Better Plants
U.S. DEPARTMENT OF ENERGY

Industrial Water Systems
Virtual INPLT Training & Assessment

Session 2

Tuesday – June 22nd, 2021

10 am – 12:30 pm

Water Virtual INPLT Agenda

- **Week 1 (June 15) – Introduction to Industrial Water Assessment and Plant Water Profiler**
- **Week 2 (June 22) – Understanding System Level Water use**
- **Week 3 (June 29) – True Cost of Water**
- **Week 4 (July 6) – Plant Water Profiler Working Session**
- **Week 5 (July 13) – Identifying Water Savings Opportunity**
- **Week 6 (July 20) – Virtual Treasure Hunt**
- **Week 7 (July 27) – Estimating Water Savings Opportunities**
- **Week 8 (August 3) – Industrial Water System VINPLT Wrap-up Presentations**

Agenda – Session Two

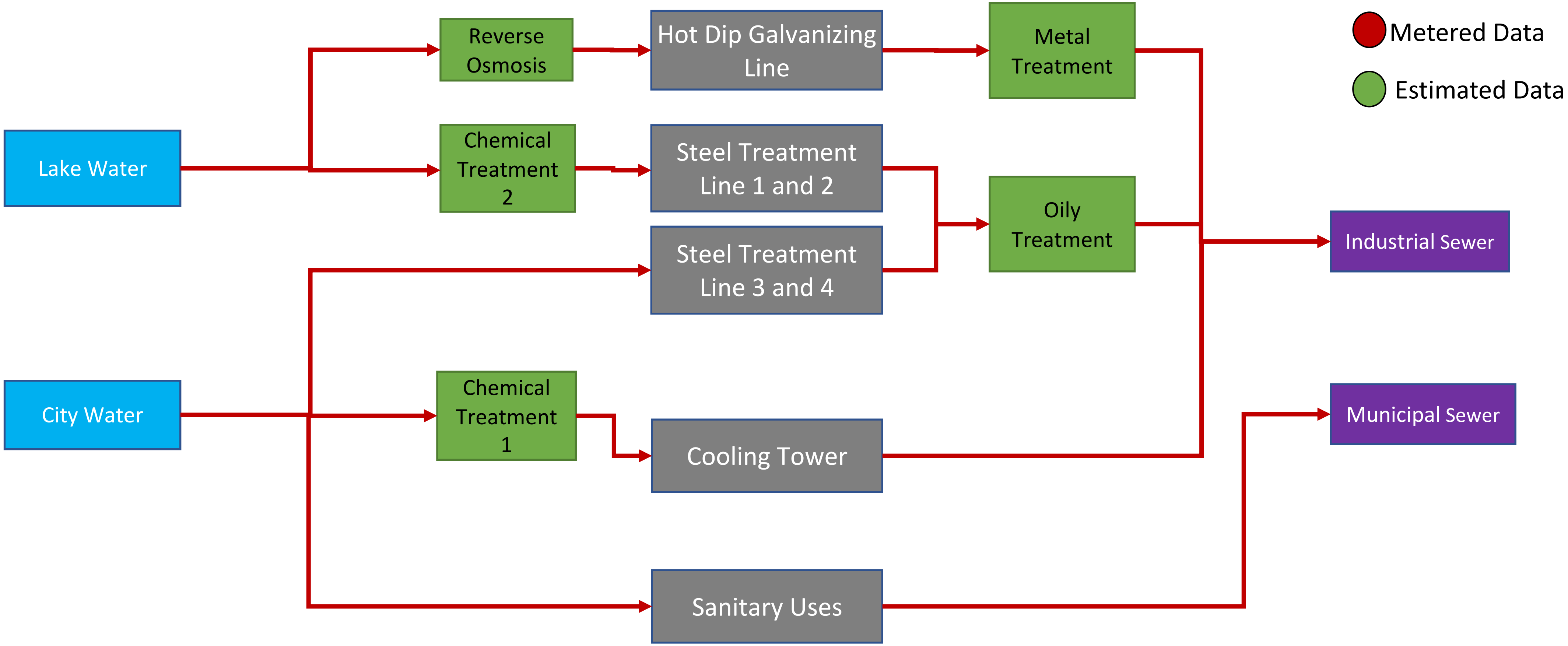
- Today's Content:
  - Day 1 Review
  - Comments on homework
  - Data Collection for baseline
    - Facility level data
    - Systems level data
  - Diagnostic equipment
- Kahoot Quiz Game
- Q&A

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

Day 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

- Blowdown from cooling tower and boiler should be added to flow – they can be significant
- Cooling towers and Boilers with similar intake and discharge can be combined if it makes data collection easier
- Some facilities had missing process flows – any process/equipment that has water make-up should be added.
- Process with non-contact cooling can be ignored if makeup water is considered as part of cooling tower/boiler

Data Confidentiality and homework assignments

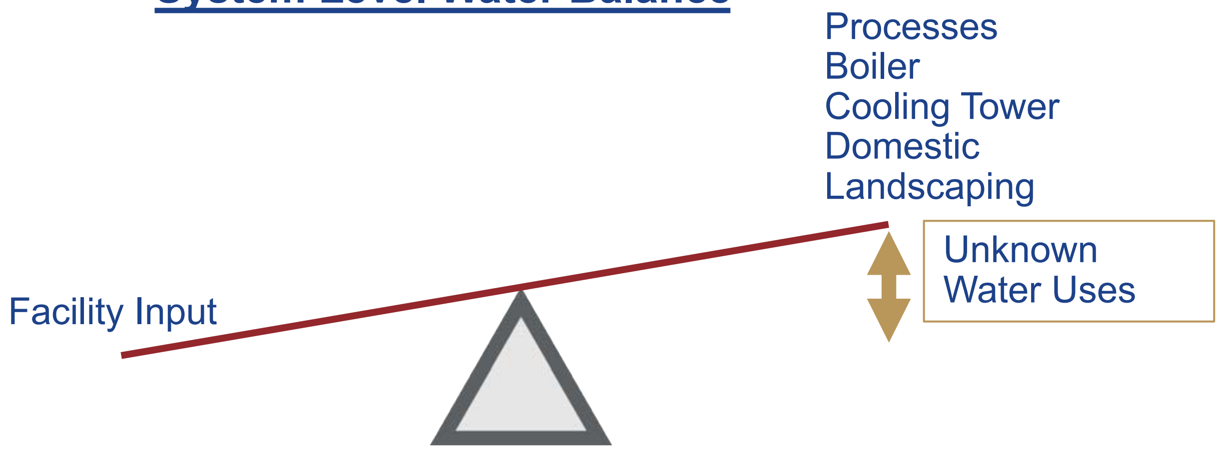
- Option 1: I am fine sharing the information submitted as part of the homework publicly – Ideal; the data from the facility will help others learn
- Option 2: I am fine sharing the information submitted as part of the homework only to participants of this workshop – We will discuss the homework during 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

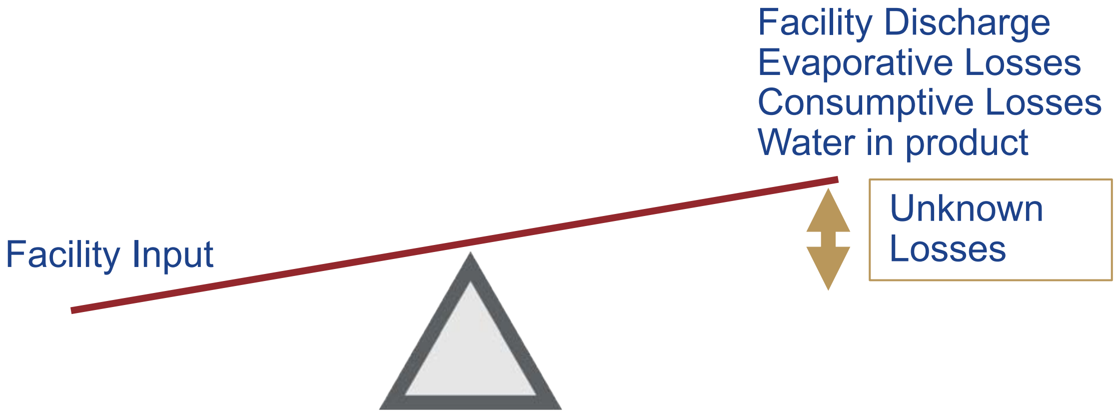
For water baseline and to perform water balance we need

- 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

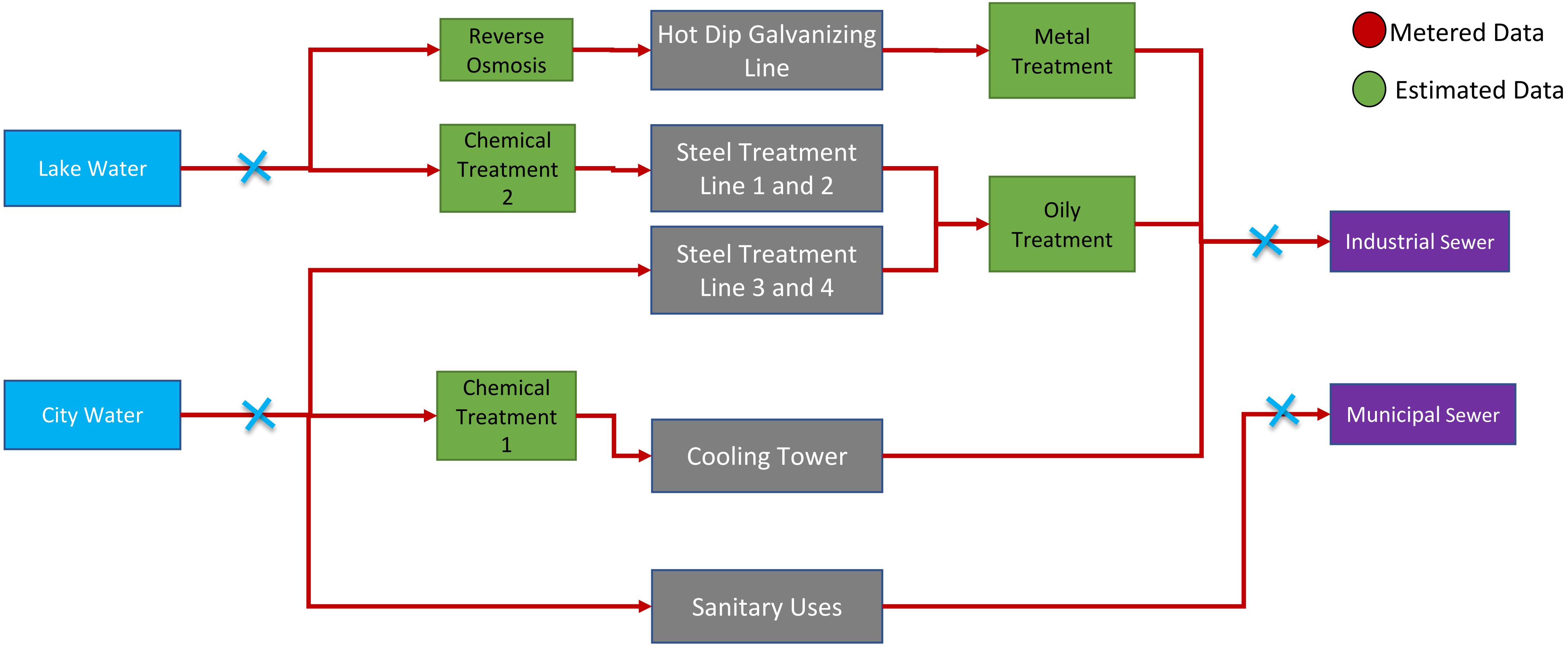
Facility Water Intake

- 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

Facility Level Water Data



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

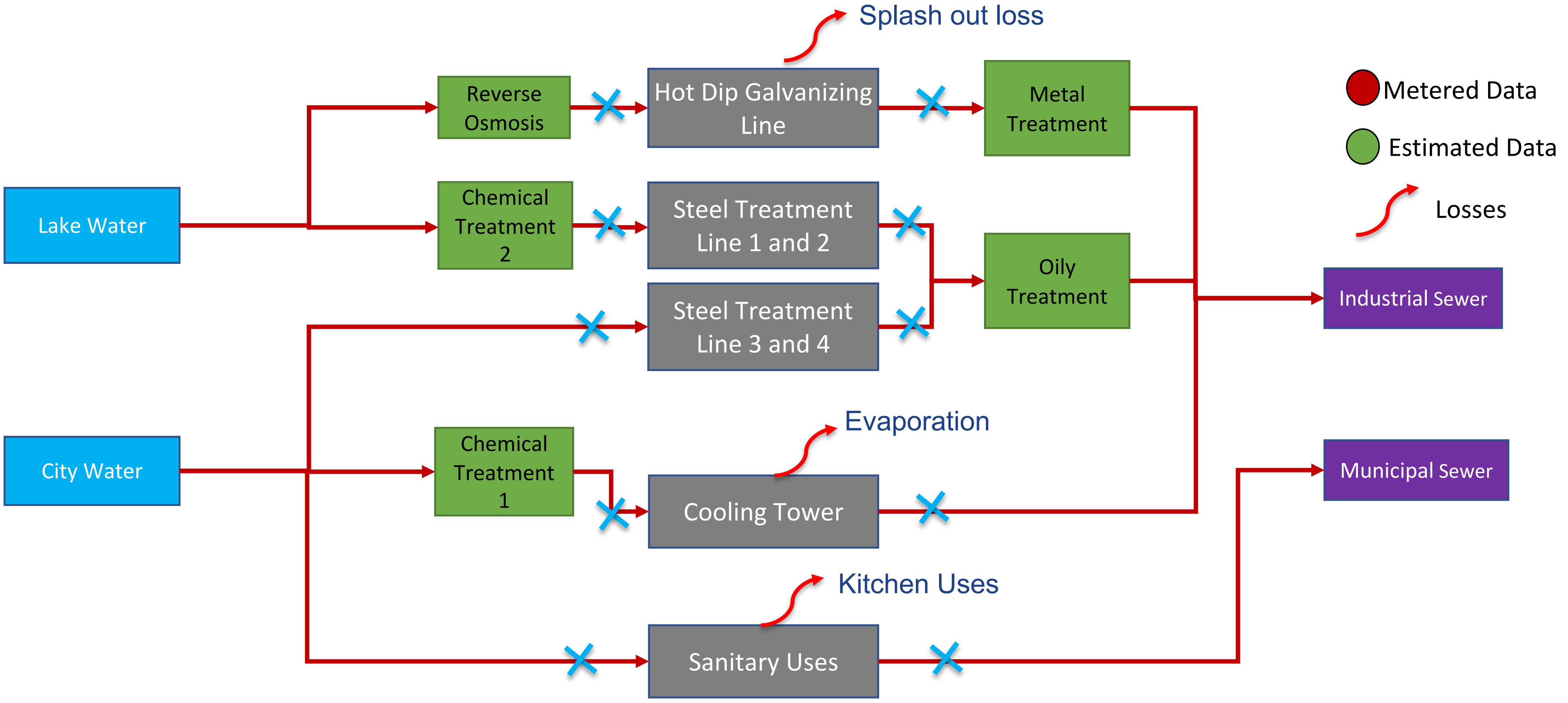
Electromagnetic Water Meter

Courtesy: KUB and Sensus

Water Using Systems

- Cooling Towers
- Boilers
- Process Use – Direct and Indirect
- Domestic Use
- Landscaping

System Level Water Data



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

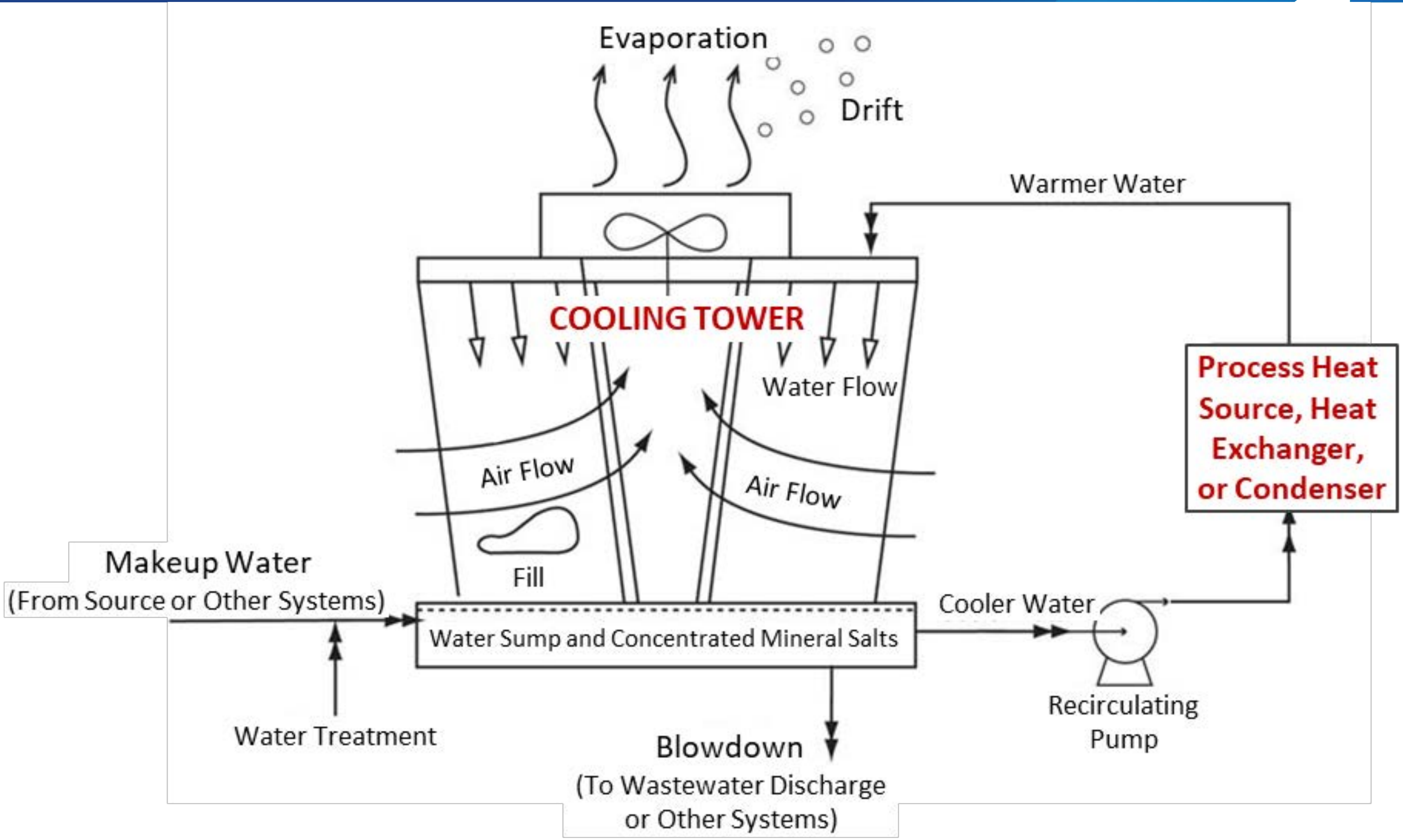
Some typical processes served by cooling towers

- 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



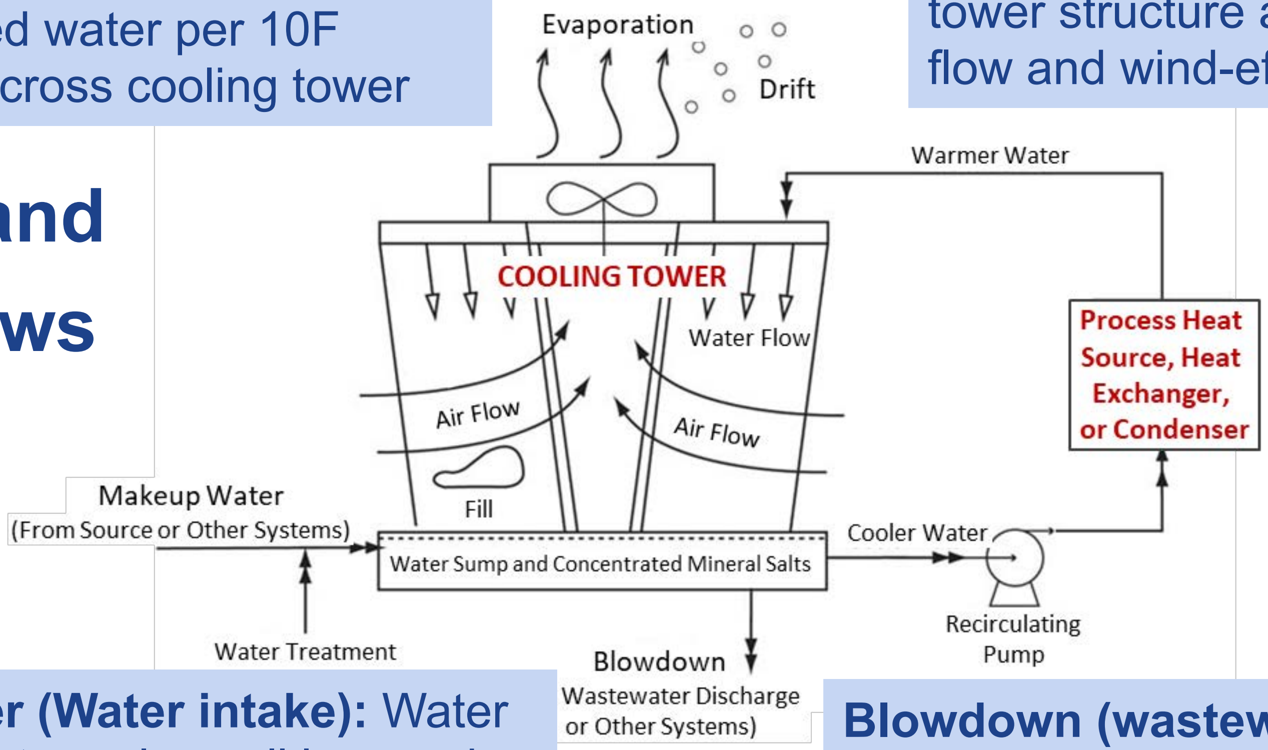
Water is often used as the working fluid or for heat rejection in a process cooling system.

Cooling and Condensing System

Evaporated water (consumption): Typically, 0.85% of recirculated water per 10F temp. drop across cooling tower

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): Typically, 3 gpm per ton of cooling

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

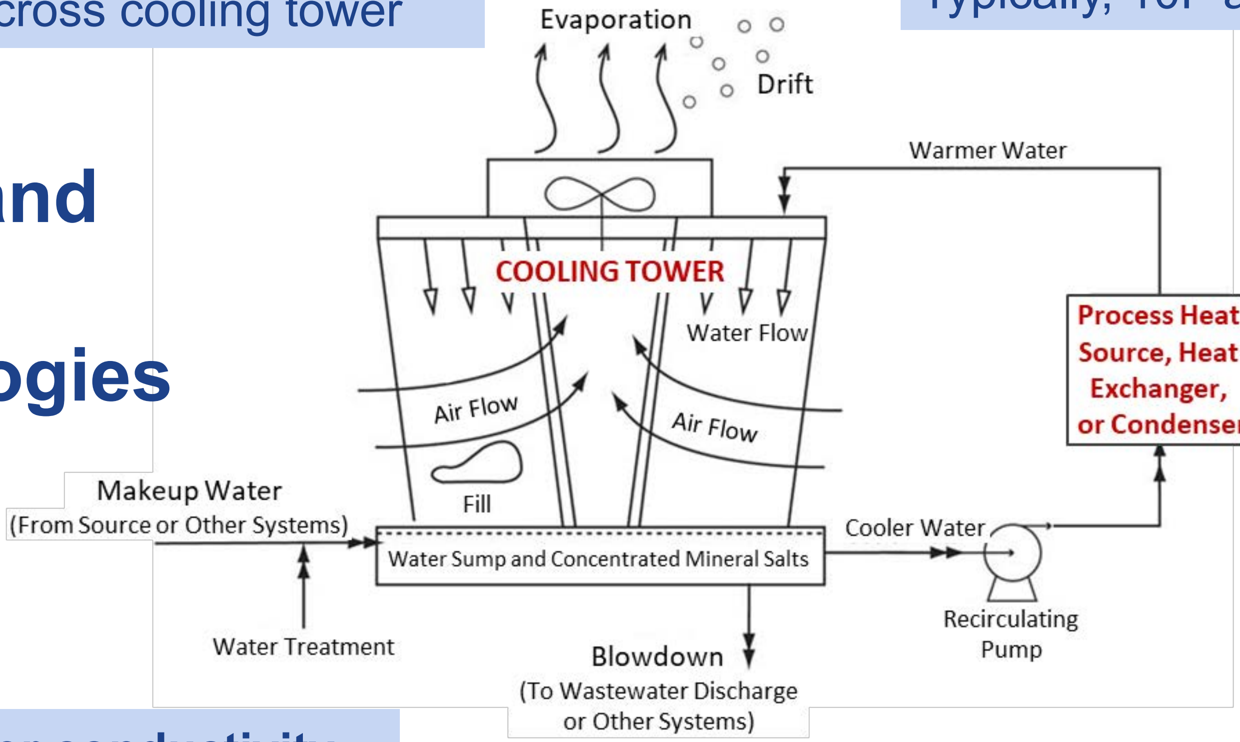
Blowdown (wastewater discharge): Water discharged from a cooling tower to remove high mineral content system water, impurities, and sediment.

Cooling and Condensing System

Evaporated rate: Typically, 0.85% of recirculated water per 10F temp. drop across cooling tower

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

Understand relevant terminologies



Load fraction: Average cooling load per tonnage; typically, 70-80%

Chiller or Cooling Tower Tonnage

Hours of operation

Makeup water conductivity
Blowdown conductivity
(from conductivity meters)

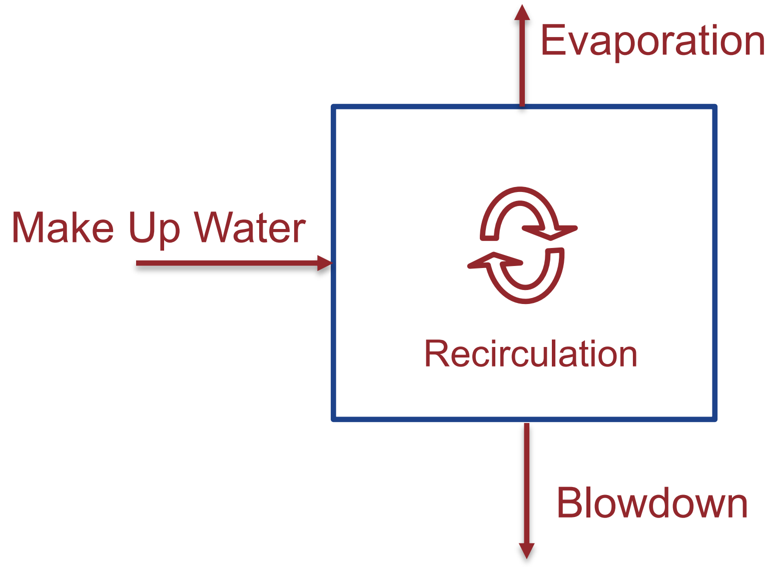
Cycles of Concentration is the number of times water is recirculated within the system before being discharged to outlet (blowdown)

Cooling Tower - Estimating Water use

Make Up Water = Evaporation + Blowdown

Intake ← Make Up Water; Blowdown → 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 Tower – Calculator 1

Cooling Tower	Hours of Operation per Year	Cooling Tower Tonnage	Load Factor (Fraction of Tonnage)	Evaporation Rate per 10°F Temp. Drop (%)	Temp. Drop Across Cooling Tower (°F)	Makeup Water Conductivity	Blowdown Conductivity	Million Gallon per Year (% of Gross Water Use)				
								Gross Water Use	Incoming	Outgoing		Recirculated Water
									Makeup Water	Blowdown	Evaporation	
								-	-	-	-	-
								-	-	-	-	-
								-	-	-	-	-
								-	-	-	-	-

Evaporation ∝ Gross Water Use x Delta T x Evaporation Rate

- Gross Water Use = 3 x Load factor x Tonnage
- Evaporation Rate
  - 0.85 - Typical
  - 0.65 - Moist Climate
  - 1.0 to 1.2 – Dry Climate

Data Needed

- Annual Hours of Operation
- Chiller Tonnage
- Load Factor
- Evaporation Rate
- Temp. Drop Across Cooling Tower
- Makeup Water Conductivity
- Blowdown Conductivity

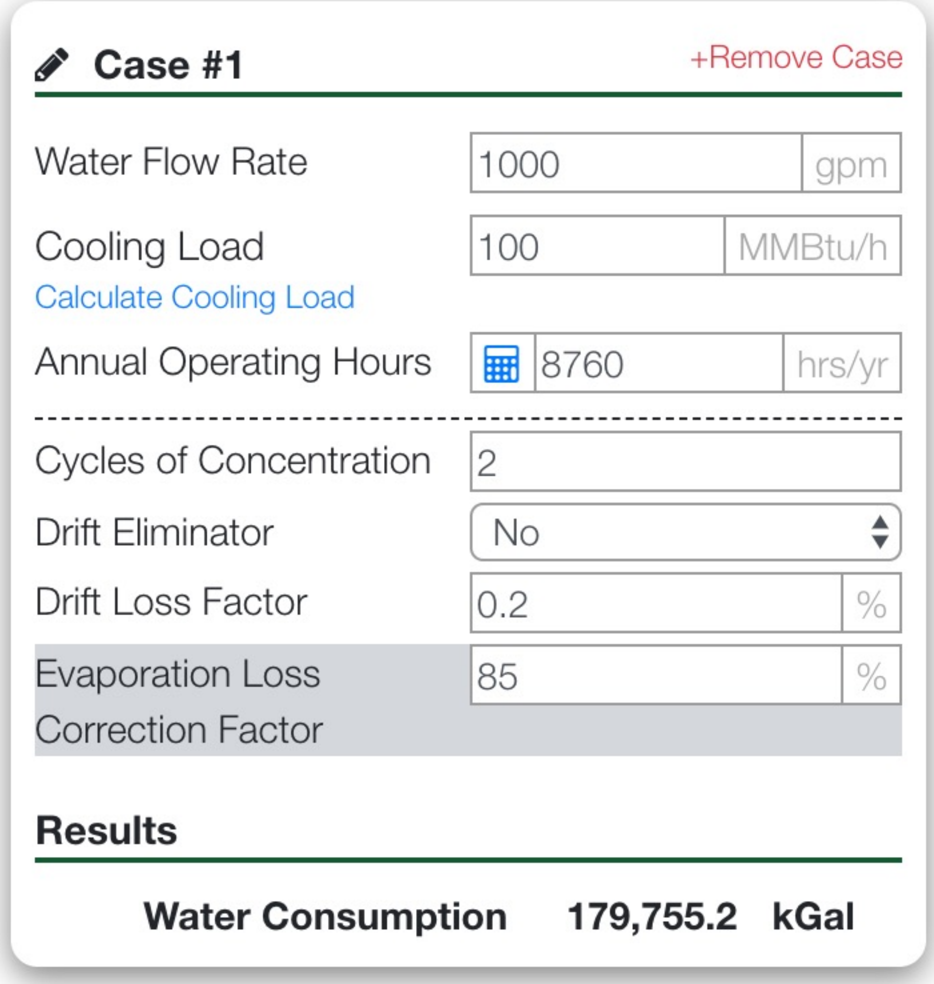
Cooling Tower – Calculator 2

Calculating Evaporation from Cooling Load - instead of Delta T

Evaporation ∝ Cooling Load

Data Needed:

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



Cooling Tower – Some tips

- Cooling Towers can be hard to make accurate engineering estimates
  - 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

Polling Question 2

Polling Question

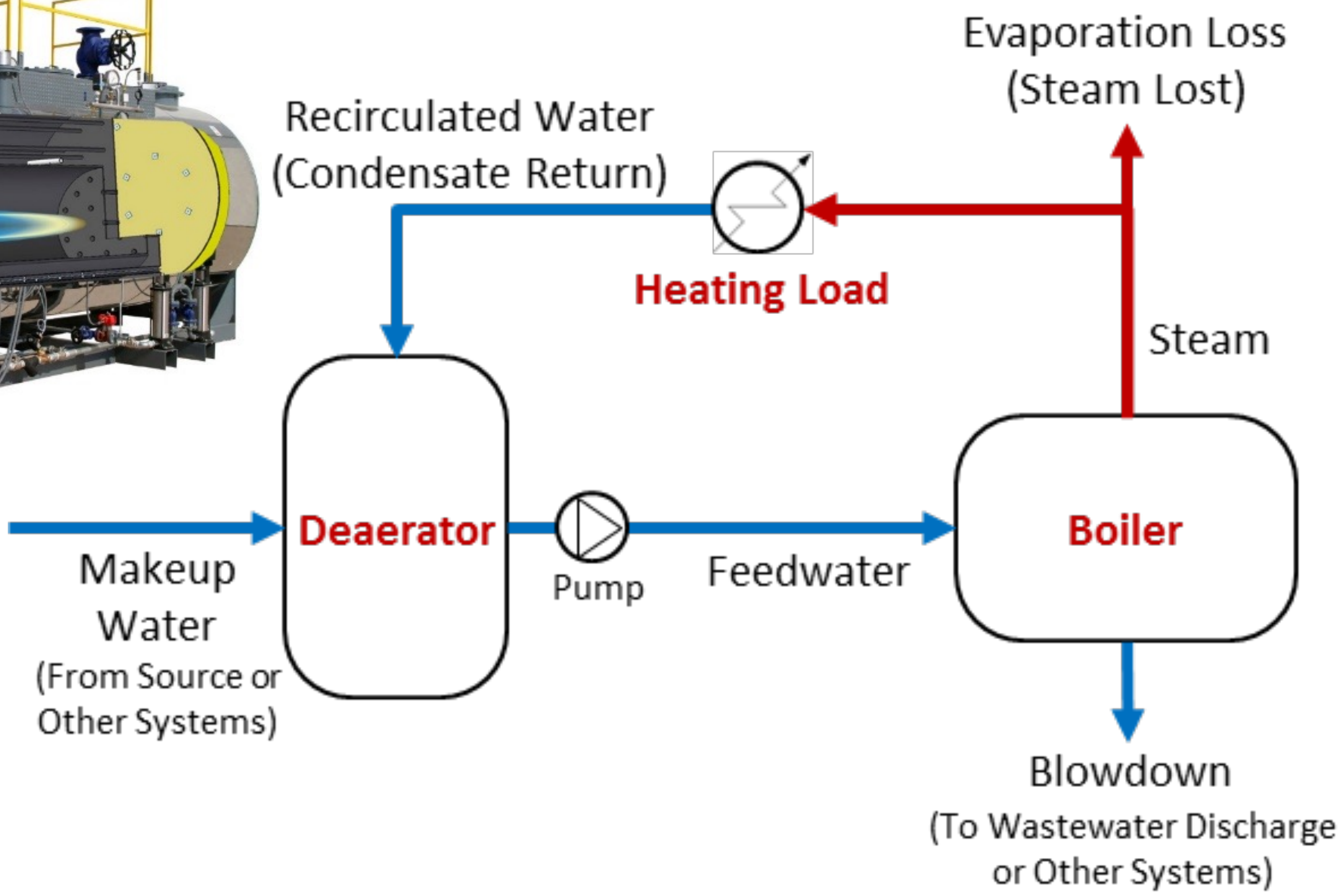
2) What is your major function of cooling tower at your facility?

A. Product/Material Cooling
B. HVAC
C. Equipment Cooling
D. Others
E. Not used

Boiler System

Major Components

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

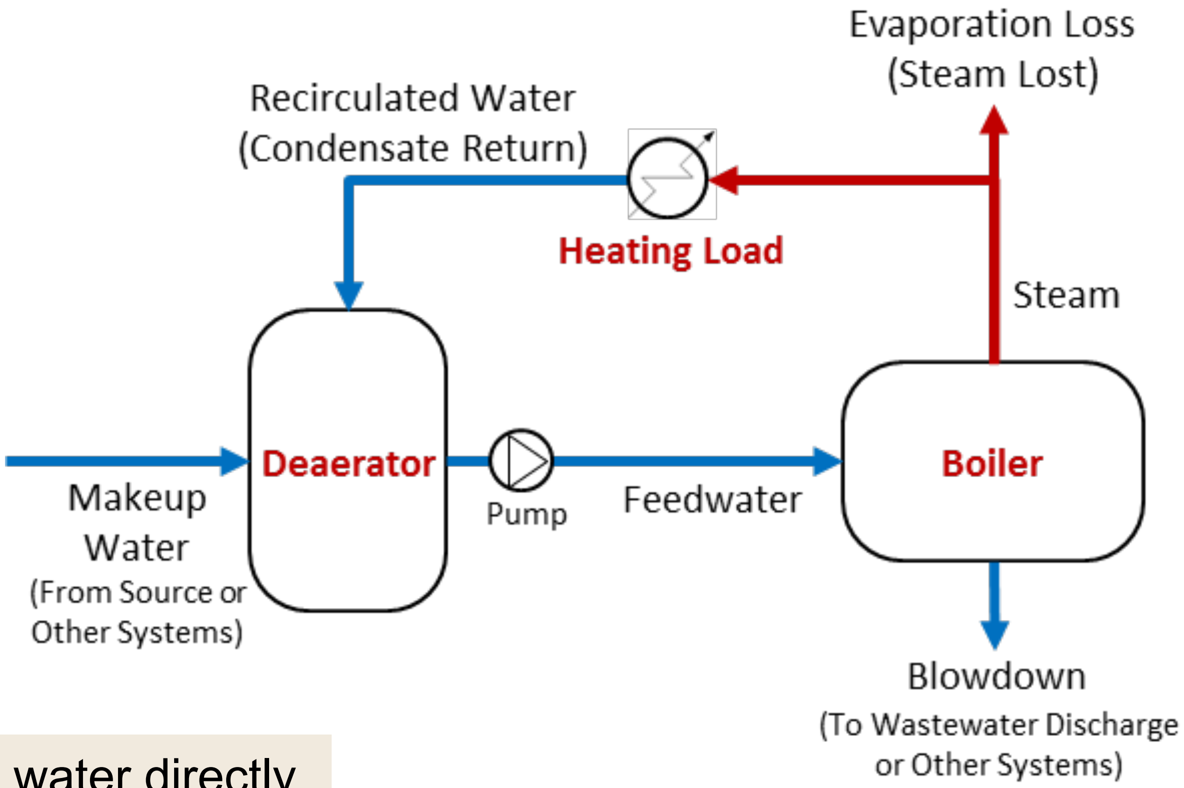


Boiler System

Understand water flows

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.

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



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.

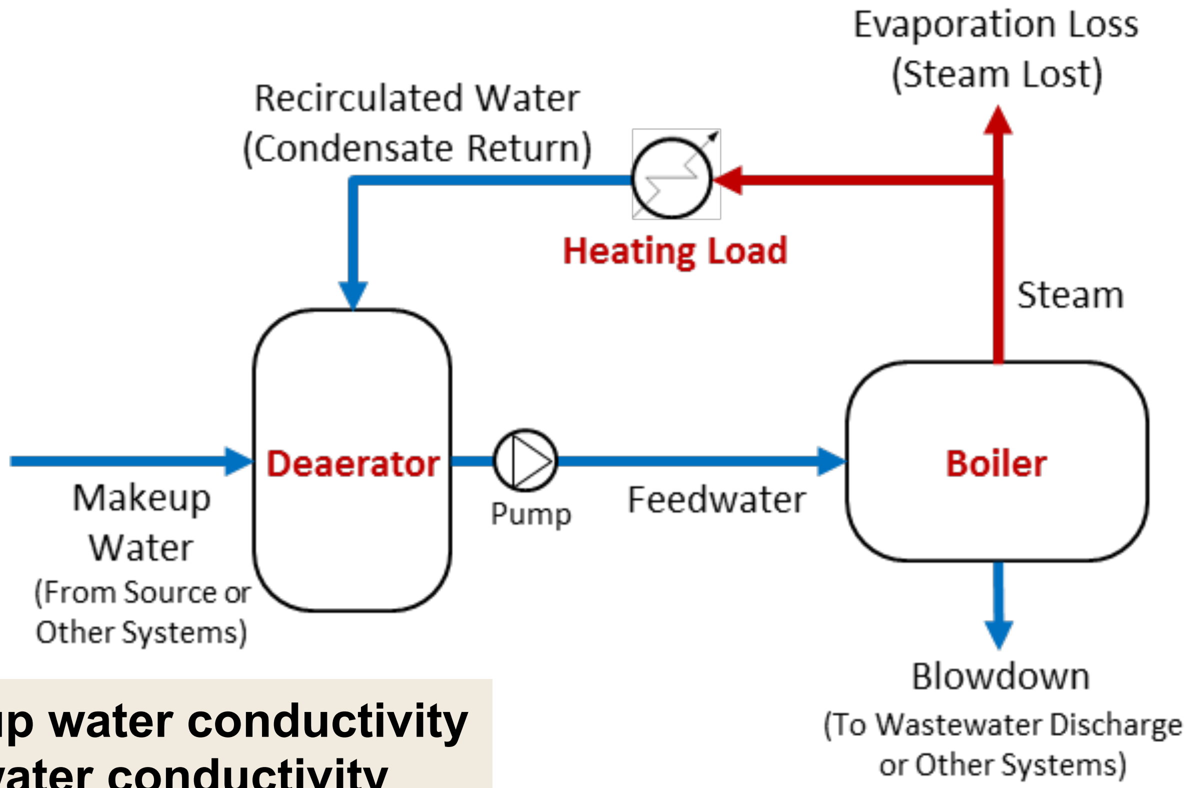
Blowdown: Water discharged from a boiler to remove high mineral content system water, impurities, and sediment.

Boiler System

Understand relevant terminologies

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

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



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)

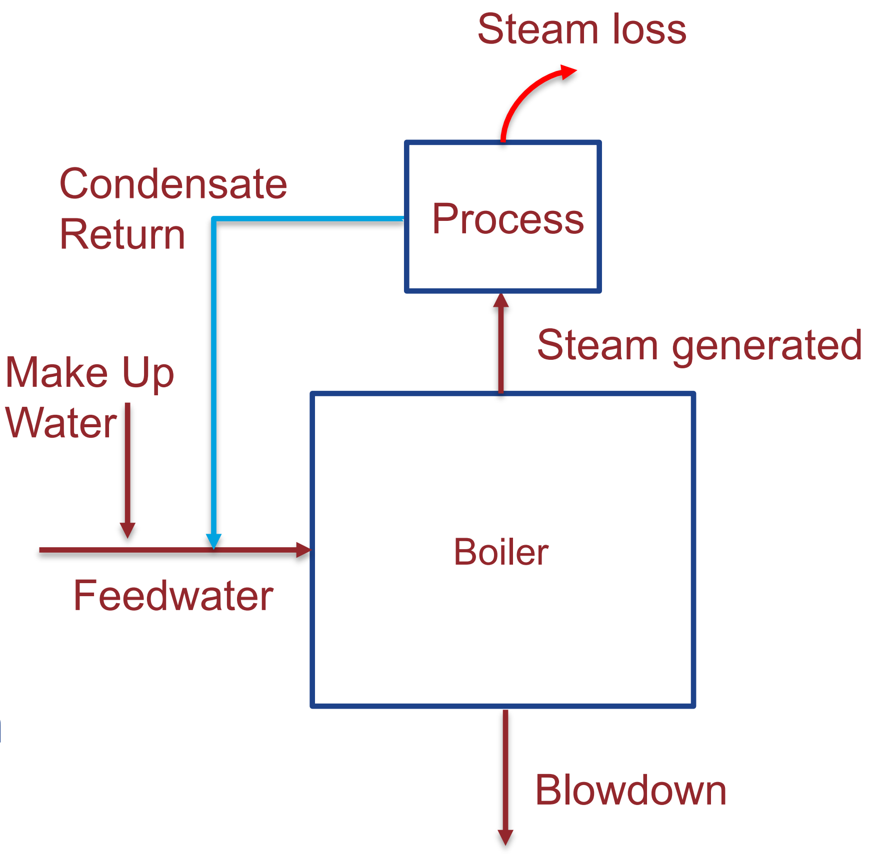
Cycles of Concentration
= blowdown conductivity / feedwater conductivity

Boiler - Estimating Water use

intake ← Make Up Water + Condensate Return

=

Steam Loss + Blowdown → Discharge



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

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

Boiler – Calculator for engineering estimation

Boiler	Hours of Operation per Year	Boiler Horsepower (BHP)	Load Factor (Fraction of BHP)	Steam Generation Rate (lb/h) per BHP	Feedwater Conductivity	Makeup Water Conductivity	Blowdown Conductivity	Million Gallon per Year (% of Gross Water Use)				
					TDS ppm	TDS ppm	TDS ppm	Feedwater	Makeup Water	Blowdown	Steam Lost	Condensate Return
									Incoming	Outgoing		
Boiler for:	8,000	100.0	0.8	34.5				-	-	-	-	-
								-	-	-	-	-
								-	-	-	-	-
								-	-	-	-	-
								-	-	-	-	-

- Gross Water Use $\propto \dfrac{\text{Steam Generation}}{\left(1 - \frac{1}{Cycles}\right)}$
- Make up, Blowdown $\propto Cycles$

Data Needed:

- Annual Hours of Operation
- Boiler Horsepower
- Load Factor
- Steam Generation Rate
- Feedwater Conductivity
- Makeup Water Conductivity
- Blowdown Conductivity

Specialty Equipment - Spray Dehumidifier

- Spray dehumidifiers use chilled water spray to remove atmospheric moisture

- Chiller water cools the air below its dewpoint and the water from the air condenses out

Process Water Use in Your Plant

Typical Process Water Use

- Process Cooling e.g., plastics extrusion, Glass, metal fabrication
- 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

Process Water Use

Process water can be Direct (contact) or Indirect (non-contact).

Direct Process Water Users

- Product cooling by contact (plastic extrusion, metal annealing ..)
- Paint mix (auto, appliances …)
- Washing, Sealant, Material transport
- In-product

Indirect Process Water User

- Indirect product Cooling (via a heat exchanger and cooling tower …)
- Hot water-based heating applications
- Once through indirect cooling system (inefficient)

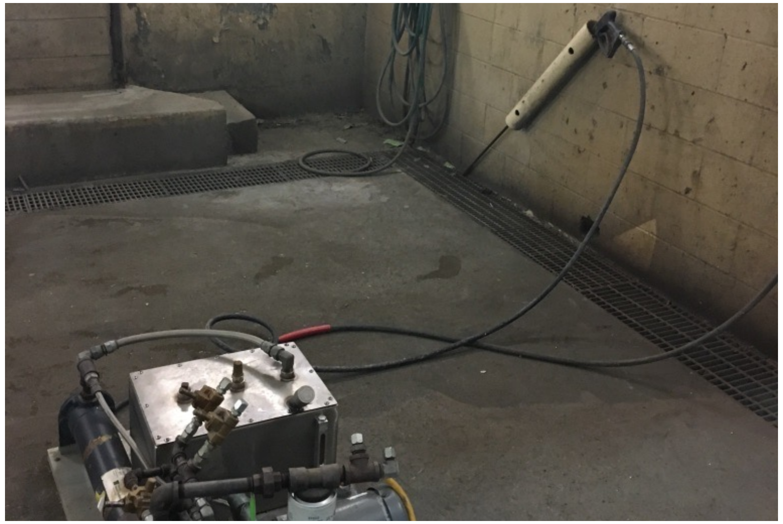
Indirect or non-contact water that does not touch any raw material, intermediate product, waste product, or finished product. They are typically part of a closed loop system and connected to a cooling tower or boiler.

Direct Process Use

- 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

Direct Process 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



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

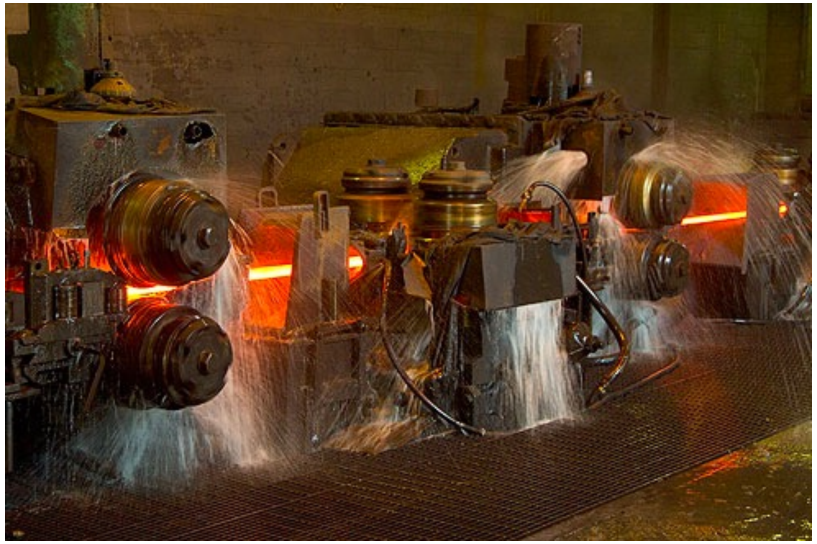
Direct Process Use – Automated Water Spray

- 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/

Direct Process Use – Water Spray (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

Direct Process – 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

Direct Process Use – Product, Dilution, Sealant

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

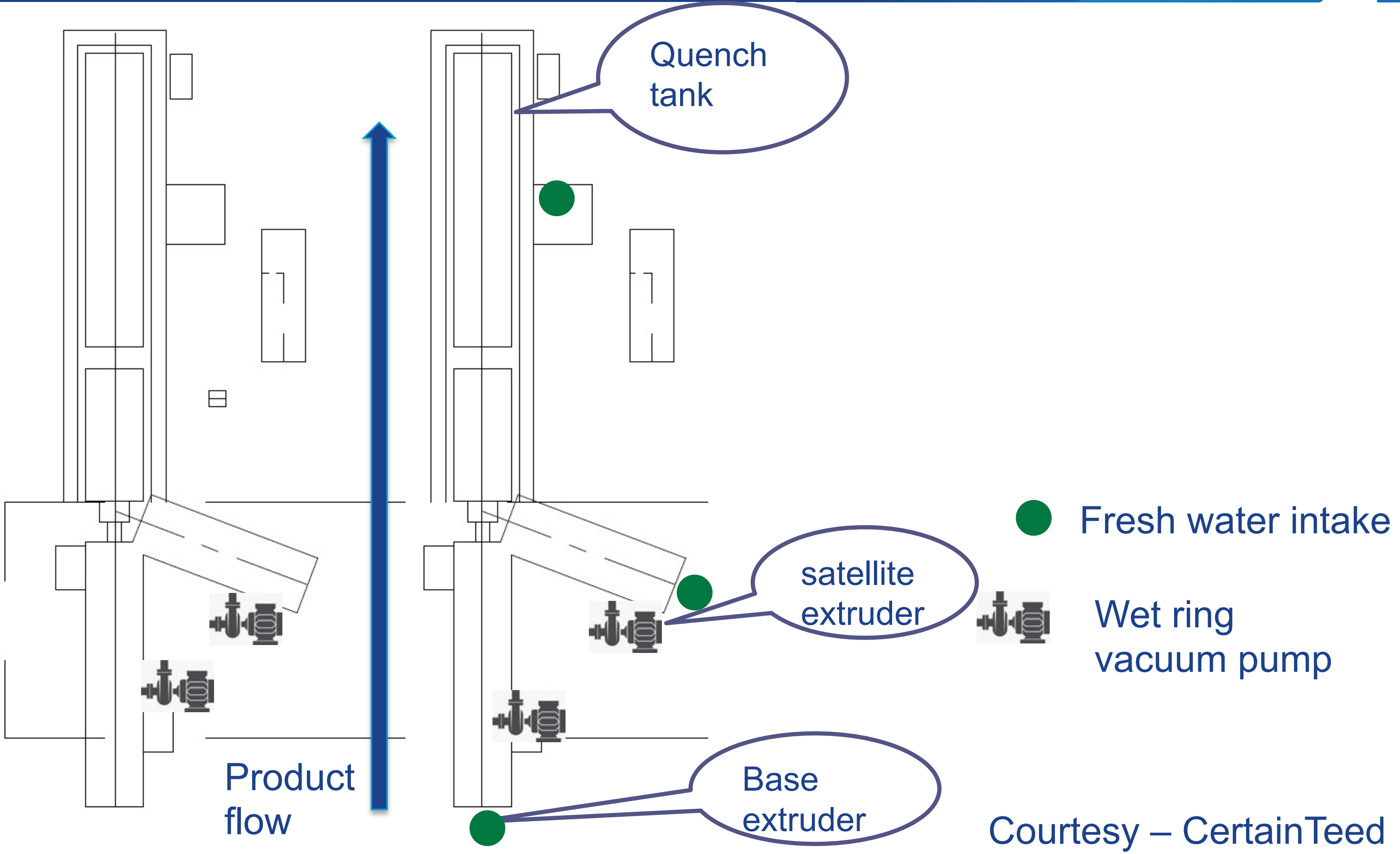
Examples

- 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

Process Application	Water Required for Processing	Process Water Consumed in Product	Process Water Losses (Evaporation/ Other)	Production Units per Year	Hours Water Used per Year	Fraction of Gross Water Use Recirculated	Total (Million Gallon per Year)					
							Gross Water Use	Source Water + Water from Other Systems	Wastewater Discharge + Recycled to Other Systems	Process Water Consumed in Product	Process Water Losses (Evaporation/ Other)	Recirculated Water
								Incoming	Outgoing (Leaving the System)			
							-	-	-	-	-	-
							-	-	-	-	-	-
							-	-	-	-	-	-

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, PWP does not have industry specific process water use calculators yet. Will be added in the future.

Data Needed

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

Indirect Process Water

- 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

Others - Sanitary Use and Landscaping

- Typically not metered – PWP has 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		

Some of the Lessons Learned from the field

- Lack of metering and sub-metering at the system-level makes it difficult to determine system level water usage.
- Water infiltrations and precipitation are difficult to estimate and cause errors in water balancing as they are typically drained to the same facility outlet.
- Individual system level discharges are difficult to meter as they usually drain to the facility outlet by gravity via underground channels which are hard to access.
- Behavior driven water consumption (e.g. open spraying) can vary significantly between shifts making it hard to accurately estimate without continuous monitoring.

Data Collection Tools

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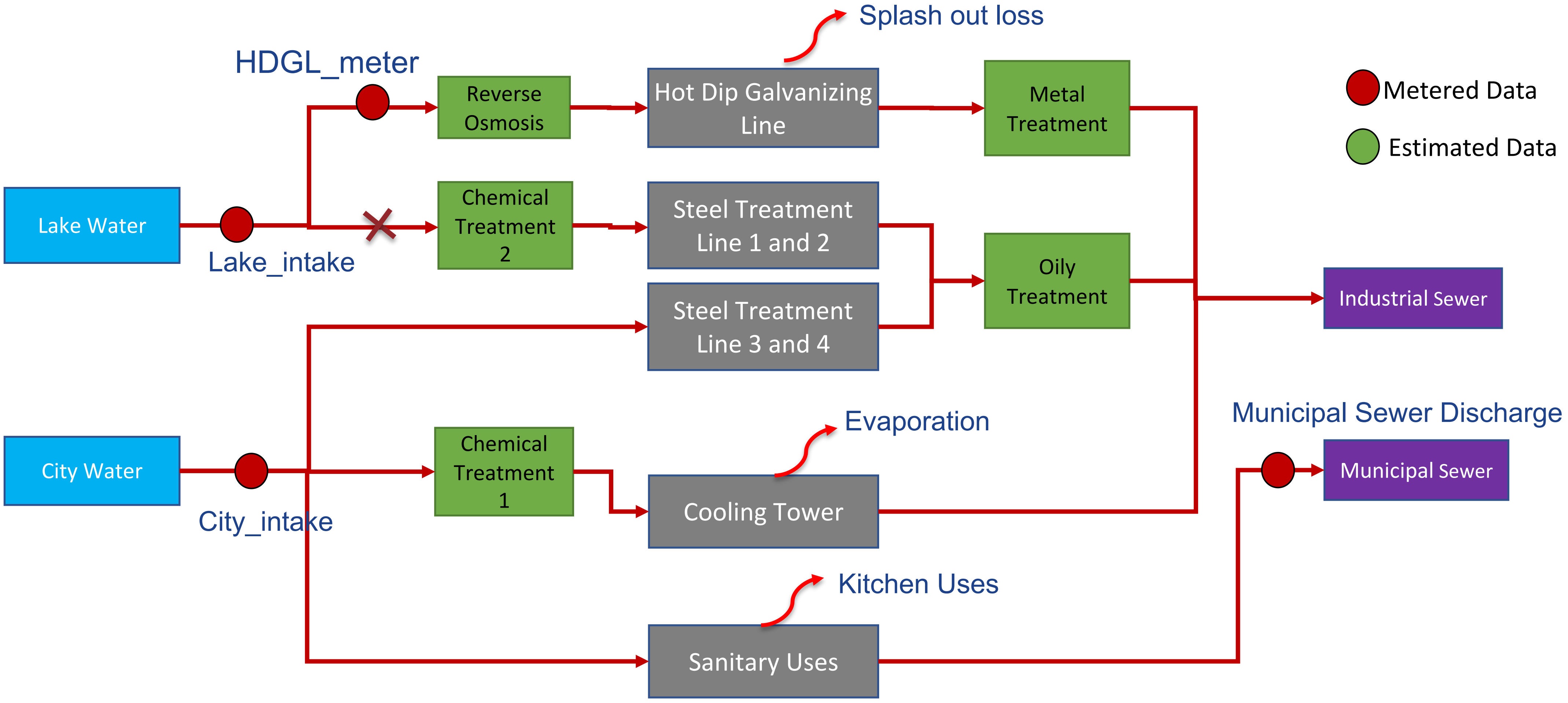
Water Baseline - Data Collection

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

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

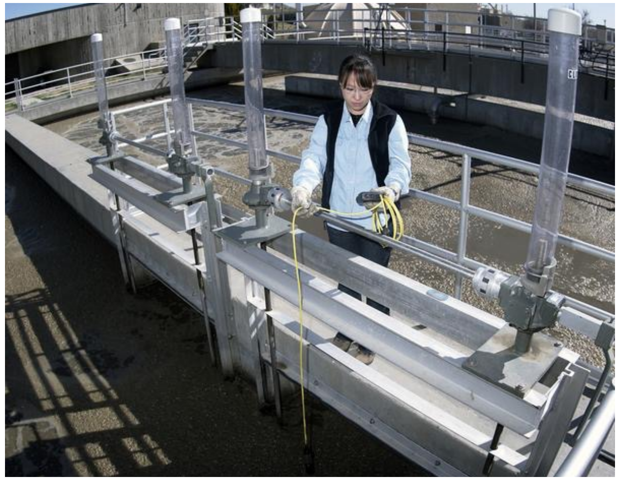
Few Tips for Clamp-on Ultrasonic Flow Meters

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



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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

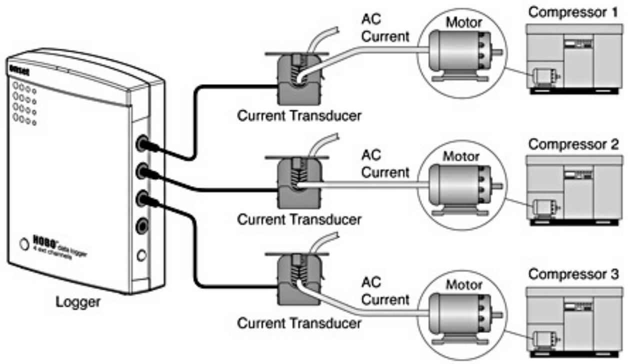
Clamp-on Current Transducers

- 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

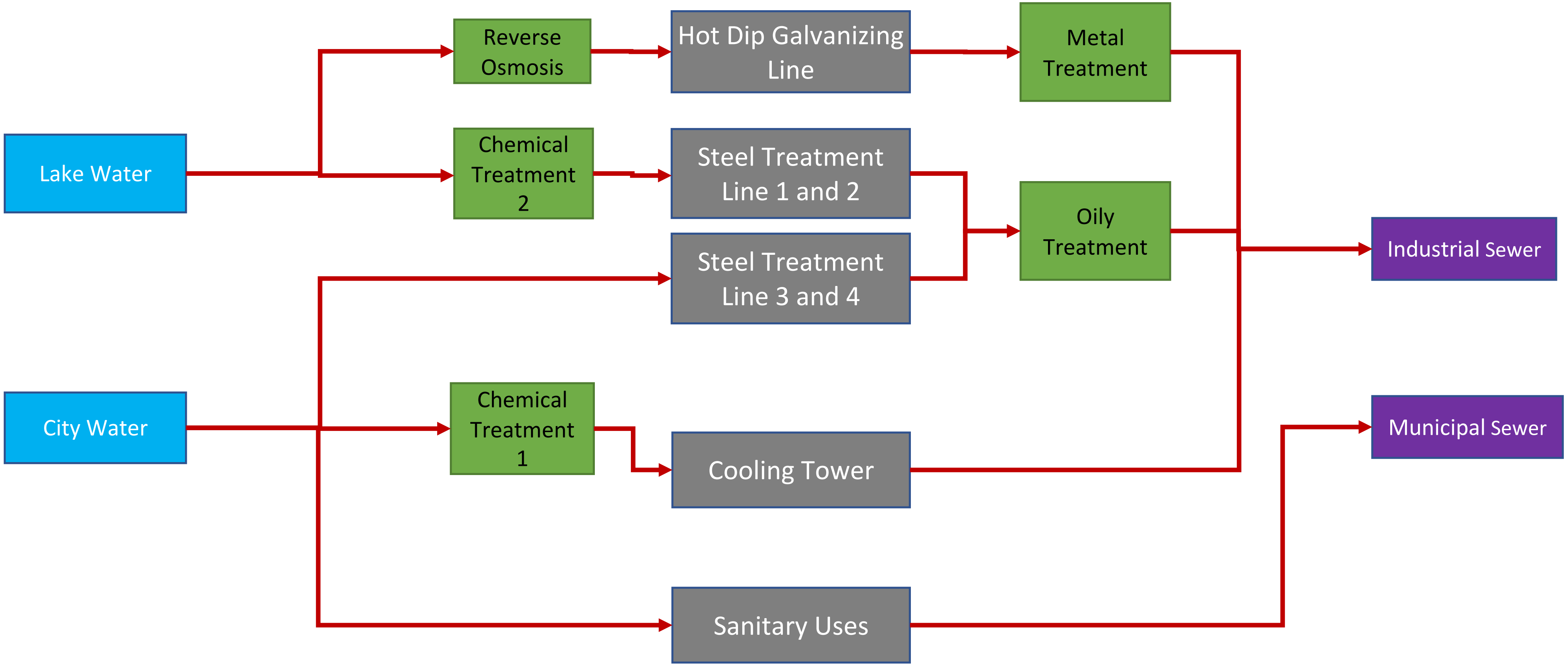
- Multimeters can be used to get the instantaneous current, energy and power quality.

- 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

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 171.7 million gallons
- Industrial sewer was charged for 299.8 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

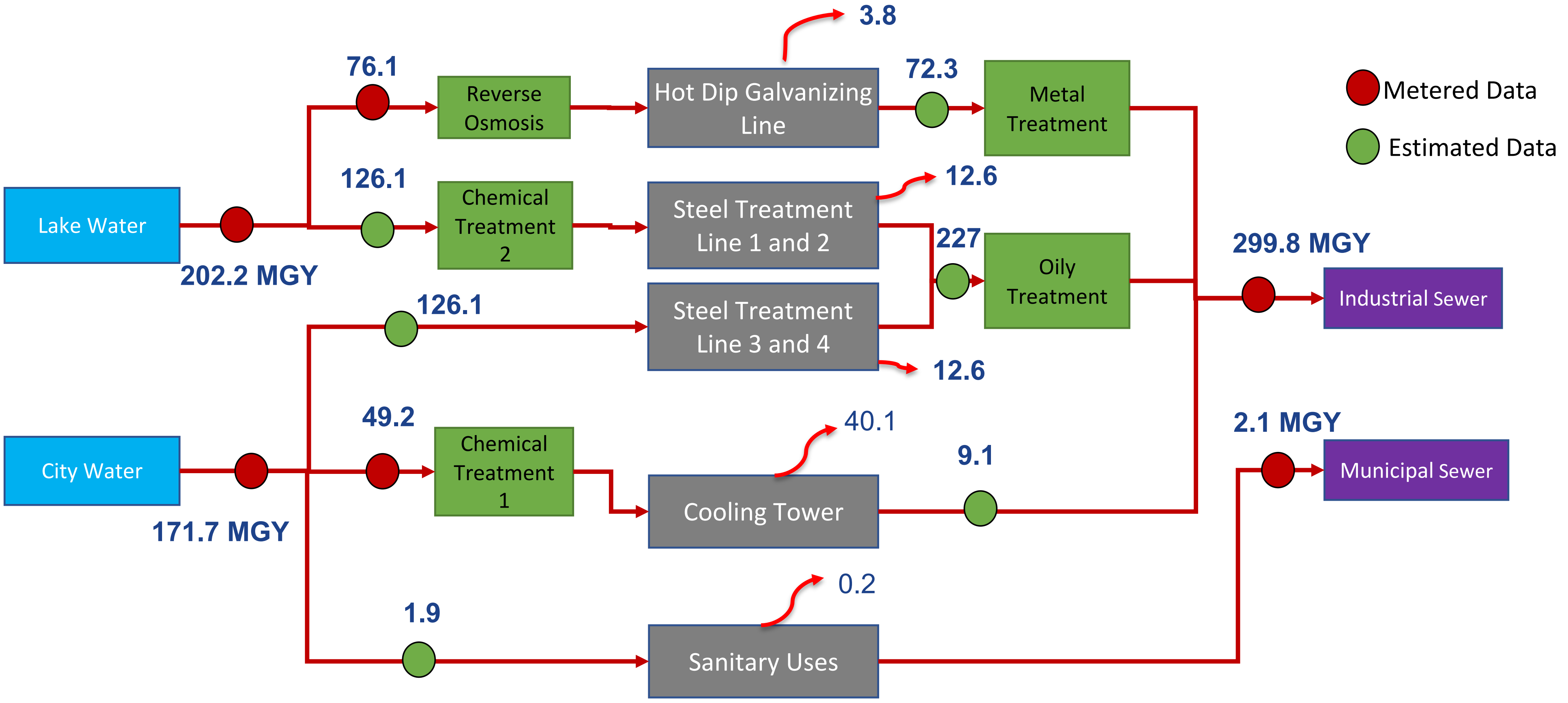
The facility engineers installed a meter on the cooling tower makeup and the intake to the HDGL line for 2 weeks. The meter values are annualized to get the following values

- 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

- 5% of the intake water is estimated to be lost due to splash of in HDGL
- All 4 steel treatment lines have the same product throughput and water spray configurations and will consume the same amount of water – The intake quantity was not determined however 10% of the intake water is estimated to lost due to evaporation in these lines
- The cooling tower is a 5000-ton unit and operates at 60% its load on an 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

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Water In-Plant Training
Data Collection Sheet

Required Information Prior to Plant Visit

Company: <u>Example Facility</u>

Location: <u>Knoxville, TN</u>

Table of Contents

Homework #2

1. Collect the necessary facility level and system data needed to perform water balance for the facility
   - Complete sections 3, 4 and 5 in the data collection sheet provided. Section 5 can be skipped for systems for which measured data is available.
   - Annualize all measured data and mark it in the plant flow diagram

Revisiting Water flow Diagram

Thank You all for attending today’s webinar.

See you all on next Tuesday – June 29, 2021 – 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