and blowdown are known

Alternatively engineering estimations based on equipment size/load and operations can be used

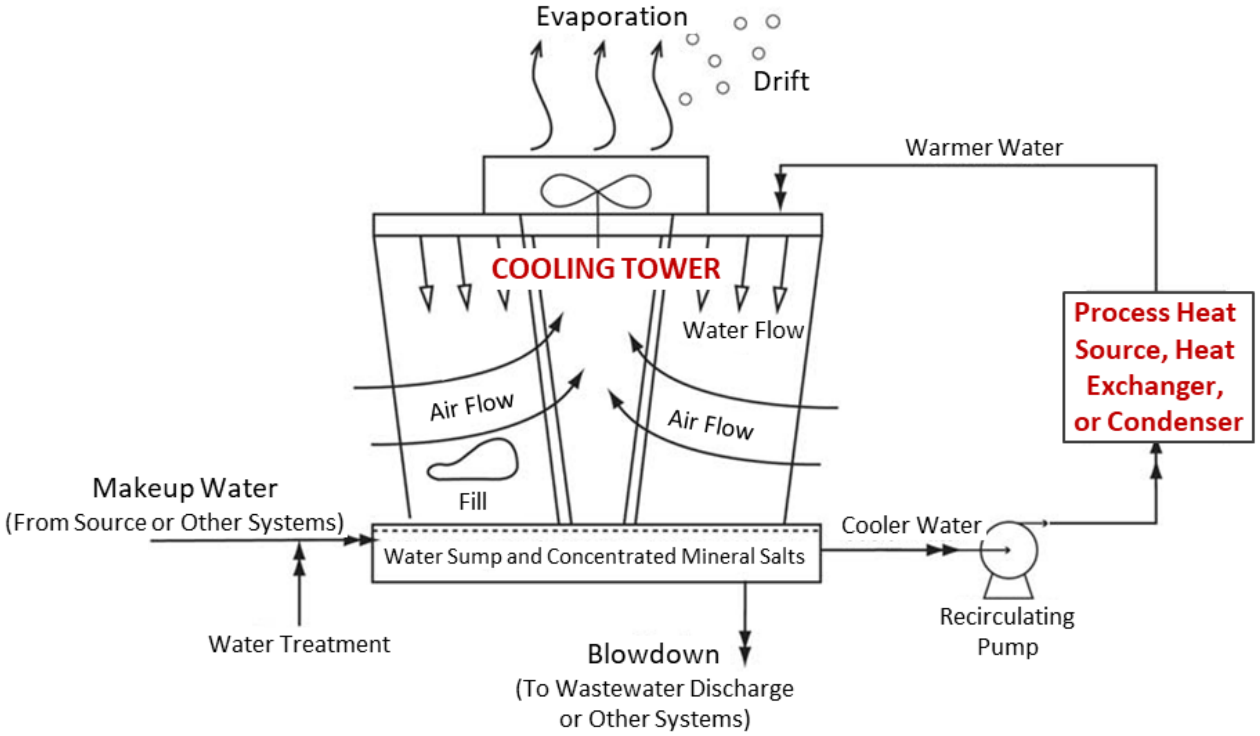
Cooling and Condensing System – Terminology

Cooling Tower Tonnage

Hours of operation

Load fraction: Average load on the cooling tower

Makeup/ Blowdown water conductivity (from conductivity meters)



Cycles of Concentration is the number of times water is recirculated within the system before being discharged to outlet (blowdown)

Evaporation ∝ Gross Water Use x Delta T x Evaporation Rate

Gross Water Use: Typically, 3 gpm per ton of cooling

Temperature drop across cooling tower: Typically, 10F at 85F WBT

Evaporated rate: Per 10F temp. drop across cooling tower

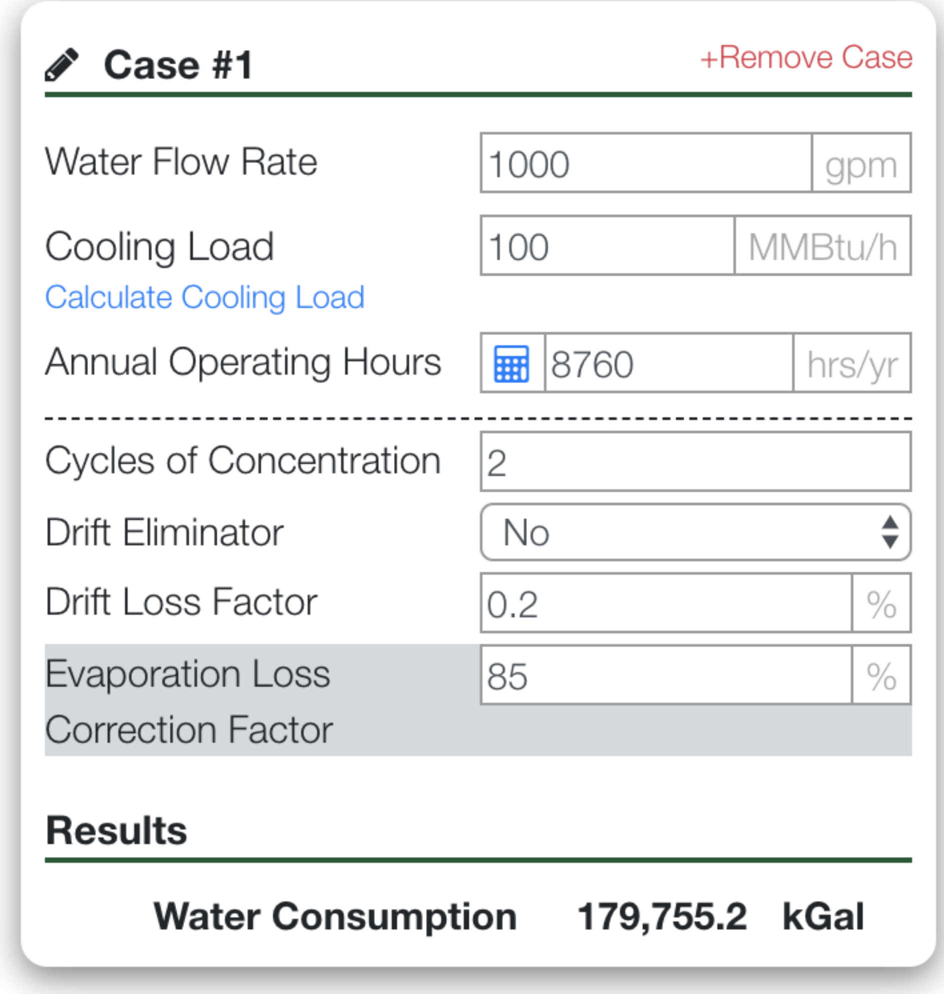
- 0.85 - Typical
- 0.65 - Moist Climate
- 1.0 to 1.2 – Dry Climate

Cooling Tower – Calculator

Calculating Evaporation from Cooling Load - instead of Delta T

Evaporation $\propto$ Cooling Load

Data Needed:
- Annual Hours of Operation
- Cooling Load
- Water Flow Rate
- Makeup Water Conductivity
- Blowdown Conductivity



Cooling Tower – Some tips

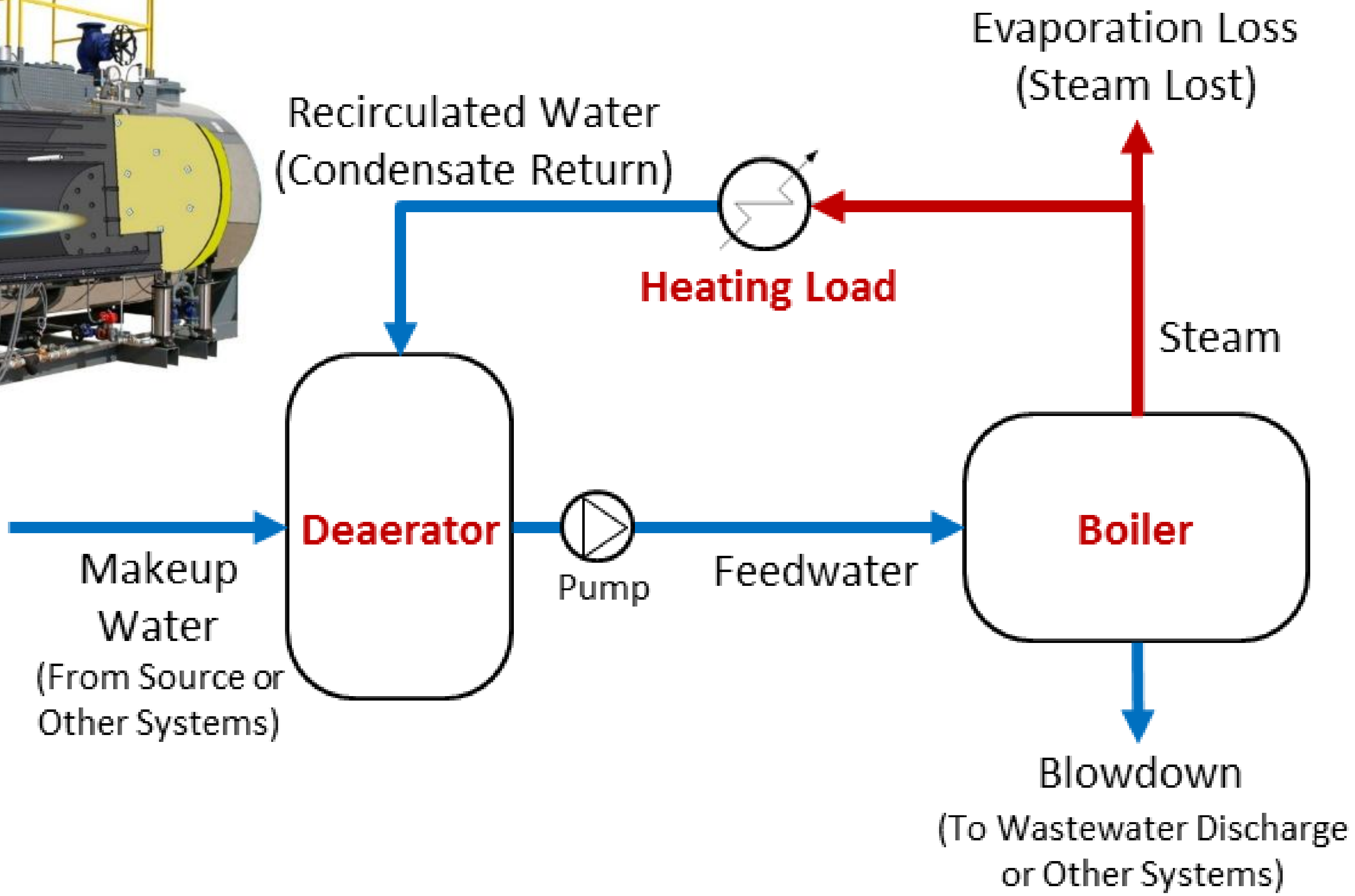
- Evaporation at a cooling towers can be difficult to make accurate engineering estimates for
  - The system loading is hard to determine accurately and is affected by various factors : number of fans running, speed of fans and pumps etc.
  - The design tonnage might be very different from the actual cooling achieved by the system

- Best practice
  - Meter either the intake (makeup water) or discharge (blowdown)
  - Calculate the missing flow from cycle of concentration which is relatively easy to measure
  - Engineering estimates based on tonnage can be used as a check to the values estimated by the above method

Boiler System

Major Components

- Boiler
- Deaerator
- Condensate Tank
- Heating Loads
- Flash tank

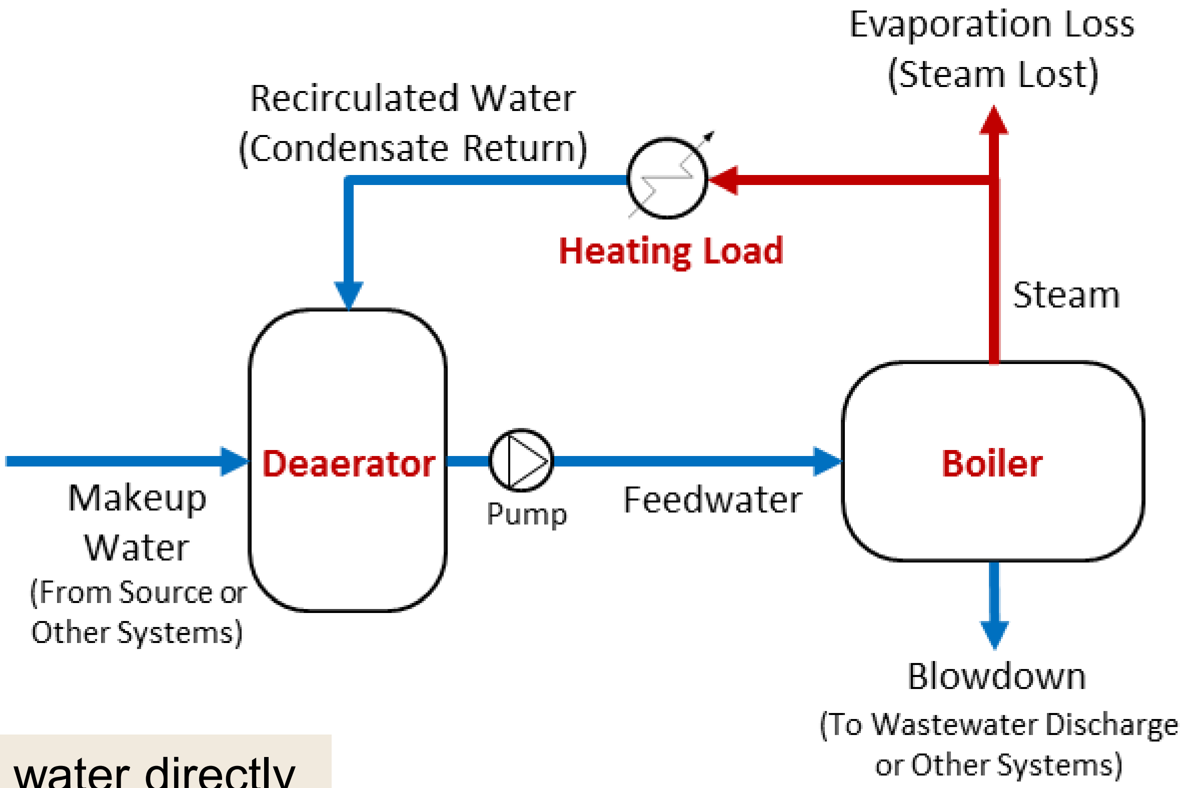


Boiler System

Understand water flows

Makeup water: Water supply needed to replace all losses due to evaporation, leaks, or discharge in boiler or cooling systems.

Condensate return: Steam that changes back to the liquid phase after process or heating applications, that is subsequently pumped back to the boiler feed water.



Steam rate: Steam generation from the boiler needed to meet the heating and/or process steam demand, usually expressed in pounds per time.

Boiler feedwater: Supply water directly to the boiler. It is the combination of make-up water and condensate return.

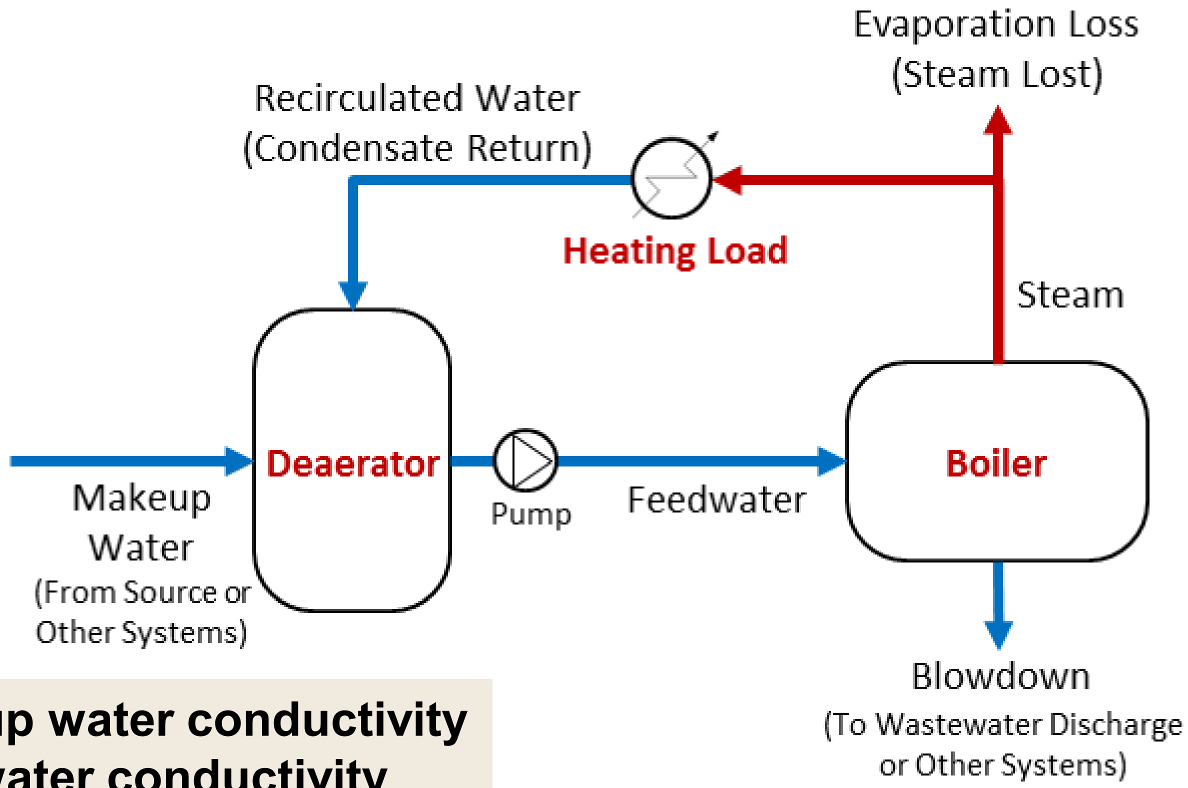
Blowdown: Water discharged from a boiler to remove high mineral content system water, impurities, and sediment.

Boiler System

Understand relevant terminologies

Makeup water conductivity
Feedwater conductivity
Blowdown conductivity
(from conductivity meters)

Load fraction: Average heating load per BHP; typically, 70-80%



Steam generation rate: Typically, 34.5 lb/h per BHP at 212°F

Boiler horsepower (BHP): from nameplate data

Hours of operation

Makeup water conductivity
Feedwater conductivity
Blowdown conductivity
(from conductivity meters)

Cycles of Concentration
= blowdown conductivity / feedwater conductivity

Boiler - Estimating Water use

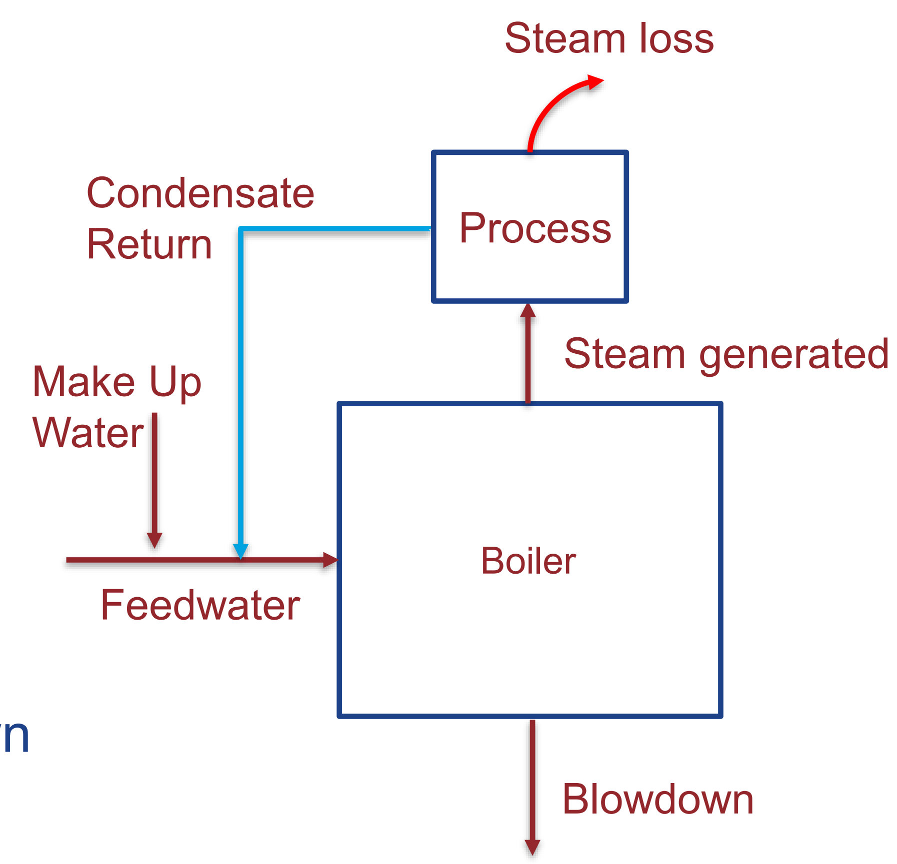
Make Up Water + Condensate Return

=

Steam Loss + Blowdown

intake

Discharge



Cycles of Concentration = $\frac{Feedwater\ (GPM)}{Blowdown\ (GPM)} = \frac{Conductivity\ of\ Blowdown}{Conductivity\ of\ Feedwater}$

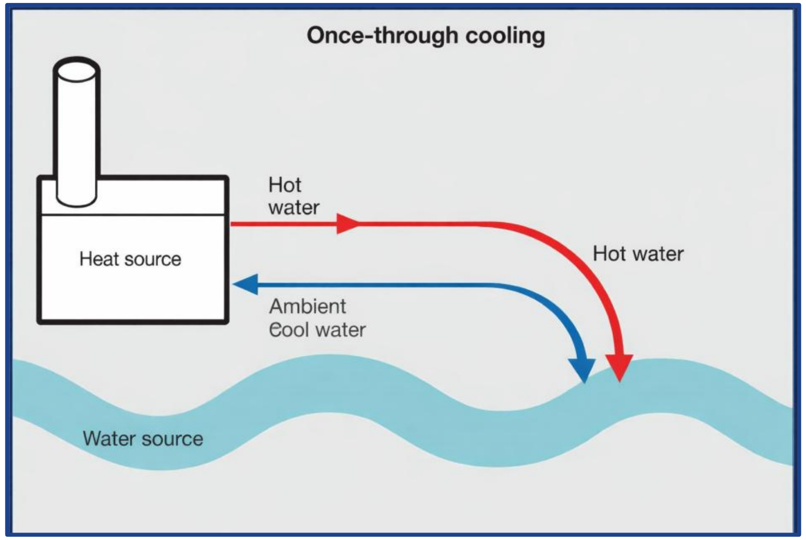
One can determine the intake, discharge and loss in a system if

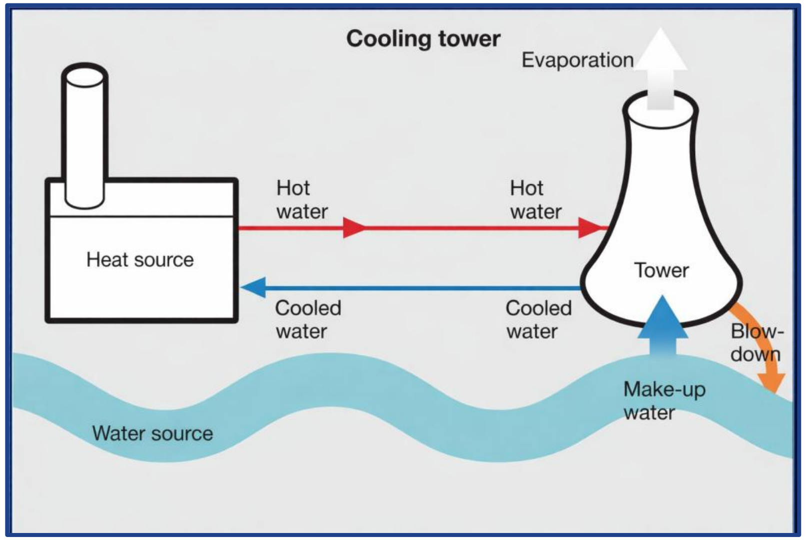
- If cycles/conductivity and makeup, condensate return are known
- If cycles/conductivity and blowdown, condensate return are known

Alternatively engineering estimations based on equipment size/load and operations can be used

Indirect Cooling or Heating loop

- To be considered if water make -up is added
- Makeup water can be added in an indirect system to compensate for losses
- System can be ignored if water use is relatively very small





Process Water Use in Your Plant

Typical Process Water Use

- Cleaning/ Washing/ Rinsing
- Fabrication/processing
  - Lubrication
  - In chemical reaction
  - Sealing using water
  - Diluting
- Transportation
- Pollution control
- Inclusion in the product
- Other process

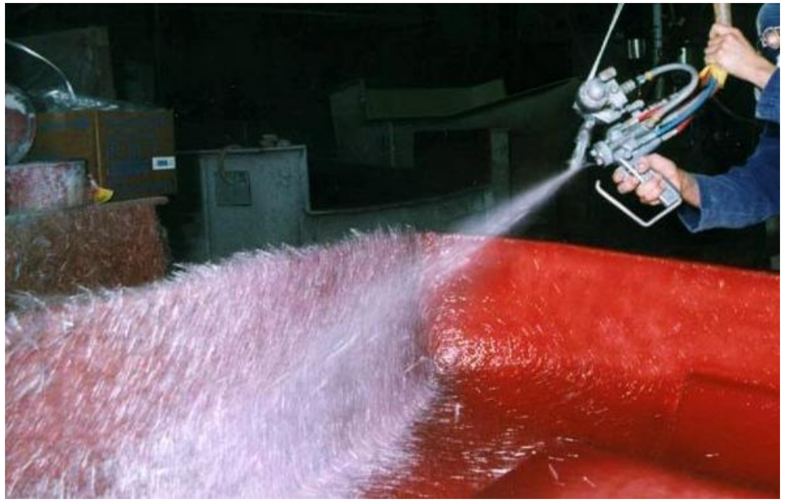
Typical Process Water Uses

Direct Water Use in Process

- While direct process water are used for very different applications (cooling, cleaning etc.) they usually have very similar water use and discharge profile
- Some types of water use in process
  - Automated nozzle spray to wash, cool
  - Manual spray nozzles for cleaning
  - Quench Tanks/ Water baths/ Cooking Vessels
  - Water consumed in product, dilution, sealant etc

Process Water Use - Manual water spray

- Typically used to clean the equipment/product
- Water can be heated before use
- Water use can vary quiet a lot based on operator (can varies with shift)
  - instantaneous measurement might not be sufficient



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https://www.russula.com/en/news/news-cascade-steel
http://compositesmanufacturingmagazine.com

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Process Water Use - Automated Water Spray

- Automated water spray are used in
  - Product Cooling
  - Cleaning
  - Rinsing

- Process Losses associated with evaporation (hard to estimate)

- No behavioral changes - water use should be consistent between shifts
  - Instantaneous measurement might be sufficient

- Could have water recirculation within the system
  - Typically seen in cleaning systems with multiple stages

https://www.russula.com/en/news/news-cascade-steel
https://www.newfoodmagazine.com/

Water Sprays (Discharge)

Water spray discharge can be difficult to meter

Water discharge may not be collected in a convenient fashion for metering

Simple techniques of collecting the discharge using premeasured buckets and noting the time to fill it can give a good rough estimate

Water discharge from a spray operation being drained to the ground floor

Premeasured bin placed to determine the volume of water discharged in given amount of time

Process Water - Water Baths; Quench Tank, Cooking Vessels

Water tanks are used in
- Quench Cooling
- Product treating
- Cooking

Splash out losses (hard to estimate)

Typical have recirculation within the system

Process Water Use – Product, Dilution, Sealant

- Consumptive use can be high and can make up the entire water intake

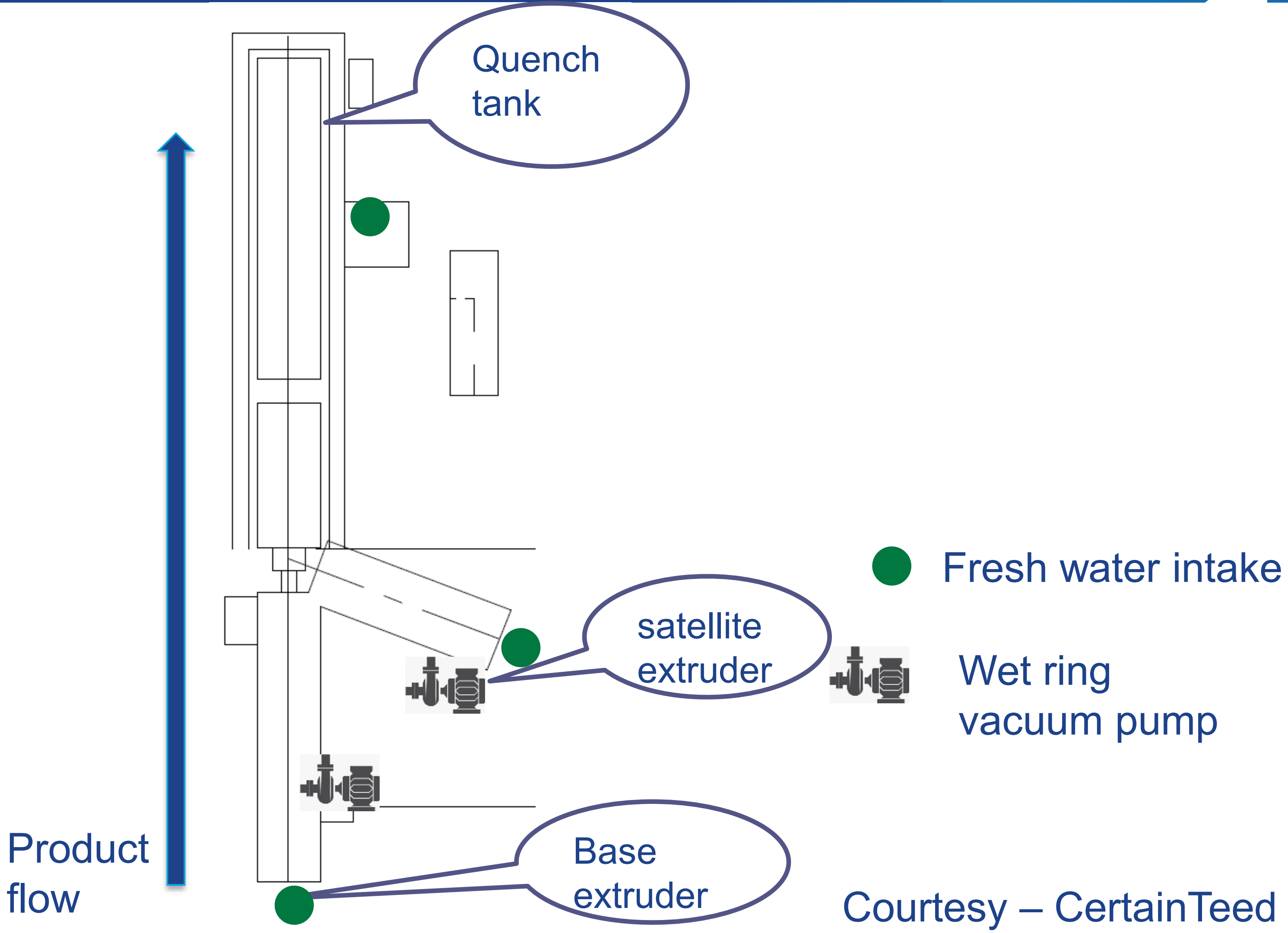
Examples

- Beverages
- Binder Mixing
- Paint shop
- Sealant in Vacuum pumps

https://blog.alchemysystems.com/5-beverage-industry-trends-to-watch-in-2021

A single production line can have multiple water uses

Example: Extrusion process where water sealant vacuum pumps are used to remove contaminates produced and the water bath (quench tank) is used to cool the product



Courtesy – CertainTeed

Process Water – Generic Calculator

Multiple ways of determining make up water used

- From Gallons per production unit
- From Gallons per hour

Water Intake = Gallons/unit × Number of units

Unfortunately, MEASUR does not have industry specific process water use calculators yet.

Data Needed

Number of Units Processed per Year
Water Required for Processing per unit product
Fraction of Water Recirculated
Water Used in Products (consumed)

Specialty Equipment - Spray Dehumidifier

- Spray dehumidifiers use chilled water spray to remove atmospheric moisture
- Chilled water cools the air below its dewpoint and the water from the air condenses out

Others - Sanitary Use and Landscaping

- Typically not metered – Calculators to make high order estimates from number of employees (sanitary use) and land area (irrigation)

- Can be ignored if water use is relatively very small

Data for Sanitary Water Use Calculations

N = Number of Employees
D = Workdays per Year
g = Water Use per Employee (Gallon per Day)
Typical range is 10-35 gallon per shift

Data Irrigation Water Use Calculations

A = Square Feet of Land Irrigated
I = Inches of Irrigated Water per Year

Data needed to estimate Water Flows from PWP calculators

Process	Cooling System	Boiler System	Domestic	Landscaping
Number of Units Processed per Year	Annual Hours of Operation	Annual Hours of Operation	Number of Employees	Area of Land Irrigated
Water Required for Processing	Chiller Tonnage	Boiler Horsepower	Workdays per Year	Inches of Irrigation Water
Fraction of Water Recirculated	Load Factor	Load Factor	Water Use/ Employee	
Water Used in Products (consumed)	Evaporation Rate	Steam Generation Rate		
	Temp. Drop Across Cooling Tower	Feedwater Conductivity		
	Makeup Water Conductivity	Makeup Water Conductivity		
	Blowdown Conductivity	Blowdown Conductivity		

Polling Question 1

What is the current status of water flow mapping and flow quantification at your manufacturing facility?

A. We have not yet mapped water flows at our site

B. We have mapped major water flow paths, but have not quantified flow volumes

C. We have mapped water flow paths and quantified some major flows

D. We have a detailed water balance with quantified flows across systems

Data Collection Tools

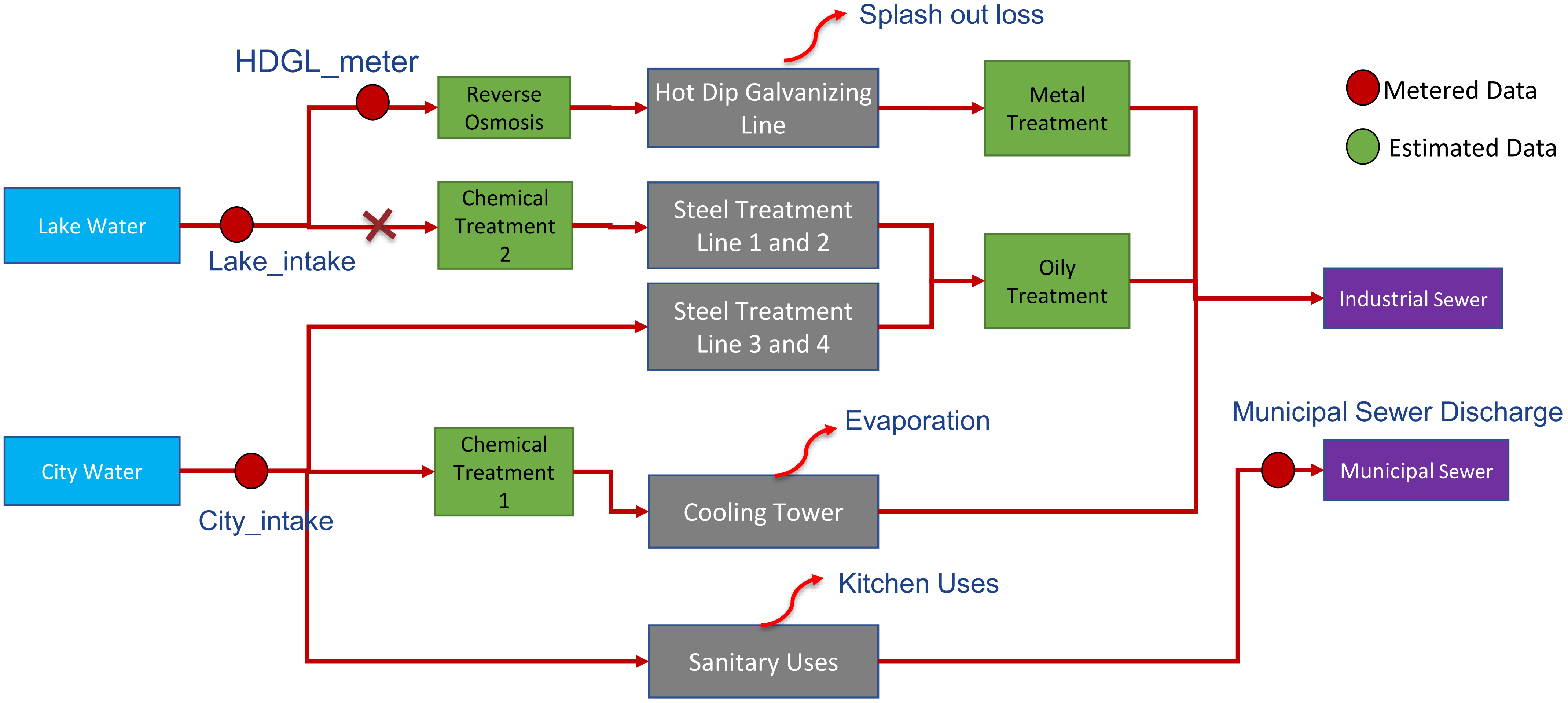
Water Baseline - Data Collection

The information required to complete the water baseline can come from the following

- Metering (ideal)
- Engineering estimates (when metering is not feasible)

The **Water Balance** activity can also be used to determine the water flow when appropriate

Determining flow from Water Balance



Steel Treatment (line 1 & 2) = Lake Intake – HDGL_meter

Determining flow from Metering

Permanent Metering

- Using facility meters, submeters and utility bills (most reliable data)

Short-Term Monitoring

- Data logging for few weeks (estimates depend on how well the monitoring period represents annual operation)

Instantaneous Measurements

- Spot measurements using hand-held devices (estimates may have high uncertainty)

Metering Challenges

Water flows typically not metered:

- Water intake from sources other than municipality
- Effluent (treated wastewater) discharge to outlets other than municipal sewer
- Water use by subprocesses

- Finding the right location to install strap-on ultrasonic flow meters for spot measurement can be challenging.

Short Term Monitoring

Water flow in a system can be known from the short-term monitoring of different equipment/flow parameters

- Water Flow Rate
- Water Quality
- Pressure
- Electricity Measurements
- Other

Diagnostic Equipment

Instruments and data loggers for onsite data collection

Better Plants Partners can request equipment at:

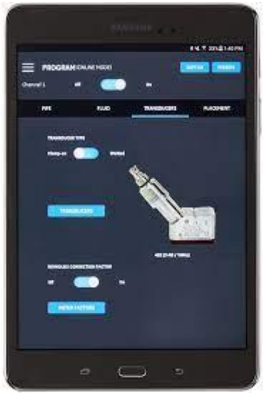
https://betterbuildingssolutioncenter.energy.gov/better-plants/diagnostic-tools

Clamp-on Ultrasonic Flow Meters

- Nonintrusive way to measure flowrate
- Transducers available for pipe sizes from 2inch to 10 inches

Portable Ultrasonic Flow Meter for Liquids - Panametrics PT 900

Flow Transmitter



Tablet/phone

Transducers with clamping fixture

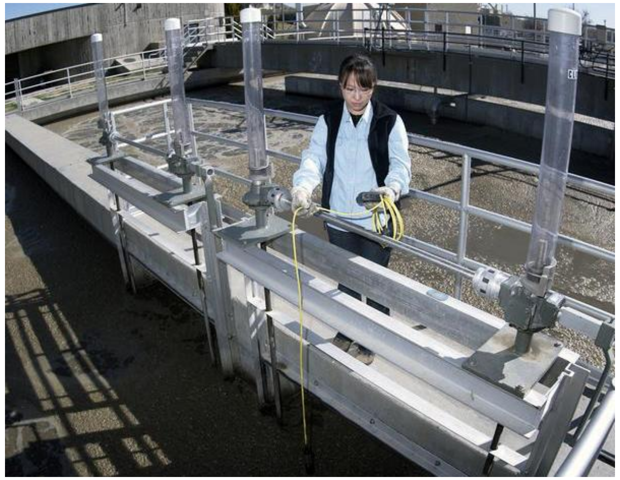
Few Tips for Clamp-on Ultrasonic Flow Meters

Demo: Courtesy TechRentals https://www.youtube.com/watch?v=zXiYDtchLGM

- The flow should be fully formed for the flow meter to work properly
  - Measuring spot should be few feet away from bends, elbows etc.
  - Pipe fittings or valves too close upstream or downstream of the transducers
  - Too-short runs of straight piping upstream & downstream of the orifice
- Cleaning the pipe surfaces dry and adding lubricant to the transducer enables proper contact, critical for error free measurement
- Adjusting transducer position can help troubleshoot a not signal error

Conductivity Meter – Water Quality Meter

- A water quality meter measures the conductivity and Total Dissolved Solids (TDS) of the liquid along with its temperature.
- Recommended maximum TDS levels depends on the type of boiler - normally ranging 2000 - 10000 ppm.
- AMPROBE WT-60 measures Conductivity up to 199.9 mS/cm and TDS up to 199.9ppt



Copyright Hach Company, Loveland, CO

Current and Pressure Transducers

Knowing the pressure and/or power drawn at a pump, the water flow through a system can be estimated using engineering principles

Pressure Transducers

- Pressure Ranges: 30 to 20,000 psi
- Operating pressure can be corelated to the power drawn to determine flow

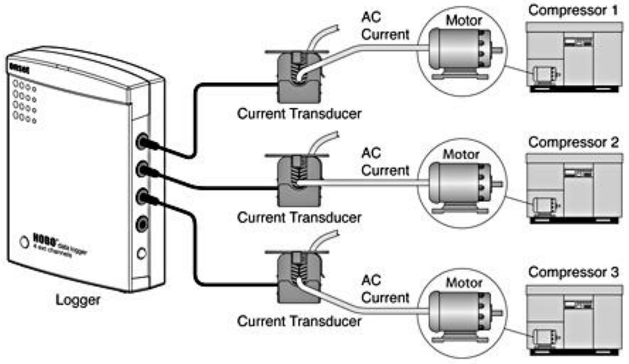
Clamp-on Current Transducers

- Current measurements can be used to deduce the power drawn by a motor

Data Loggers

- Used to collect data over an extended period

- Can be interfaced with most current and pressure transducers



Digital Multimeters

- Multimeters can be used to get the instantaneous current, energy and power quality.

- Limited logging capability and used primarily for spot measurements

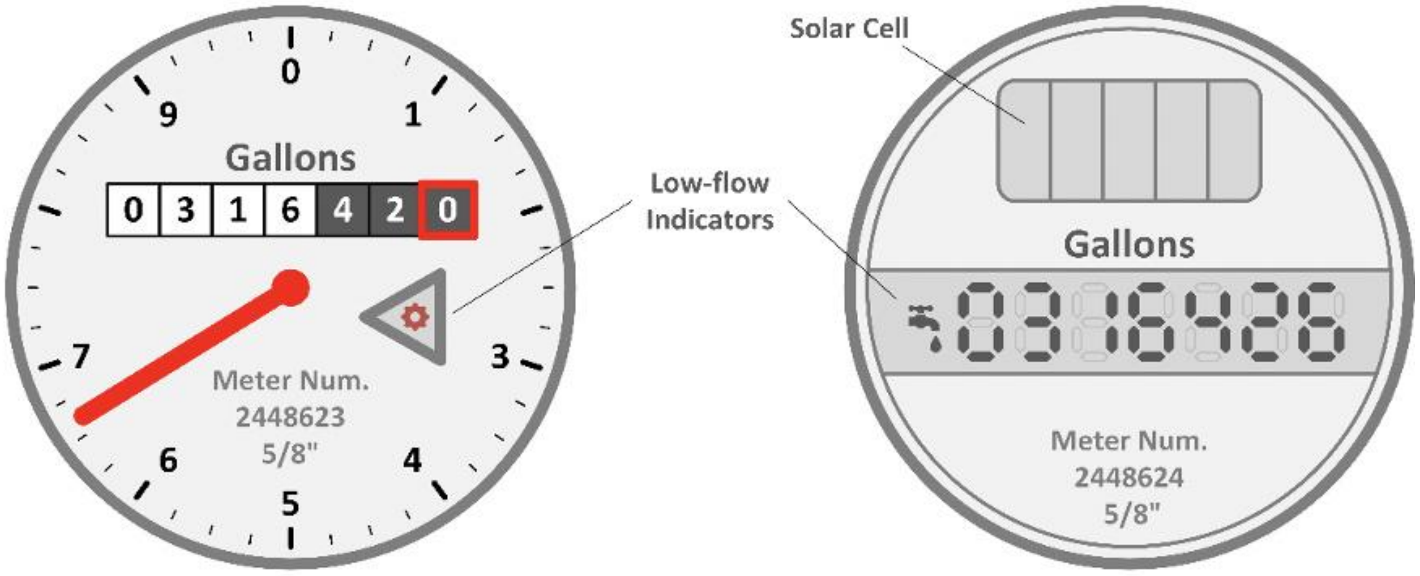
Run time Loggers

- Used to collect the run time of a motor system over a period
- Simple to setup and use and provides the operating hours of a system

Existing Meters

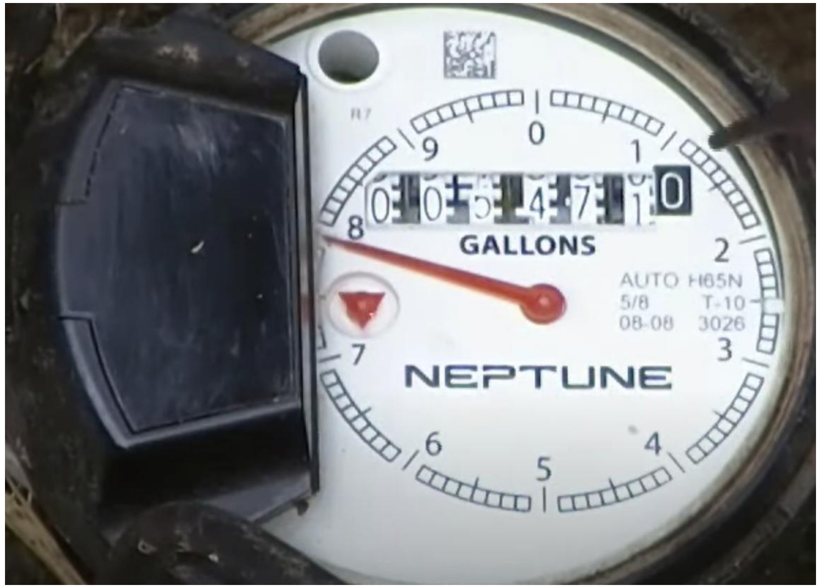
Analog meters are read by reading the rolling tick dial which records to the tens place.

The value in the red box fixed and the last whole digit is read by reading the sweeping hand



(a) Analog (b) Digital

Both reading 316,426 gallons



Bucket and Timer

$$GPM = \frac{60}{Time\ to\ fill\ in\ Sec} \times Volume\ of\ Bucket\ \ in\ Gallons$$

Best Practices for Data Collection

- Use any **existing metering** already in place
  - **Utility meters** are a good starting point for determining **facility-level intake and discharge**
  - Many facilities have **older meters**, so it is important to **walk the site** and identify where meters are located
  - Confirm what each meter is actually measuring, since meters in **recirculation loops** usually do not provide the intake and discharge data needed for a water balance
  - If **tank levels** are tracked, changes in tank level can be used to estimate withdrawals and calculate water flows

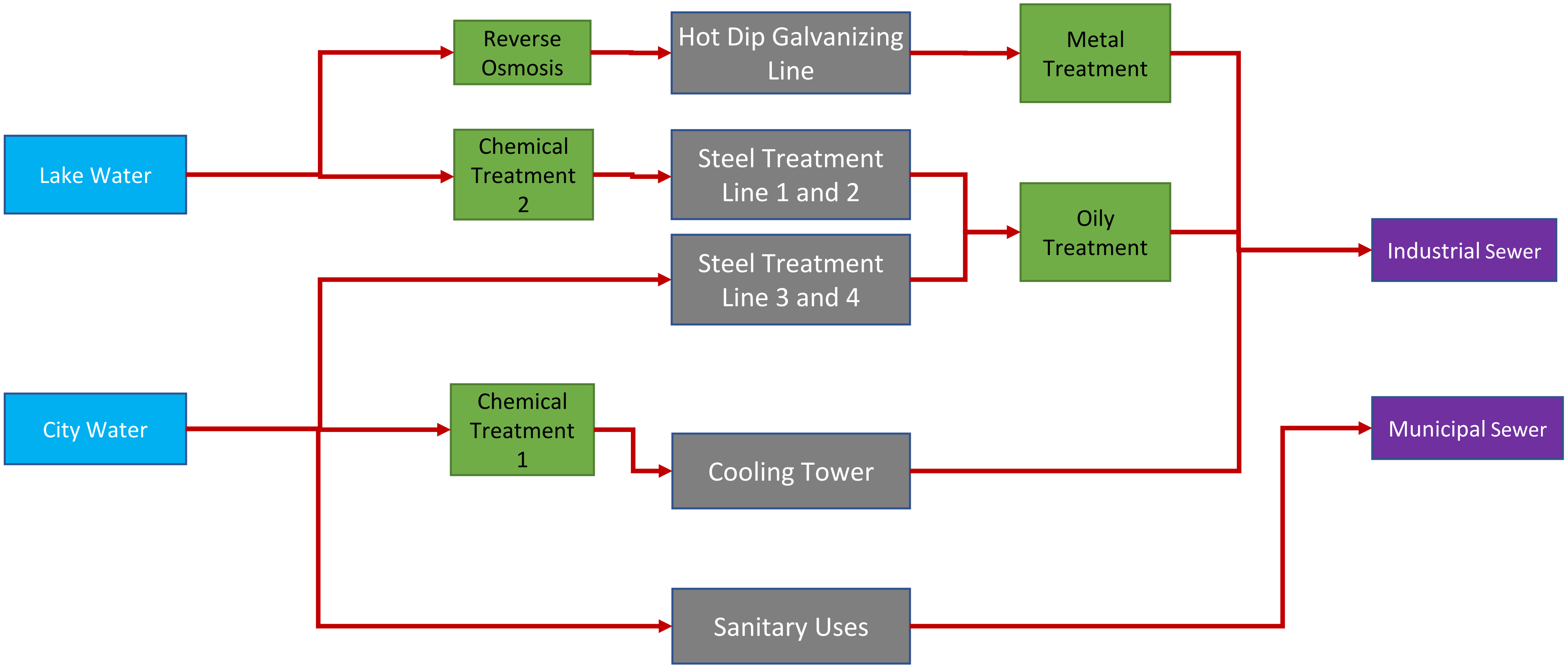
- **Additional Measurements**
  - **Direct flow measurement (using ultrasonic flow meters)** can be effective but might not always be possible
  - In some cases, simple **bucket and timer methods** can be effective for estimating flow rates
  - Motor run times can be used to know how often a pump runs and hence the flows though a system
  - Boilers and Cooling Towers it's a best practice to meter either the intake (makeup water) or discharge (blowdown) and calculate the other side from the Cycles of Concentration

- **Engineering Estimations**
  - Estimates can be based on **equipment specifications, operating schedules, design capacities, and process assumptions**

Some lessons learned from the field

- Water infiltrations and precipitation can cause errors in water balancing as they are typically drained to the same facility outlet.
- Individual system level discharges can be difficult to meter and assumption for losses need to be made to estimate it
- Behavior driven water consumption (e.g., open spraying) vary significantly between shifts making it hard to accurately estimate without continuous monitoring.
- An imbalance of 5-10% in facility level flows is common for the first attempt. The water balance can be made more accurate with incremental improvement to the data collection strategy

Example Facility – Water Flow Diagram



Example Facility – Data Collected

The following information was collected at our example facility

From 2020 Utility Bills
- The city water use is 177.2 million gallons
- Industrial sewer was charged for 308.4 million gallons
- Municipal sewer was charged for 2.1 million gallons

From Onsite meters
- The onsite lake water meter logs indicate consumed 202.2 Million gallons of lake water was used in 2020

Short term Monitoring
The facility engineers installed a meter on the cooling tower makeup and the intake to the HDGL line for 2 weeks. The meter values are annualized to get the following values

- The cooling tower makeup is 49.2 mgy
- The hot dip galvanization line intake 76.1 mgy

Other systems level information gathered from the facility

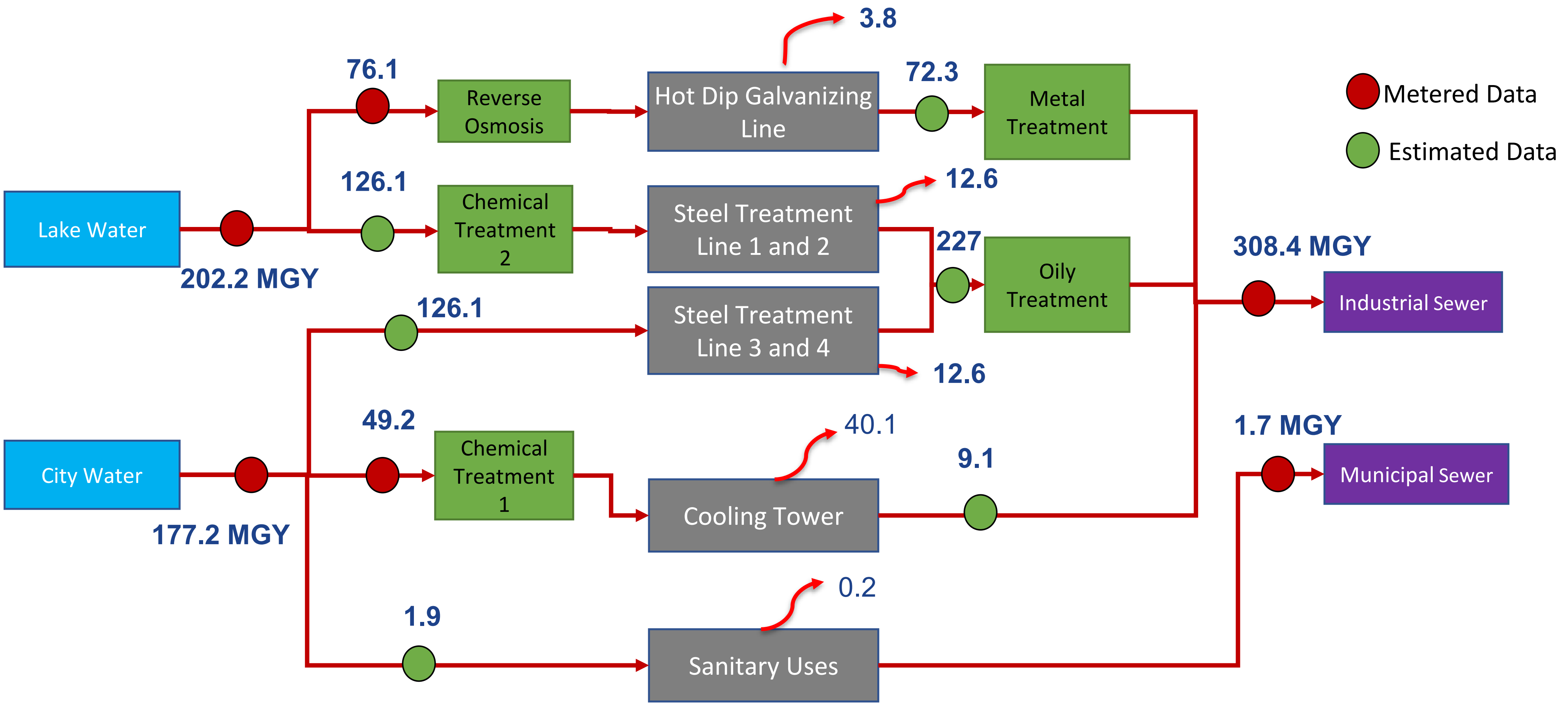
HDGL
- 5% of the intake water is estimated to be lost due to splash off

Steel treatment lines
- Same product throughput and water spray configurations
- 10% of the intake water is estimated to lost due to evaporation in these lines

Cooling tower
- 5000-ton unit and operates at 60% its load on average.
- The unit runs throughout the year and has a temperature drop of 10 F.
- The conductivity readings measured 100 μS/cm at the makeup and 525 μS/cm at blowdown

- The facility has 150 employees at any given time

Example Facility – With Data



Review your data - How can we refine the numbers?

- Any additional place we can submeter?
  - The Steel Treatment Lines can be metered
- Can we better estimate the losses in the process?
  - Meter the water inflow to the wastewater treatment trains
  - Consider the losses in the treatment processes
- Compare engineering estimates and metered data for cooling tower

Data Collection Sheet

Helps collect all the necessary data to complete the Plant Water Profiler Tool

Oak Ridge National Laboratory

Better Plants U.S. DEPARTMENT OF ENERGY

Water In-Plant Training
Data Collection Sheet

Required Information Prior to Plant Visit

Company: Example Facility

Location: Knoxville, TN

Table of Contents

Homework #2

1. Collect monthly water use values for the last year for intake and discharge (if available) and plot it in a chart.

2. Start collecting the system level data (intake and discharge) needed to perform water balance for the facility
   - Annualize all measured data and mark it in the plant flow diagram
   - MEASUR tool can be used.

Thank You all for attending today's webinar.

See you all on next Tuesday – June 30th , 2026 – 10 am ET

If you have specific questions, please stay online and we will try and answer them.

Alternately, you can email questions to me at thirumarank@ornl.gov

U.S. DEPARTMENT OF ENERGY