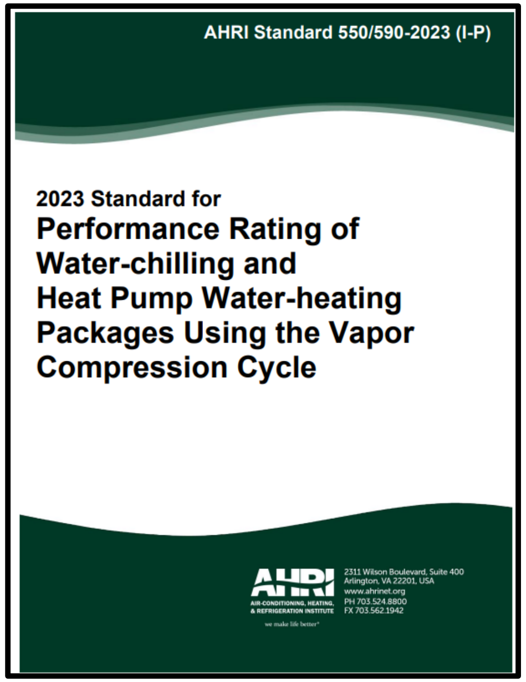
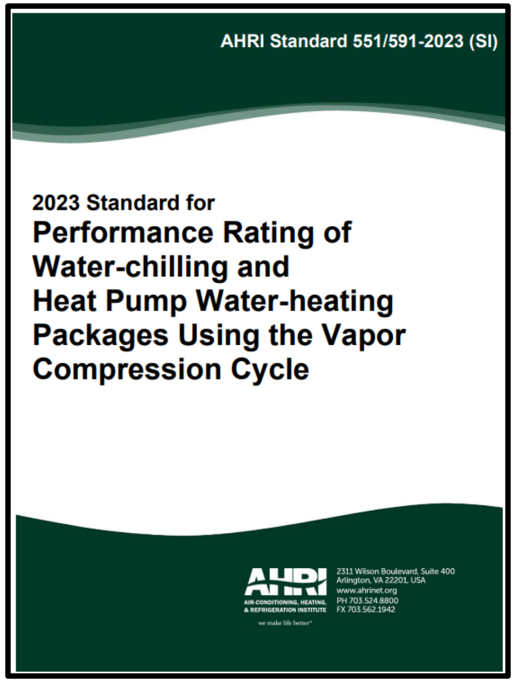
Large Chilled Water System Design Seminar

Courtesy of Oslin Nation Company

Chilled Water Production

American Heating & Refrigeration Institute (AHRI)





American Heating & Refrigeration Institute *(AHRI 550/590-2023)* Water Chilling rating conditions:

- Entering/Leaving evaporator *(chilled)* water temperatures - 54°F/44°F
- Chilled water flowrate - 2.4 GPM/Ton (10°F ΔT)
- Entering/Leaving condenser water temperature - 85°F/94.3°F
- Condenser water flow rate - 3.3/3.0 GPM/Ton (9°F-10°F ΔT)

“Vapor Compression” Chiller Types: Water or Air Cooled


Reciprocating


Scroll

Screw


Centrifugal

- **Air Cooled:**
  - Chiller mounted outdoors, heat rejection using ambient air
  - Can perform well in freezing temperatures and return to full capacity quicker
  - Generally lower installation and maintenance costs
- **Water Cooled:**
  - Chiller mounted indoors, heat rejection using water evaporation via Cooling Tower mounted outdoors
  - Larger capacities, greater energy efficiencies possible, longer equipment life expectancy
  - Quieter operation

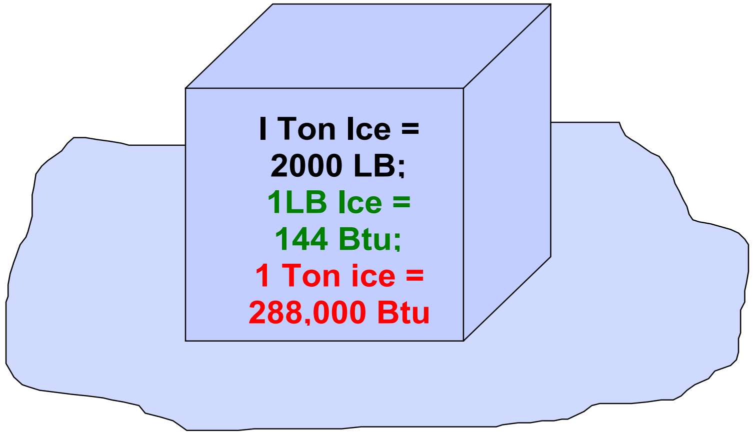
General "Points of Knowledge" for Chillers

- Allowable Water Velocity:
  - **3 Ft/Sec** minimum tube velocity to prevent fouling and air binding
  - **12 Ft/Sec** maximum tube velocity to prevent erosion and vibration
- Required System Volume:
  - **3 gal/ton** *(Min.)*, **5-8 gal/ton** *(Preferred)* **[HVAC]**
  - **6 gal/ton** *(Min.)*, **7-11 gal/ton** *(Preferred)* **[Process]**
- Operating Efficiencies:
  - **Constant Speed** chiller optimum efficiency around 70%-90% loading
  - **Variable Speed** chiller optimum efficiency around 40%-60% loading

Key Terms and Definitions for Chillers

Refrigeration Ton: The amount of heat energy (Btu/Hr) that can be removed by a chiller, using the refrigeration cycle, to melt **1 Ton** *(2,000 Lbs.)* of ice in *24 hours*

NOTE: It takes 144 Btu's to melt 1 Lb. of Ice at 32°F to water



Evaporator *(Chilled Water)*: (2,000 Lbs.)(144 Btu/Lb.) ÷ 24 hours = **12,000 Btu/Hr per Ton**

Condenser *(Cooling Tower Water)*: 12,000 Btu/Hr x 1.25* = **15,000 Btu/Hr per Ton**

***NOTE:** Compressor adds 25% due to Heat of Compression

Key Terms and Definitions for Chillers (cont'd)

$$Q = m\,C_p\,(t_s - t_r)$$

$$\text{Btu/Hr} = 500 \times \text{GPM} \times \Delta T$$

$$\text{GPM} = \text{Btu/Hr} \div 500 \times \Delta T$$

Evaporator *(Chilled Water)*: GPM/Ton = 12,000 Btu/Hr ÷ (500 x ΔT °F) = 24/ΔT °F

Condenser *(Cooling Tower Water)*: GPM/Ton = 15,000 Btu/Hr ÷ (500 x ΔT °F) = 30/ΔT °F

NOTE: If using fluid other than water, specific heat must be added to the equation

Example

A cooling load calculation determines a **600 Ton** chiller is required for a mixed-use building. The system fluid will be **water**, with a design chilled water supply temperature of **44°F** and a **15°F ΔT** at all coils in the system. The condenser will receive **85°F** water from the cooling tower, with an expected leaving temperature of **95°F.** Determine the required chilled and condenser water flows for pump selections.

Step 1: **Evaporator: 600T x 12,000 Btu/Hr/Ton = 7,200,000 Btu/Hr**

Condenser: 600T x 15,000 Btu/Hr/Ton = 9,000,000 Btu/Hr

Step 2: **Evaporator: 7,200,000 Btu/Hr ÷ (500 x 15) = 960 GPM**

Condenser: 9,000,000 Btu/Hr ÷ (500 x 10) = 1,800 GPM

Example

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Step 1: **Evaporator: GPM/Ton = 24/15°F = 1.6 GPM/Ton x 600 = 960 GPM**

Condenser: GPM/Ton = 30/10°F = 3.0 GPM/Ton x 600 = 1,800 GPM

What if we used 35% Propylene Glycol instead of water on Evaporator Side?

Example with 35% Propylene Glycol

$$GPM = \frac{Btu/hr}{(500 \times \Delta T)(C_p)(SG)}$$

Density of Water @ 44°F = 62.42 Lbs/ft³

Density of 35% PG @ 44°F = 64.90 Lbs/ft³

$$SG = \frac{\rho \text{ of Fluid}}{\rho \text{ of Water}} = \frac{64.90}{62.42} = 1.04$$

Cp of 35% PG @ 44°F = **0.89** Btu/lb °F

500 x 15°F ΔT = **7,500**

Answer: $\frac{7,200,000}{(7,500)(0.89)(1.04)}$ = 1,037 GPM (+ 77 GPM)

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Let's Solve Water

Water Cooled Chillers

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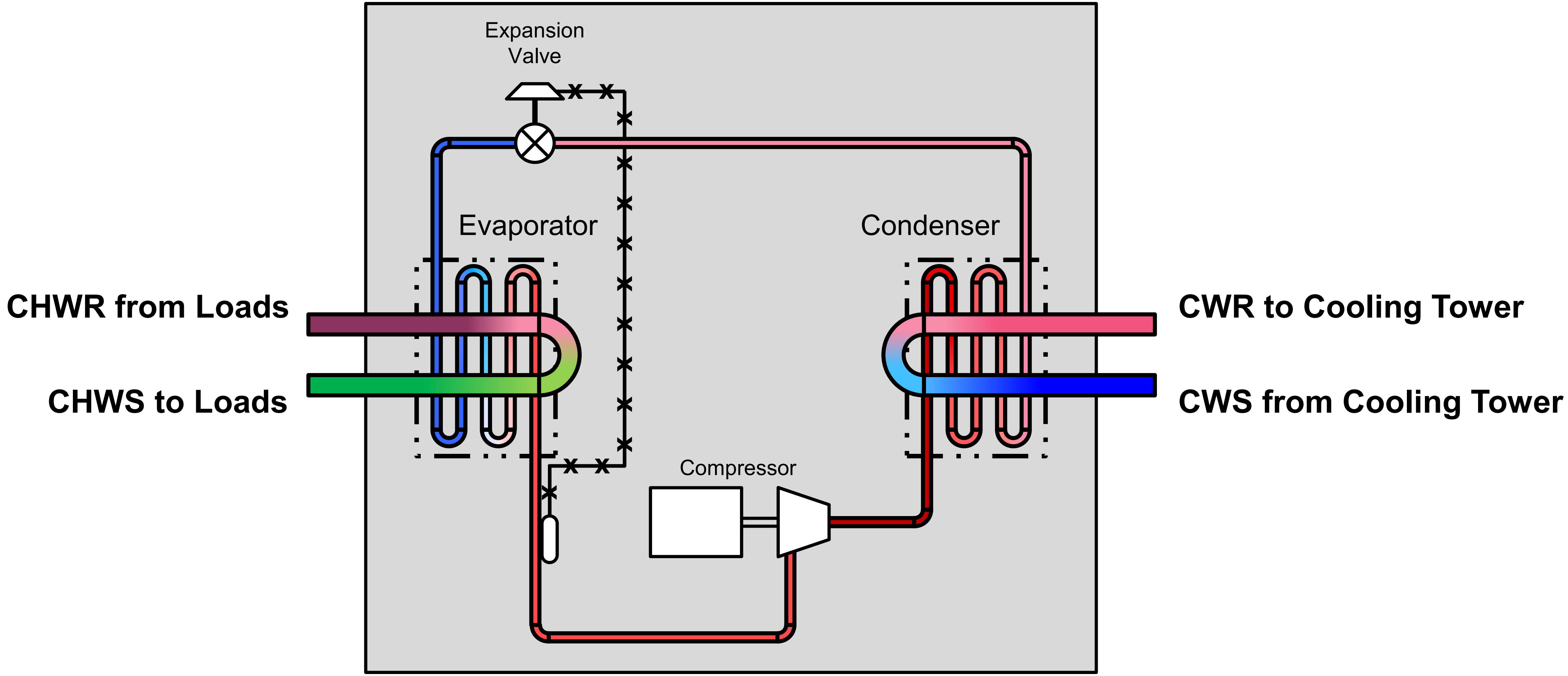
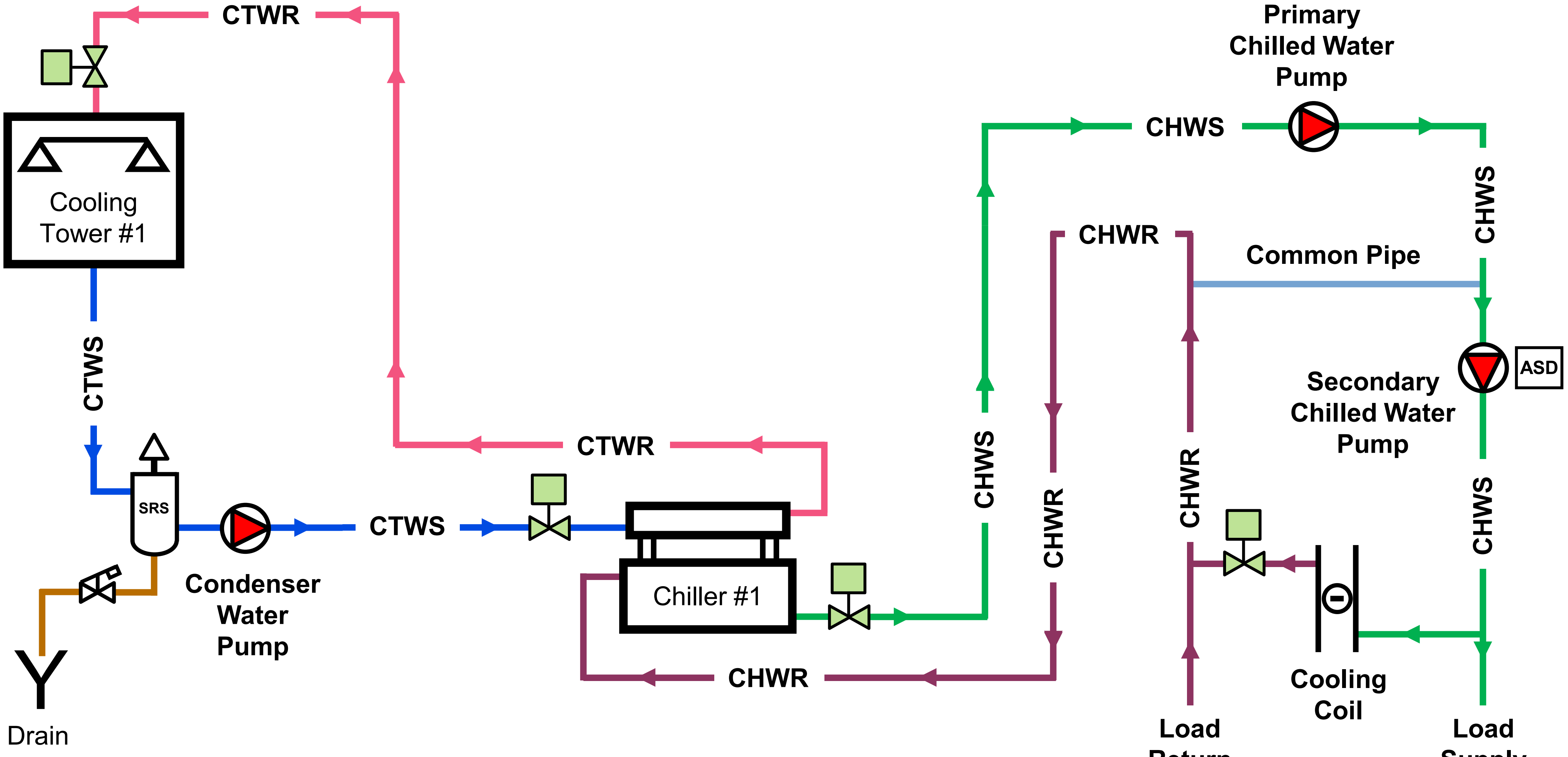
Water Cooled Chiller



Basic Chilled Water System Piping: Water Cooled Chiller



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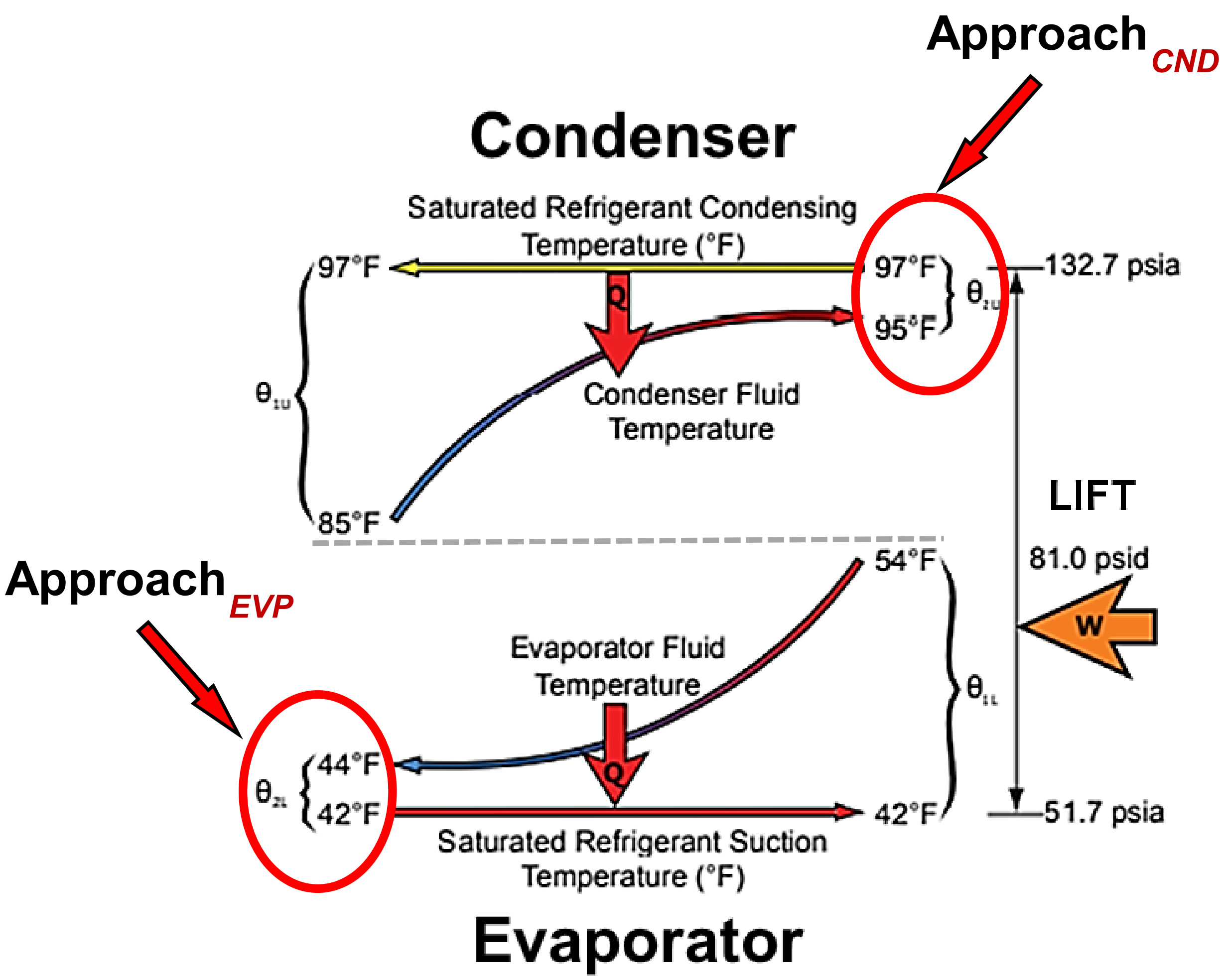
Water Cooled Chiller: Sensible and Latent Heat Exchange

Condenser

- **Refrigerant** changes from Gas to Liquid by releasing ***Latent Heat of Condensation***, refrigerant temperature remains constant.
- **Cooling tower water** gains ***Sensible Heat***, changes temperature.

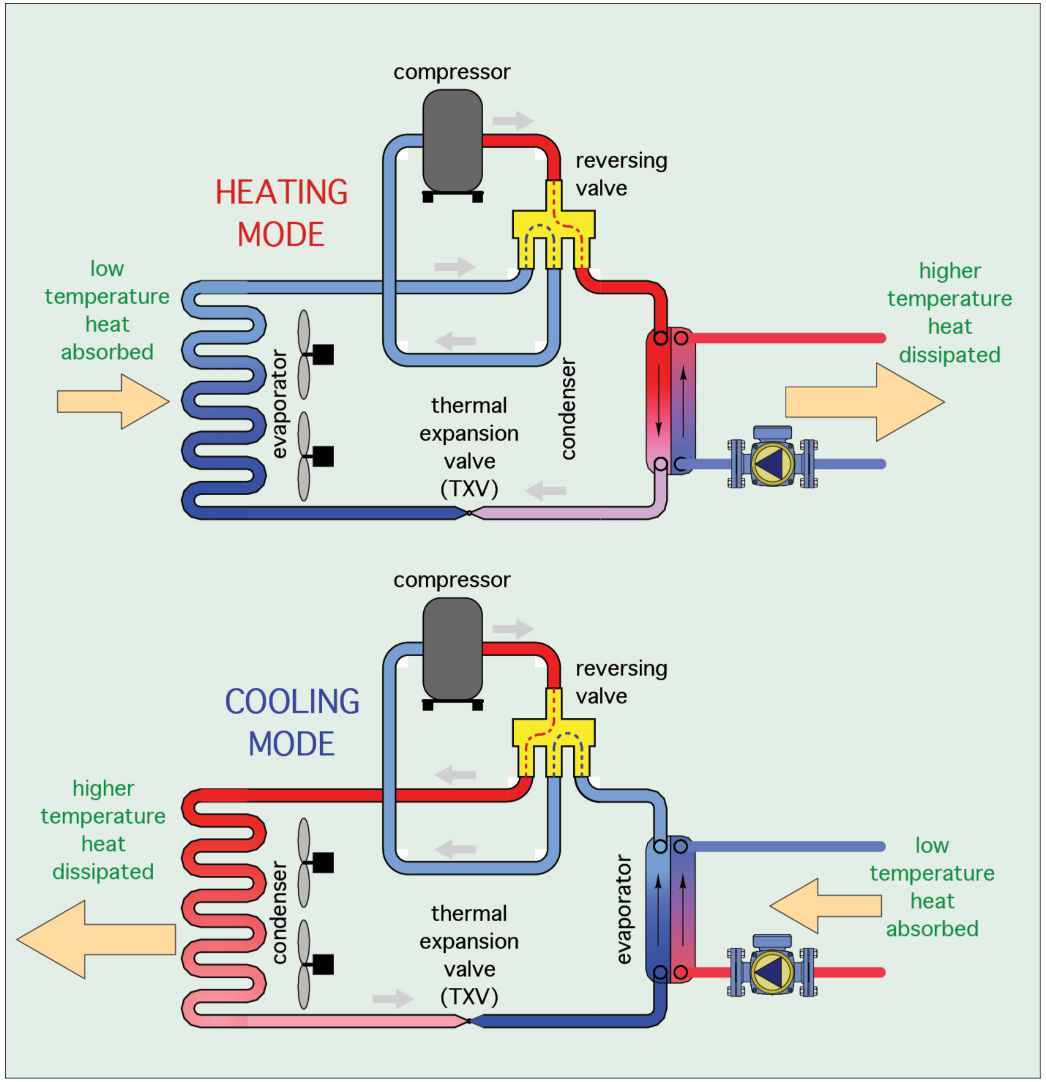
Evaporator

- **Refrigerant** changes from Liquid to Gas by absorbing ***Latent Heat of Vaporization***, refrigerant temperature remains constant.
- **Chilled water** releases ***Sensible Heat***, changes temperature.



Heat Pumps

Air to Water Heat Pump Basic Operation



Images Courtesy of Caleffi Idronics, Daikin, and Trane

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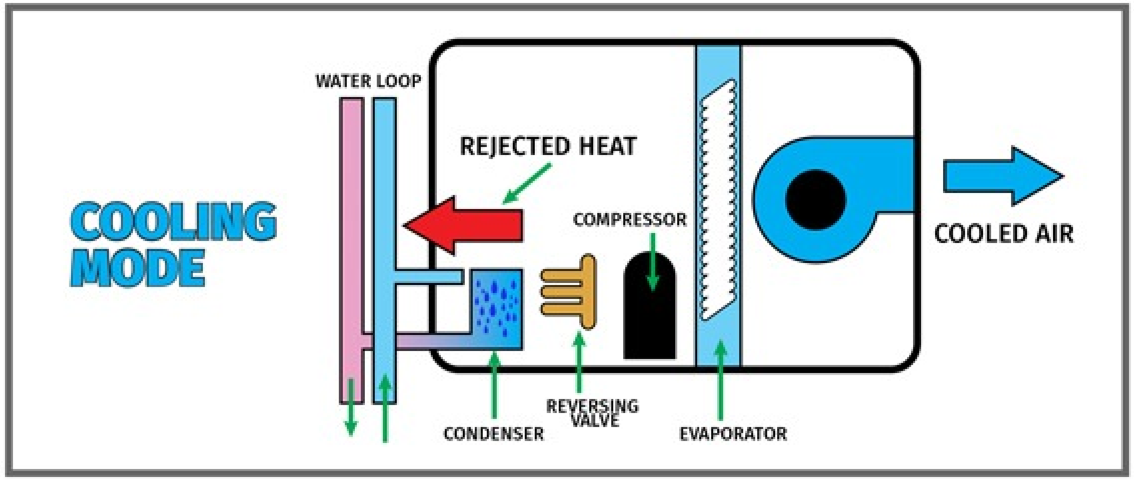
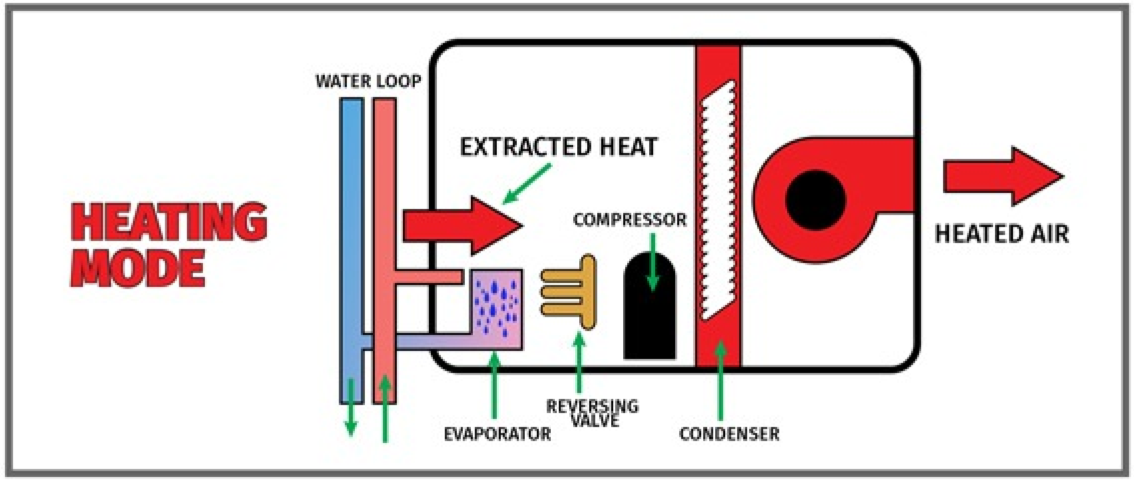
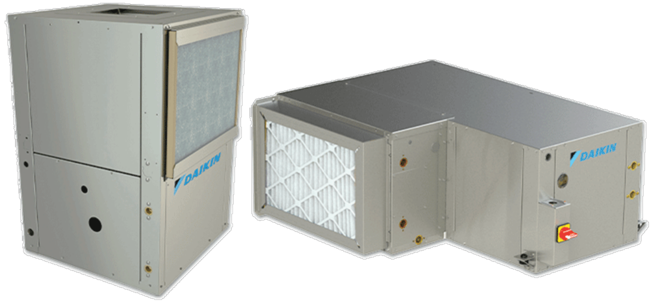
Water Source Heat Pump Basic Operation







Images Courtesy of United Air Cool, Trane, and Daikin

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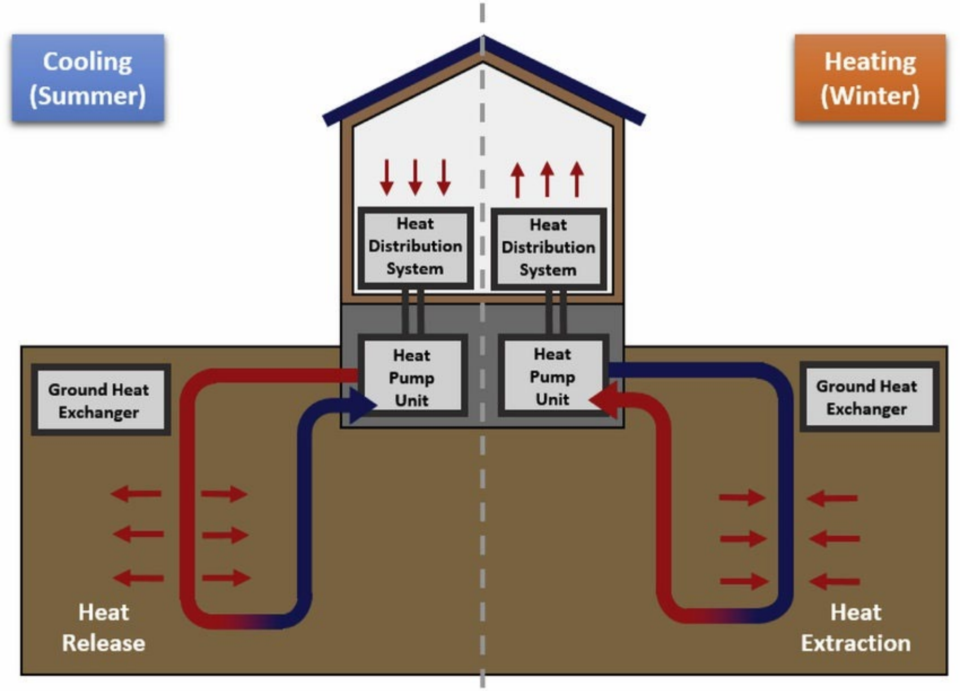
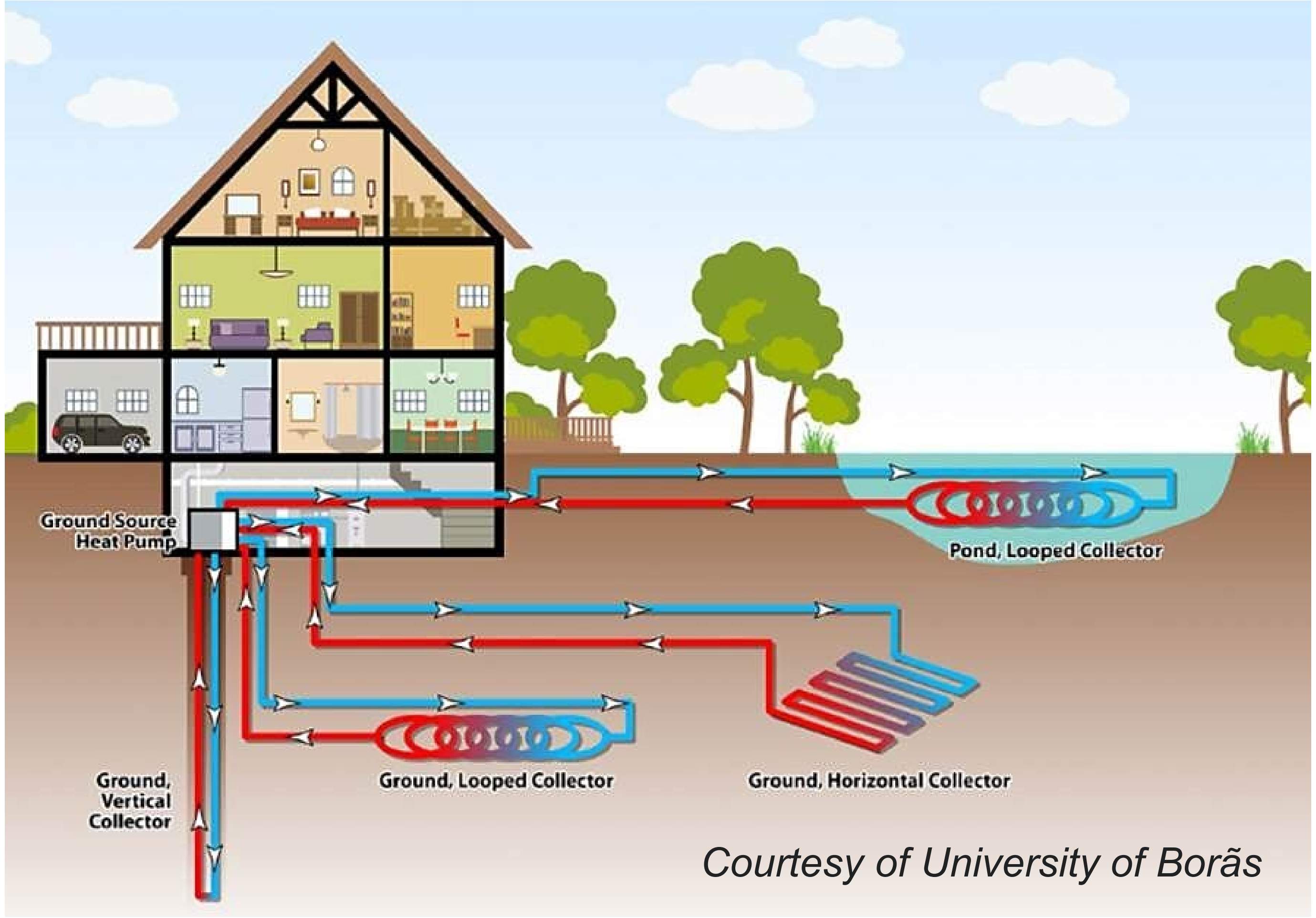
Geothermal Heat Pump Systems – Ground Loop Options





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Let's Solve Water

Open Cooling Towers & Closed-Circuit Fluid Coolers

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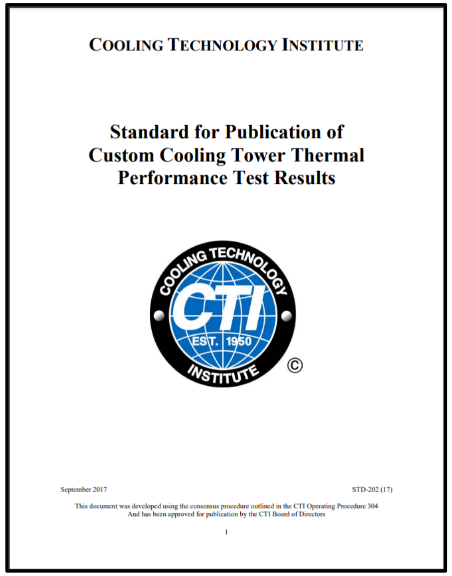
Cooling Technology Institute (CTI)



COOLING TECHNOLOGY INSTITUTE

Standard for Publication of
Custom Cooling Tower Thermal
Performance Test Results

September 2017 STD-202 (17)

This document was developed using the consensus procedure outlined in the CTI Operating Procedure 304
And has been approved for publication by the CTI Board of Directors

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Cooling Technology Institute *(CTI STD 202)* Cooling Tower rating conditions:

- Entering water temperature - 95°F
- Leaving water temperature - 85°F *(7°F Approach)*
- Outdoor Wet Bulb temperature - 78°F
- Entering water flow rate - 3.0 GPM/Ton *(rejects15,000 Btuh)*
- Range at 100% Load - 10°F

Key Terms & Definitions for Cooling Tower Sizing

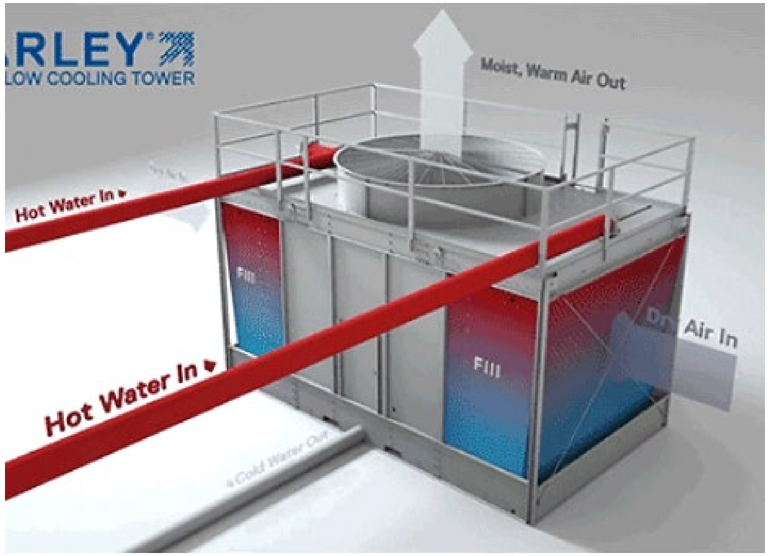
Tower Approach: The difference between the leaving cold water temperature and the Wet Bulb temperature. **5°F - 7°F** allows practical cooling tower sizing

Tower Range: The temperature difference between the hot water inlet and cold water outlet

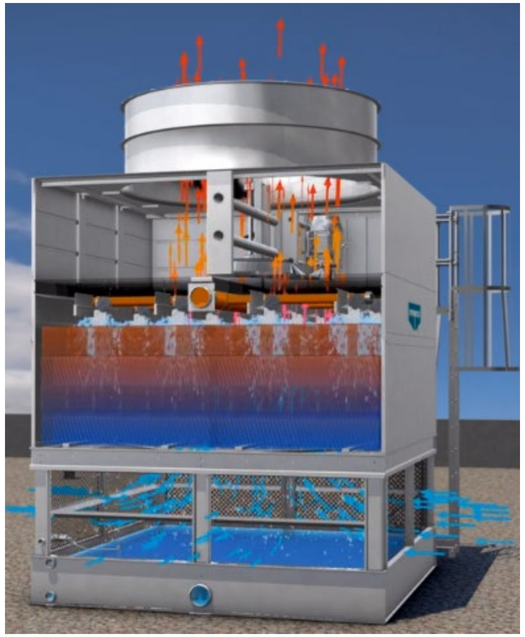
Heat Load: Total heat to be removed from the water by the cooling tower per unit time **(Btu/hr)**

Wet Bulb Temperature: The lowest temperature air can be cooled by evaporating water into the air at constant pressure.

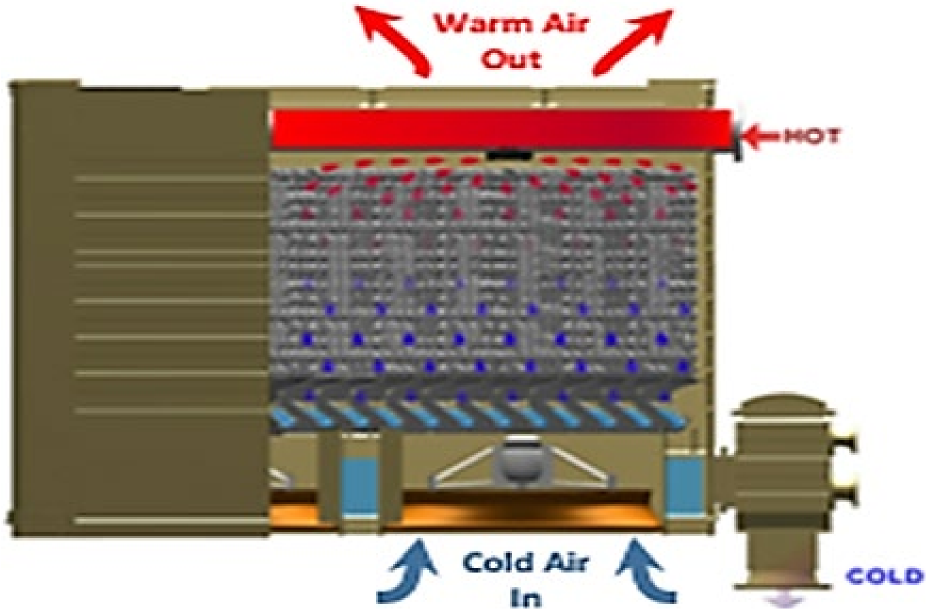
Open Cooling Tower Design Options



Induced Draft
Cross-Flow



Induced Draft
Counter-Flow



Forced Draft
Counter-Flow

- Constant and Variable water flow models available.
  - Induced Draft – Fan located at top, drawing air through louvers and fill
  - Forced Draft – Fan located at bottom, pushing air through louvers and fill

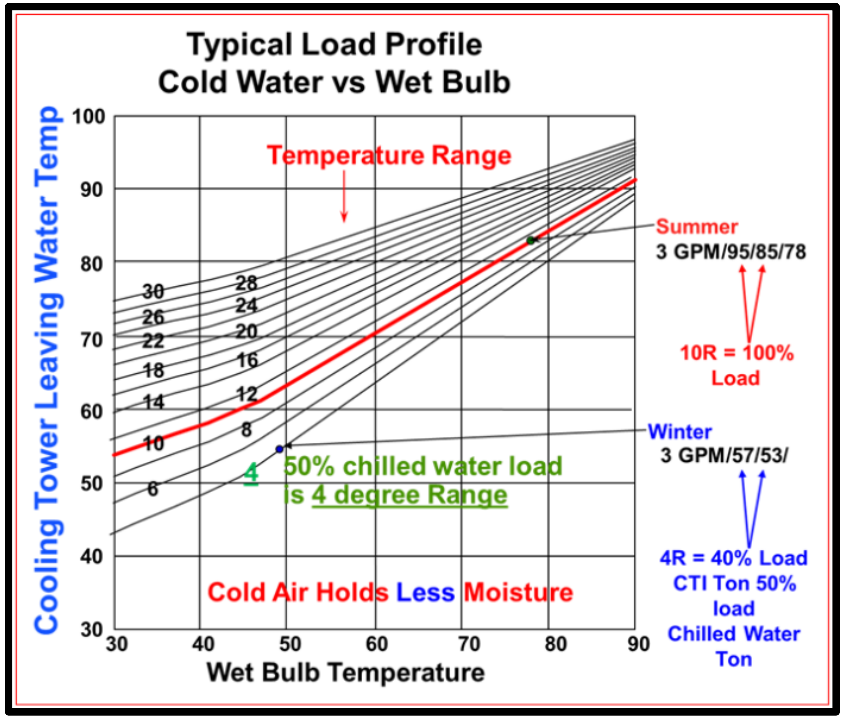
Images Courtesy of SPX Marley, Evapco, and Tower Tech Inc.

Basic Operating Principles for Open Cooling Towers

- Rejects heat to surrounding outdoor air through process of evaporation.

  (970 Btu to evaporate 1 Lb. of water)
- Capacity *(Tons of Cooling)* dependent on air

  Relative Humidity *(Wet Bulb Temperature)*
- Very Humid Air or Cold Air **holds less moisture**



Summary

- Flowrate and Heat Load determine "Range"
- As Outdoor Wet Bulb decreases, colder supply water possible
- **42°F- 45°F** is lowest suggested cold water setpoint to prevent freezing
- Evaporation rate slows with colder air, tower heat load capacity is reduced

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Key Terms & Definitions for Cooling Tower Water Management

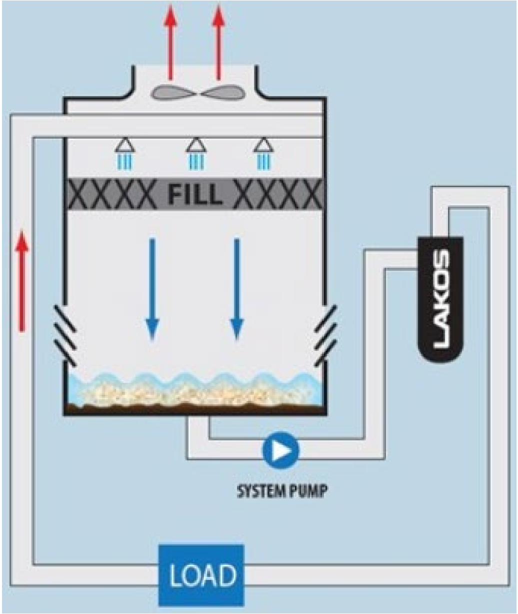
Cycles of Concentration: The ratio of solids concentration in the cooling tower system water as compared to the makeup water

Blowdown: The water discharged to remove system water with high mineral content *(solids)*

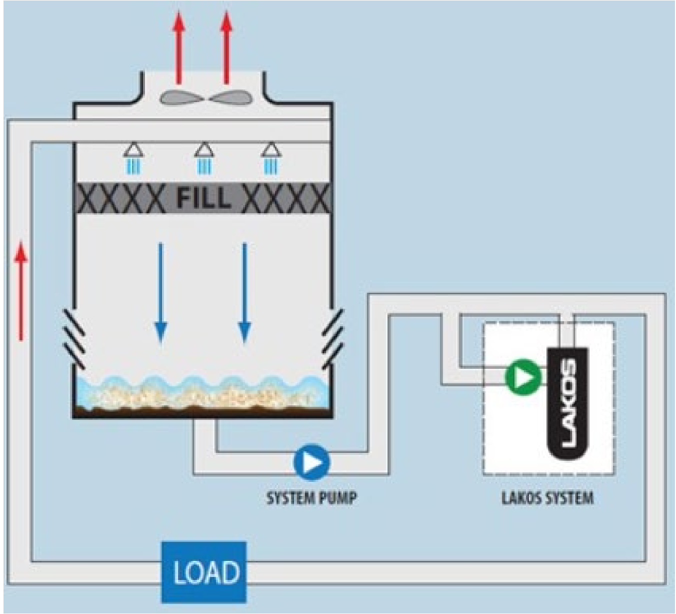
Drift: The concentration of water droplets contained in the exhaust air from top of cooling tower. On average, will be **.0005%** of system flow rate.

Make-Up: The water supply needed to replace system water losses due to evaporation, drift, and blowdown

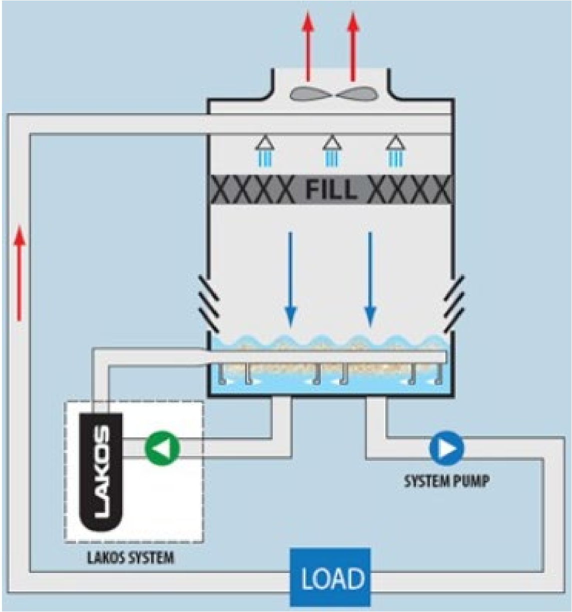
Open Cooling Tower: System & Basin Filtration Options



Full Flow
Filtration



Side Stream
Filtration

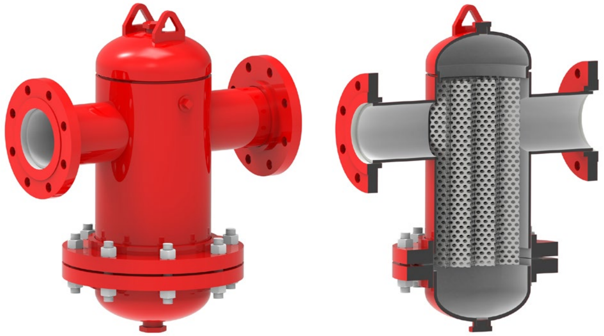


Basin Cleaning
Filtration

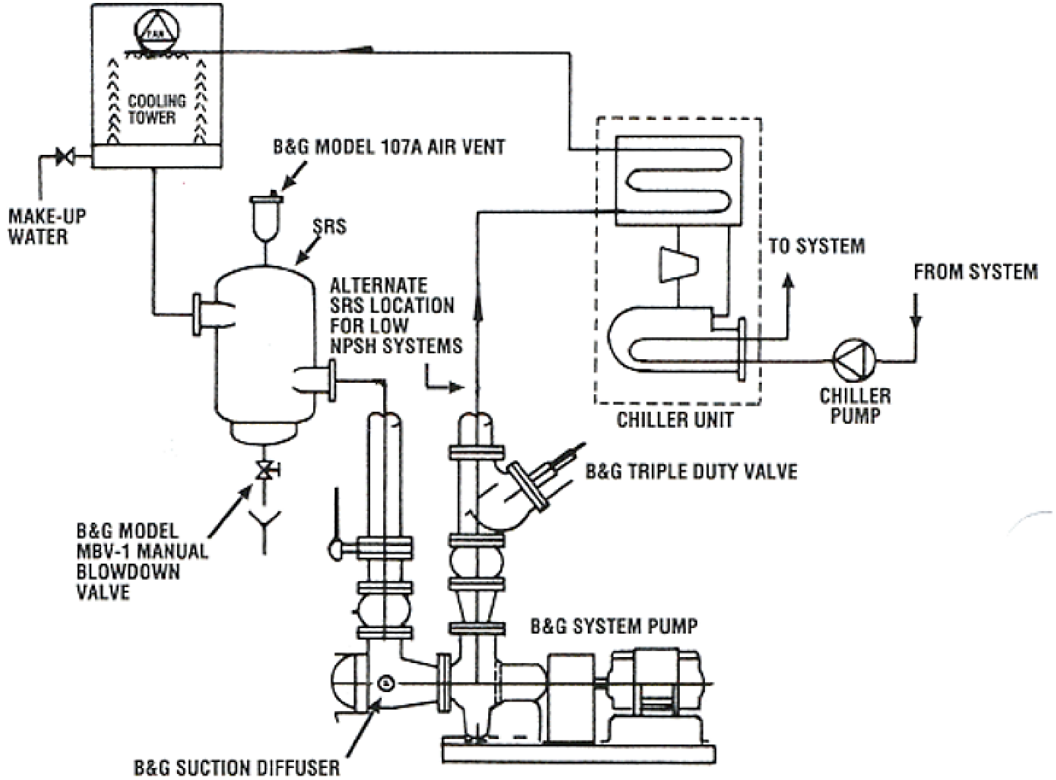
- **Full Flow:** Filtering 100% of system flow
- **Side Stream Flow:** Filtering a percentage of system flow (Typically 10%-25%)
- **Basin Cleaning:** Filtering 10%-20% of system flow, Sweeper Piping in basin

Images Courtesy of Lakos

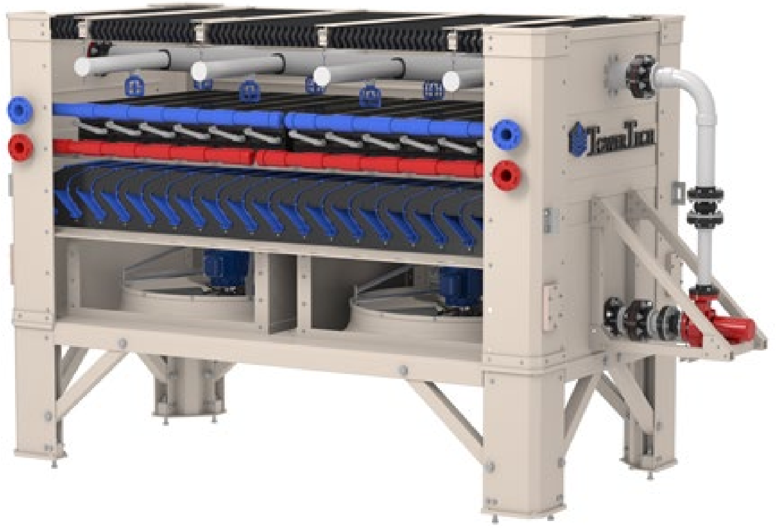
Open Cooling Tower: System Full Flow Sediment Separation

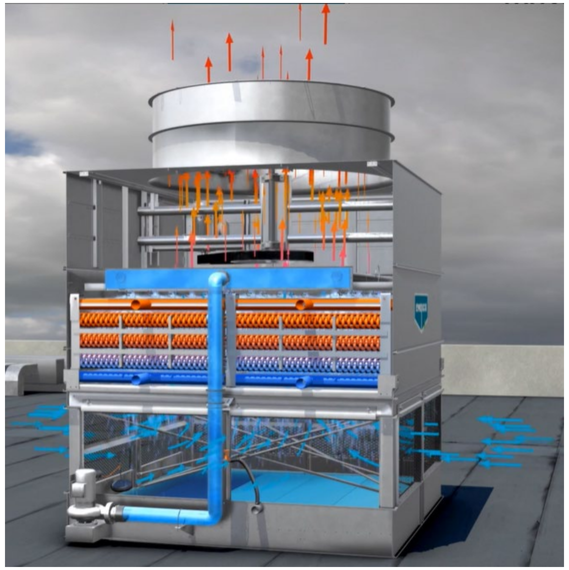


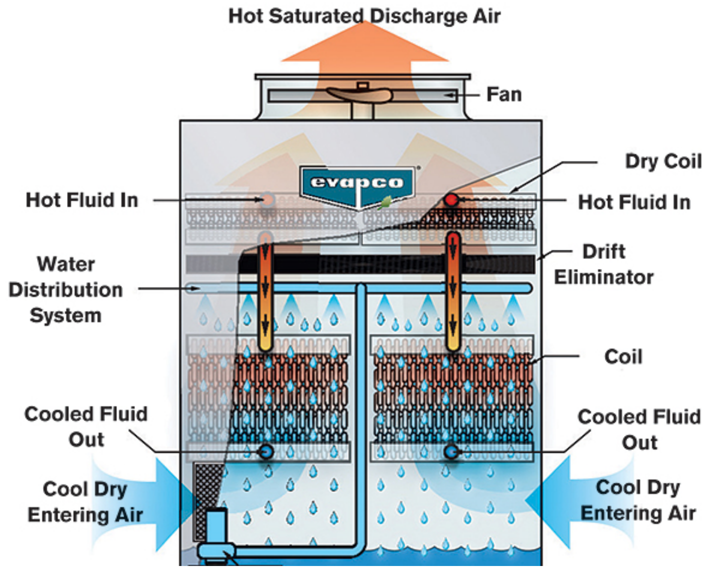
Chiller – Cooling Tower



Closed-Circuit Fluid Coolers







- Heat transferred from process fluid to ambient air through heat exchange coil
  - Isolates process fluid from outside air, keeping it clean and contaminate free
  - Can use process fluids other than water for freeze protection
- Integral spray pump distributes water across heat exchange coil
  - Absorbs heat from process fluid inside coil
  - Releases heat to atmosphere as portion of water evaporates

Images Courtesy of Evapco, and Tower Tech Inc.

Closed Circuit Fluid Cooler Application Considerations

Suggested when:

- Winter load too low for Open Tower to prevent freezing *(Glycol can be used)*
- Overall water consumption and equipment maintenance reductions are required
- System fluid cannot be exposed to atmosphere *(i.e. Water Source Heat Pumps)*
- Good chemical treatment program not available

Closed Circuit Fluid Cooler Application Considerations

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Concessions:

- Often require larger installed footprint that Open Tower
- First cost typically higher
- Higher system pump head maybe required due to large pressure drop in coil
- Requires additional “Spray” pump to circulate water from basin to nozzles

Questions?

Comments?

Observations?