
How to Determine the Ideal Location for a Cooling Tower

Nick McCall, P.E., Woodard & Curran
Keynote Speaker

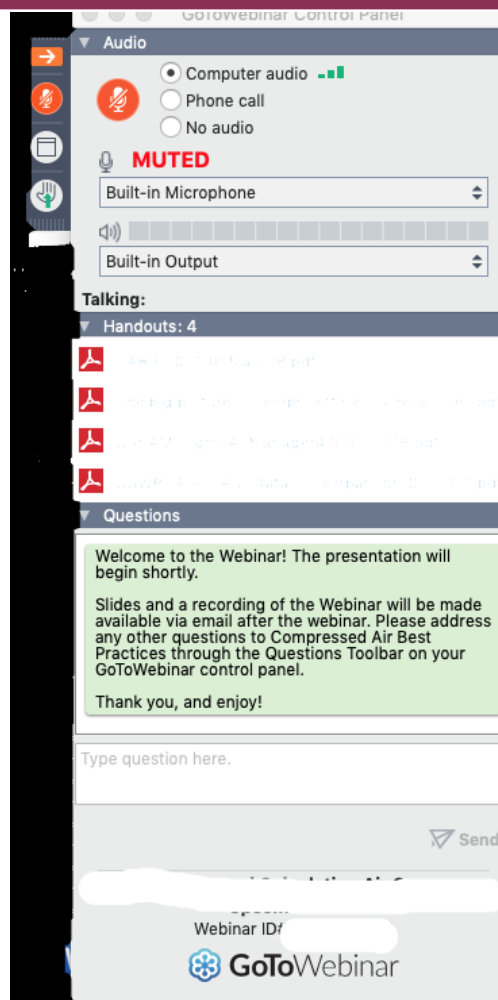
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From our environmental costs to the range of consulting, engineering, and operations expertise we provide today, we work for a diverse clientele — including municipalities, energy developers, colleges and universities, the real estate community, food and beverage manufacturers, and industry.

Talented people are at the heart of our firm. Our company was founded in 1979 on a simple business concept: provide an enjoyable place to work with opportunity, integrity, and commitment, and we will attract talented people. It happened. At the heart of our company are people who are experts in their field and passionate about what they do, showing a level of commitment and integrity that drive results for our clients. You experience this power every day in our actions, our solutions, and our personal life.

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Woodard & Curran has extensive experience in process and utility design engineering, ranging from small redesign projects to new plant process, utility, and mechanical design. Our engineers use the latest technology to produce state-of-the-art facilities for the food, beverage, life sciences and bottled water industries.

Experience includes all aspects of the process. We have completed preliminary design for entire plants and provided a variety of redesign and expansion services for existing facilities. We assist clients with ongoing user process requirements and establishing a design basis. Whether retrofitting a system or designing a Greenfield facility, Woodard & Curran will thoroughly review the operational details necessary for consideration and work closely with equipment manufacturers to make sure equipment meets precise specifications.

Our process and utility engineering team has the expertise to develop systems from the ground up. We can take a product from its point-of-origin to a tanker load out or through a production facility to the filler and packaging equipment.

We have utilized skid modularization to create custom designed processes combining onto one compact skid. This allows our clients to conduct intensive shop acceptance testing before the skid leaves the fabricator. It also allows for a more efficient start-up and reduces construction and integration field costs. The installation quality also improves due to the controlled shop environment.

We have the experience and expertise to fulfill all aspects of process and utility engineering, including:

- Process Systems**
 - treatment technologies, such as aeration, ultraviolet light, ion exchange tanks, activated carbon, reverse osmosis, and distillation
 - process design and controls
 - flow panels and valve clusters
 - blending skids
 - skid-in-place CIP and quality isolation systems
- Utility Systems**
 - chilled and tower water systems
 - low pressure and high pressure air systems
 - steam and hot water boilers
 - water distribution and controls
- Water and Wastewater**
 - wastewater treatment and utility water systems
 - chemical storage and feed systems
 - HVAC systems and controls



Our engineers are the latest technology to produce state-of-the-art facilities for the beverage and bottled water industries.

We can take a product from its point-of-origin to a tanker load out or through a production facility to the filler and packaging equipment.



We develop custom skids by joining skid-in-place, skid-in-place and skid-in-place equipment and components and integrating them into a single unit.

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Rank your customer's priorities by order of importance to uncover optimal products for the application.

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Compare models side-by-side.

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Need more personalized selection help? Your local Marley rep is all that's ready to assist you in the evaporative cooling equipment selection process!

MARLEY® applications engineering

Crossflow vs. Counterflow Cooling Towers

Crossflow and counterflow are two ways to describe how air moving through a cooling tower interacts with the process water being cooled and their fundamental differences. The focus is on factory-assembled, industrial-draft crossflow and counterflow cooling towers. For more information on other types of crossflow and counterflow towers, refer to the white paper, "Classifying Cooling Towers" AI-05-19.

The fundamental difference between crossflow and counterflow cooling towers is how the air moving through the cooling tower interacts with the process water being cooled in a crossflow tower, air travels horizontally across the direction of the falling water whereas in a counterflow tower air travels in the opposite direction (counter) to the direction of the falling water. See Figure 1 and Figure 2 for a visual explanation.

Space Requirements
The method by which air interacts with the process water creates two different types of plume areas as illustrated in Figure 1 and Figure 2 which has a direct effect on the footprint of the cooling tower. Up to about 750 tons (EQEWS 400), a counterflow cooling tower requires less plume area than a crossflow cooling tower, which makes counterflow cooling towers advantageous in densely populated areas with limited space. At about the 750 ton mark, counterflow towers offer little to no advantage in footprint compared to a crossflow tower. Furthermore, it is critical to realize not all available real estate can be treated the same. Depending on the application, a crossflow cooling tower may require less total area than a counterflow tower even at heat loads less than 750 tons. This is because of the air intake on each side of a tower. A counterflow tower only has two air inlets compared to four on a counterflow cooling tower. See Figure 3 and Figure 4.

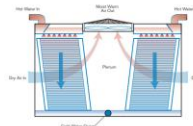


Figure 1 Crossflow cooling tower schematic

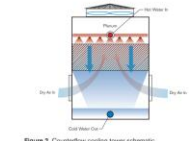


Figure 2 Counterflow cooling tower schematic



Figure 3 Crossflow effective footprint

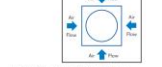


Figure 4 Counterflow effective footprint

Products and Services



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How to Determine the Ideal Location for a Cooling Tower

Introduction

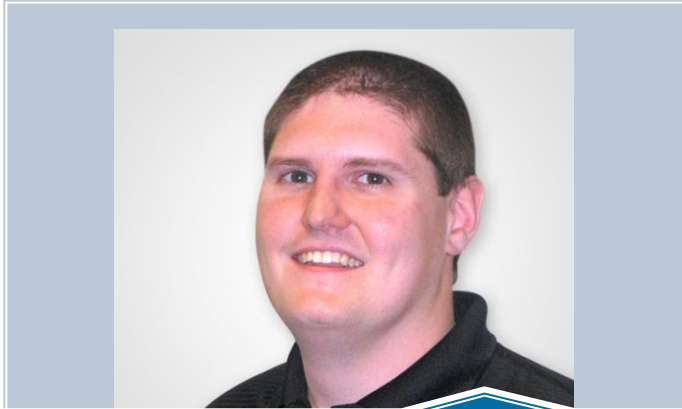
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About the Speaker



Nick McCall, P.E.
Woodard & Curran

- Technical Manager, Woodard & Curran
- Utilities engineer since 2008
- Handle utilities installations including chillers, air compressors, dryers, boilers, and cooling towers as well as supporting utilities for manufacturing equipment

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Outline

- Interference
- Recirculation
- Plume behavior and recirculation potential
- Tower siting and orientation

Interference

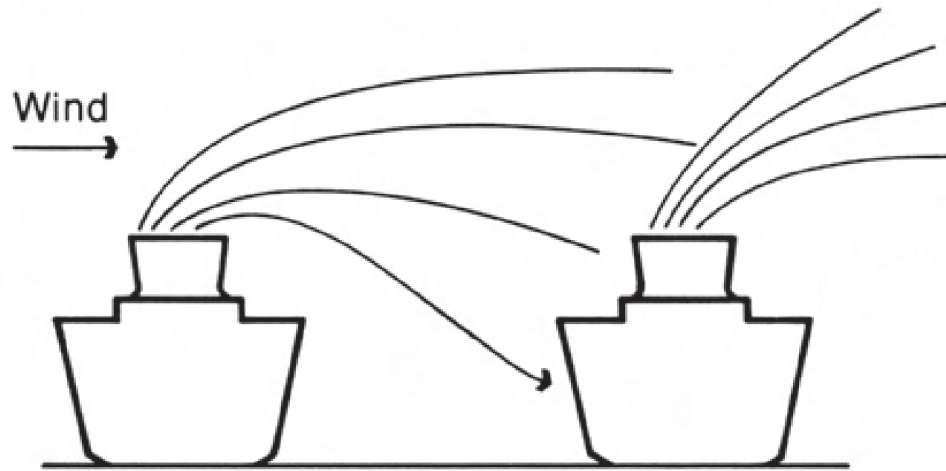


Figure 29 — Interference.

- Local heat sources upwind of the tower can elevate the wet bulb temperature of air entering the tower, detrimentally affecting the tower performance. This could include existing towers or other heat rejecting equipment.
- Proper location and orientation can minimize interference effects. Adjustments to tower layout/designs may be necessary to mitigate interference effects.
- New towers should be located out of the lee of any existing towers and capacity increased if it must be placed within the lee of any existing towers. Site specific conditions will need to be considered.

Interference

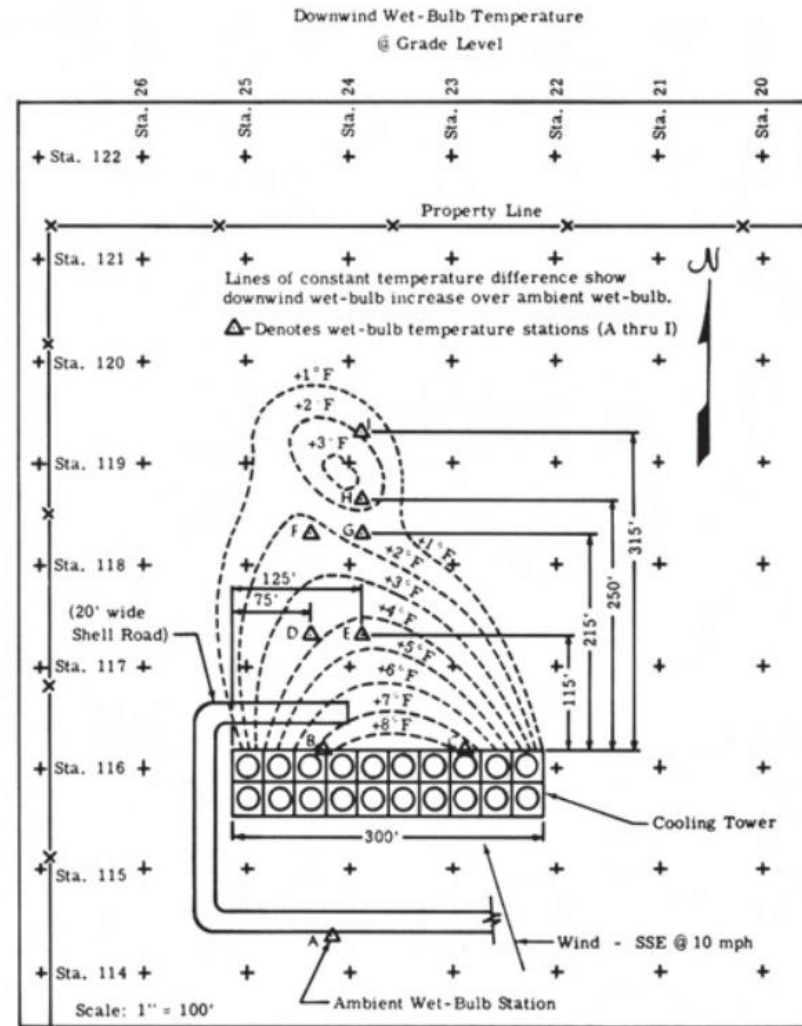


Figure 30 — Downwind wet-bulb contour of large existing cooling tower.

Recirculation

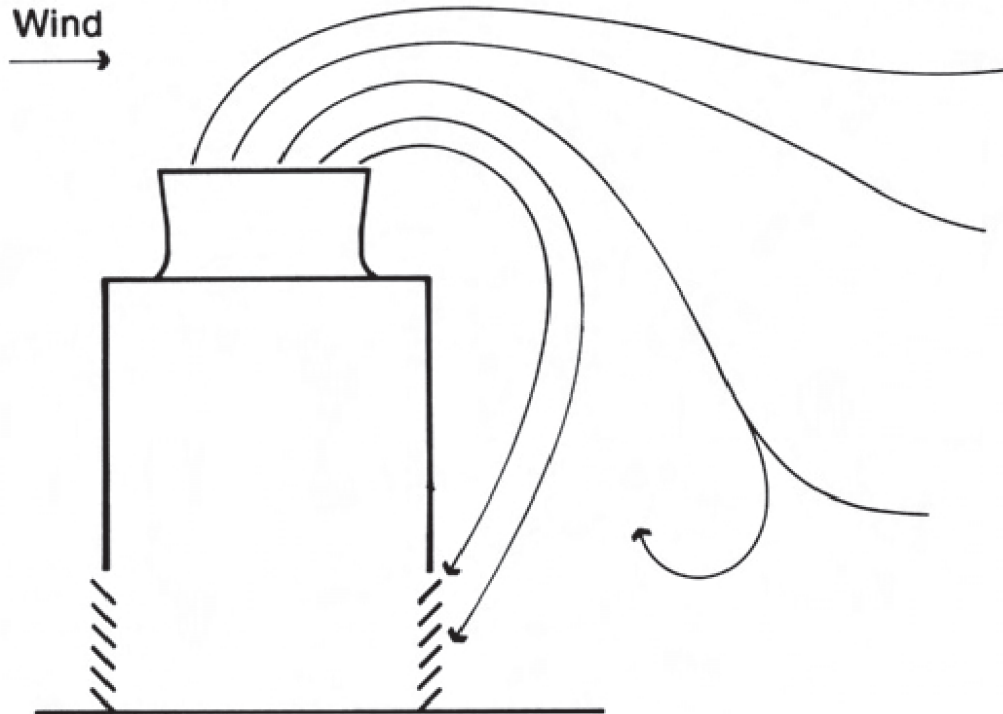


Figure 31 — Recirculation.

- Tower entering wet-bulb temperatures can be affected by some amount of saturated air exiting the tower being drawn back into the tower air intakes (recirculation). Tower manufacturers usually have designed their towers to minimize this effect.
- Recirculation potential is determined by wind force and direction. Recirculation effects tend to increase with wind velocity increases. Towers are typically tested to codes relating to thermal performance at wind velocities of 10 mph or less.

Plume Behavior and Recirculation Potential

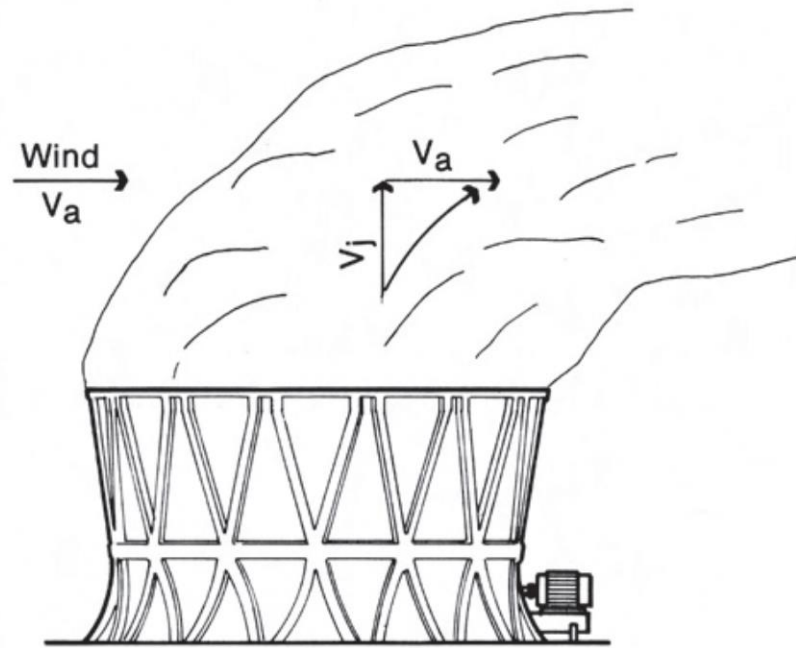


Figure 34 — Effect of wind velocity and discharge velocity on plume behavior.

- Fan imparts kinetic energy to the air and the heat load reduces the density of the effluent exiting the tower. The result is the air is pushed upward out of the tower, and the plume final height is determined by these two factors (independent of prevailing wind).
- Plume travels in direction dependent on speed, direction, and psychrometry of the prevailing wind. Low wind speeds result in almost vertical plume.
- For induced draft towers in calm conditions, the entering and ambient wet bulb temperatures are typically considered to be the same.
- With increasing wind speeds, plume direction becomes more horizontal. The plume to becomes drawn down and into the lee side of the tower.

Plume Behavior and Recirculation Potential

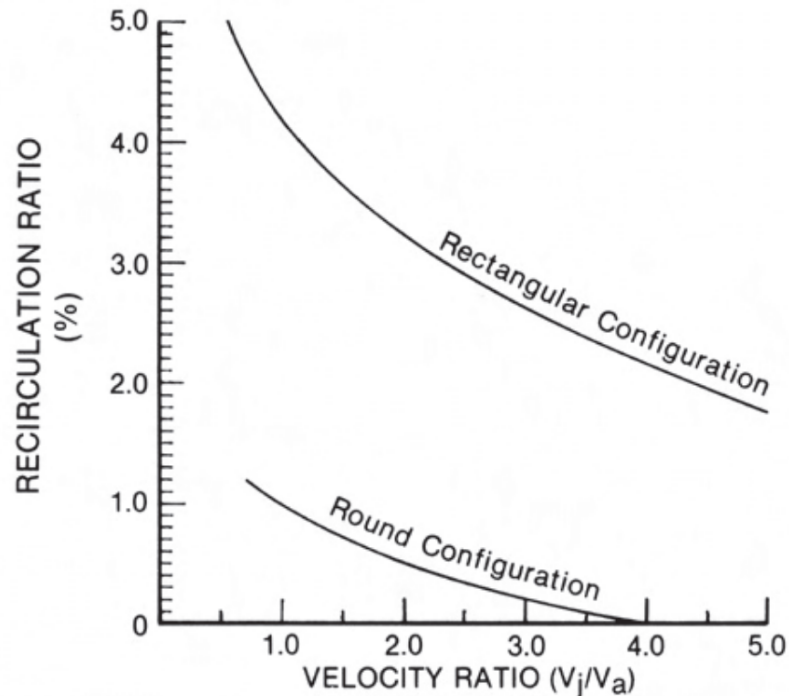


Figure 35 — Comparative recirculation potential of round and rectangular towers.

- Velocity ratio: plume discharge velocity divided by the ambient wind velocity.
- Recirculation ratio: percentage of total effluent air that is reintroduced into the tower by recirculation.
- Lower velocity ratios (higher wind velocities) result in higher recirculation ratios.
- Values in Figure 35 for the Rectangular Configuration represent a moderately sized industrial tower broadside to the prevailing wind. Recirculation ratios for that tower could be minimized if the tower were oriented 90 degrees from it's shown configuration (parallel to prevailing wind).
- Velocity ratio is also a function of the tower discharge air velocity. Velocity ratio will decrease if the tower discharge air velocity is decreased, resulting in a higher recirculation ratio.

Plume Behavior and Recirculation Potential

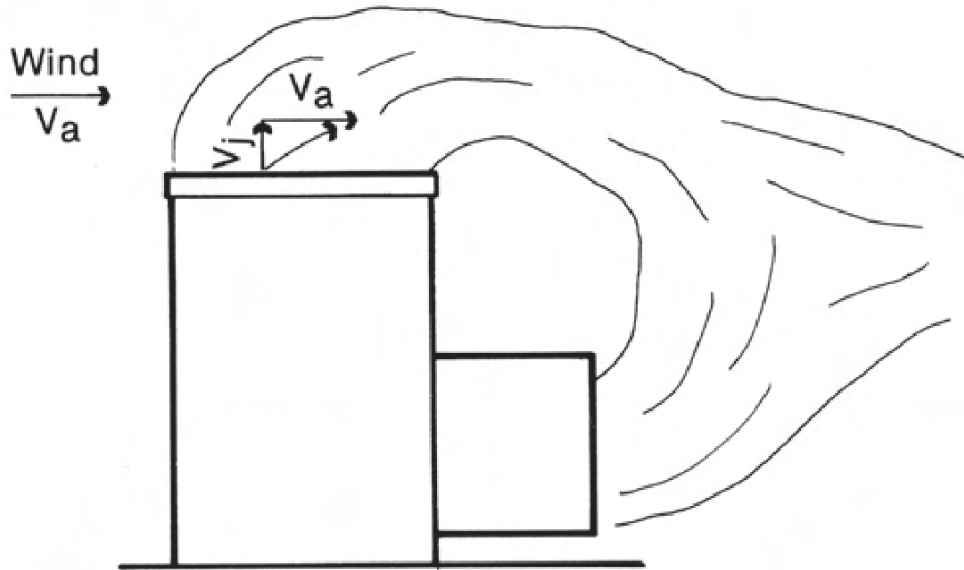


Figure 36 — Recirculation potential in a forced draft cooling tower.

- Forced draft towers are susceptible to lower velocity ratios.
- Normal discharge velocities from an induced draft tower are around 20 mph, while velocities from a forced draft tower are around 5-6 mph.
- This 4:1 difference results in a greater recirculation ratio in a forced draft tower.

Other Factors Affecting Recirculation



Figure 32 — Round mechanical draft tower operating in a significant wind. Compare plume rise to flat trajectory of smoke leaving stack.

- Tower shape: wind flow around obstructions is affected by the shape of the obstruction. Flowing wind leaves a low-pressure zone or “wake” on the downwind side of the obstruction. Wind will typically fill this area by the shortest possible route.
- Tall and narrow objects: wind can flow easily on either side of the obstruction.
- Low and long objects (like towers): wind typically flows over the top of the obstruction and down. This can present a difference in air intake wet bulb temperatures, degrading performance.
- Wind tends to flow with a smaller to negligible “wake” around round cylindrical shapes (Figure 32).

Other Factors Affecting Recirculation

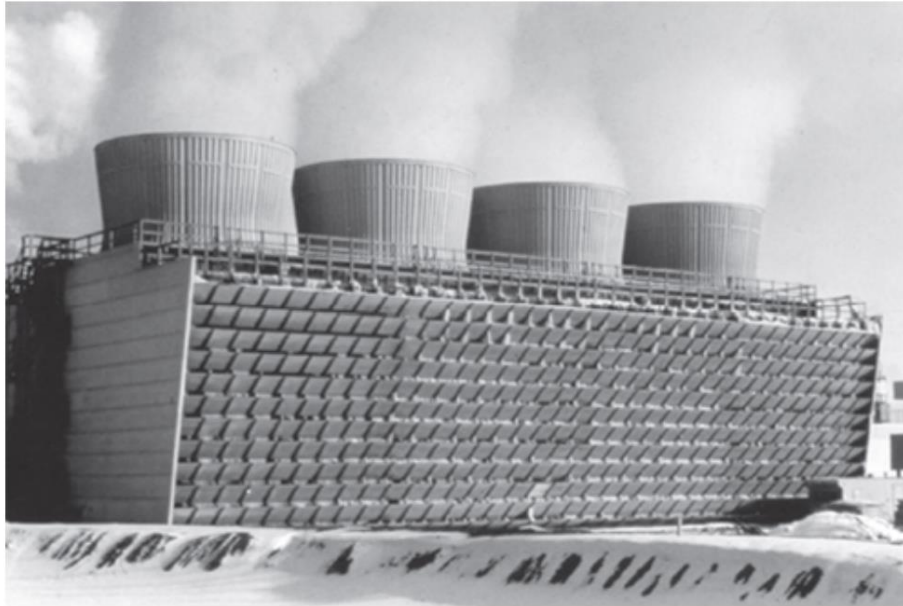


Figure 33 — Longitudinal wind direction concentrates separate stack plumes into one of high buoyancy.

- Orientation with prevailing wind: tower orientation can be altered to minimize wind effects (turning tower 90 degrees to face the narrower side of the tower towards the prevailing wind). This minimizes the tower “wake” and causes the fan effluents to “stack”, forming an exhaust plume that is more concentrated and buoyant.
- Round mechanical draft towers are unaffected by wind direction, and the center clustered fan arrangement produces a plume that is both concentrated and buoyant.

Other Factors Affecting Recirculation

- Fan cylinder height and spacing: discharge heights of tower fan cylinders can be increased, and spacing can be altered to provide more space between them to allow wind to flow more freely around the cylinders. Both of these are usually done together and can greatly reduce the recirculation potential in most situations (at an increase to the tower cost).

Tower Siting and Orientation

- Air Restrictions: towers are often screened from view by barriers/enclosures for aesthetic reasons. These screening devices can restrict air flow around the tower. Shrubs, fences, or walls with louvers should be placed several feet away from the air inlets to allow normal air flow to the tower. Consult tower manufacturer for input on screening barriers and enclosures concerning design and placement.

Tower Siting and Orientation

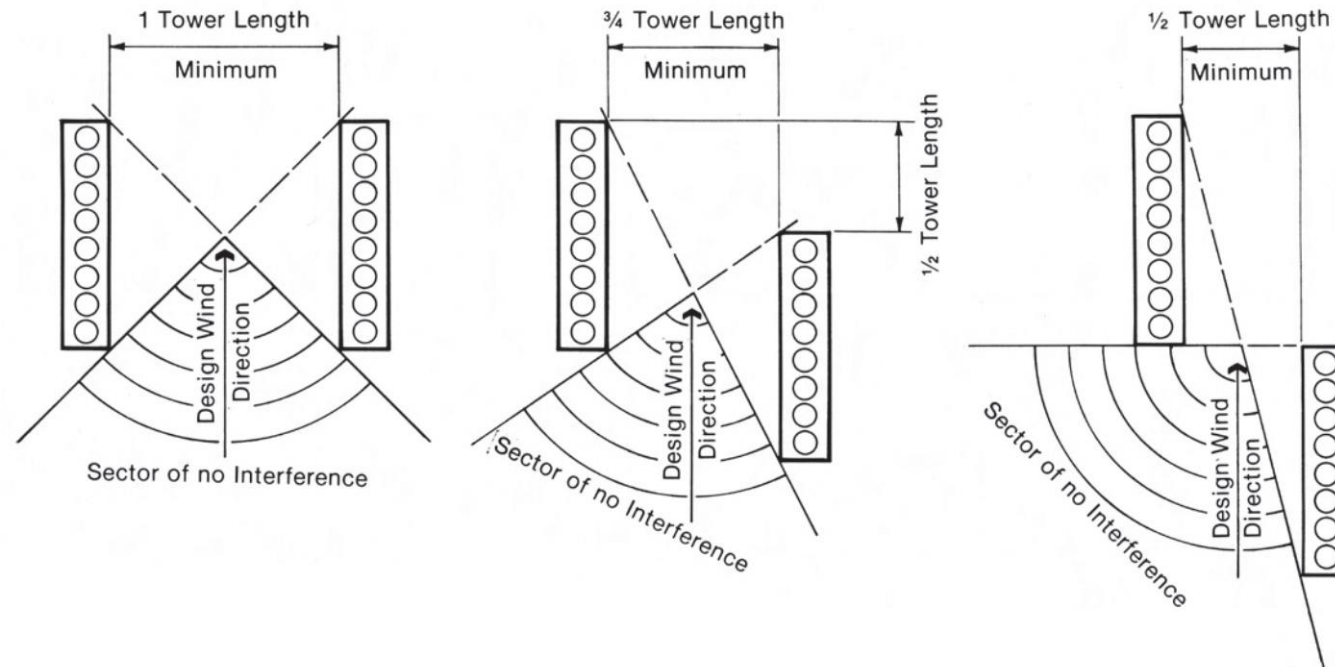


Figure 37 — Proper orientation of towers in a prevailing longitudinal wind. (Requires relatively minimal tower size adjustment to compensate for recirculation and interference effects.)

Tower Siting and Orientation

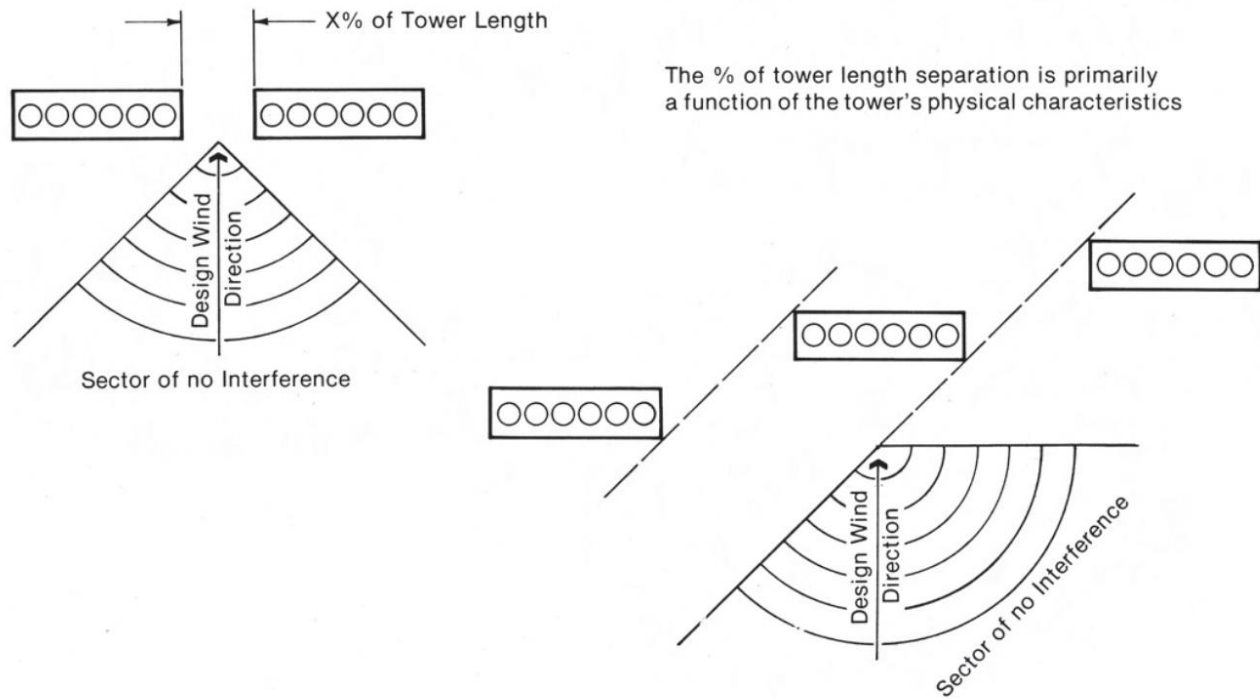


Figure 38 — Proper orientation of towers in a prevailing broadside wind. (Requires significantly greater tower size adjustment to compensate for recirculation and interference effects.)

Siting Configuration and Effect on Site Piping

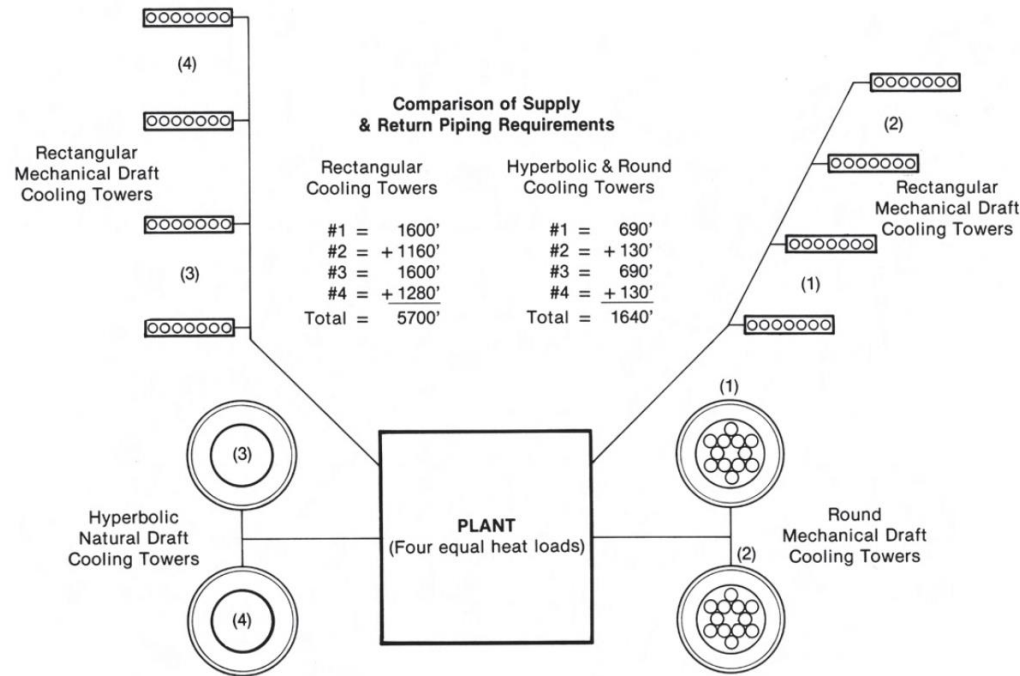


Figure 39 — Comparison of piping and ground use for both rectilinear towers and round towers. (Both types selected for equal performance.)

- Effect on site piping: Proper siting/orientation of towers generally takes precedence over concerns regarding complexity/quantity of site piping to towers. For smaller installations, tower location typically has minimal impact on total site piping costs. For larger installations (multiple towers), there may be on the order of hundreds of feet of large diameter piping required to site the towers in the proper location, and piping costs can represent a large portion of the overall project budget. Due to the variation in water distribution systems for towers, the amount of required site piping can be kept to a minimum for rectangular tower layouts. However, more effective reductions in site piping requirements can be made using round mechanical draft/hyperbolic towers due to tolerance for much closer spacing.

Summary

- Recirculation and interference both affect the long term capability/performance of cooling towers; determining proper site placement cannot be overstated.
- Tower performance is dependent on the amount and quality of air entering the tower. Any external influences on the wet-bulb temperature of the air or restrictions to its flow can negatively affect tower thermal performance.
- Attention must be paid to the distance between the heat load and the tower, effects around piping and wiring distance, noise/vibration issues, drift/fogging in areas sensitive to moisture or vision obstructions, and working access to all sides of the tower for repair and maintenance.
- Orienting the tower such that the louvered intake faces are parallel to the prevailing winds is the proper placement to minimize recirculation effects.
- Towers should not be situated such that any one tower is located within another tower's/heat source's (air cooled chiller, boiler stack, etc.) downwind interference zone or lee. If this is not possible, the tower should have it's design wet bulb adjusted accordingly.
- Round towers do not suffer greatly from recirculation, but they are not immune to interference effects and they can also act as interference sources as well.
- There are no hard and fast rules to cover all possible tower installation scenarios. Location/orientation of the tower can affect the entering wet bulb temperature by anywhere from 0.5 deg F to 5 deg F, and it would be wise to consult the cooling tower manufacturer for guidance in these areas, especially on sites with critical processes and substantial heat loads.

Thank you for watching!

Nick McCall, PE
nmccall@woodardcurran.com

About the Speaker



Mark Pfeifer, P.E.
SPX Cooling Tech, LLC

- Sr. Manager, Technical Services, SPX Cooling Tech, LLC
- 30+ years of cooling tower experience
- Secretary of ASHRAE's Technical Committee for Cooling Towers and Evaporative Condensers (TC8.6)

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October 20, 2022

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Agenda

Why Evaporative Cooling

Selection & Design

Tower Type Effects

Sound Mitigation Effects

Making it Fit - How Manufacturers can Help

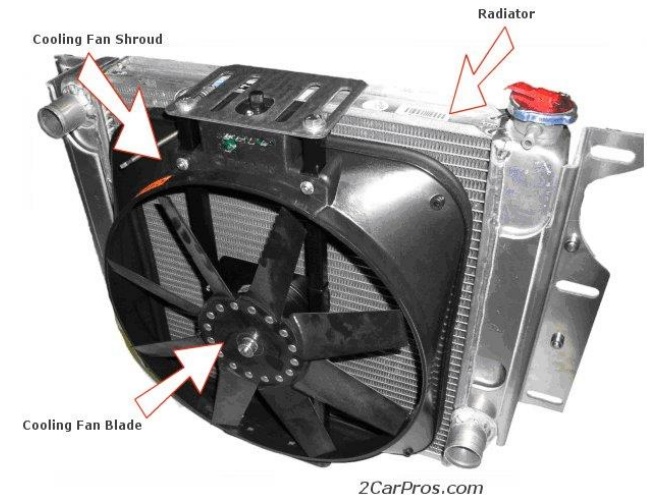
Product Selection Tool

Piping Layout Options

The “Cooling” in Cooling Towers

Sensible (aka dry cooling)

- Sensible Cooling of 1 lb of water 1°F rejects 1 btu.
- Dry Bulb temperature is the driving force
- Hard to cool 95° water with 95° air
- Example: Car radiator



Latent (aka evaporative cooling)

- Evaporating that same 1 lb of water rejects 1,000 btu!
- Example: Perspiration evaporating



The “Cooling” in Cooling Towers

Evaporative cooling

- Can cool water approaching the wet bulb temperature
 - providing colder water to process
 - **Providing additional system efficiency**

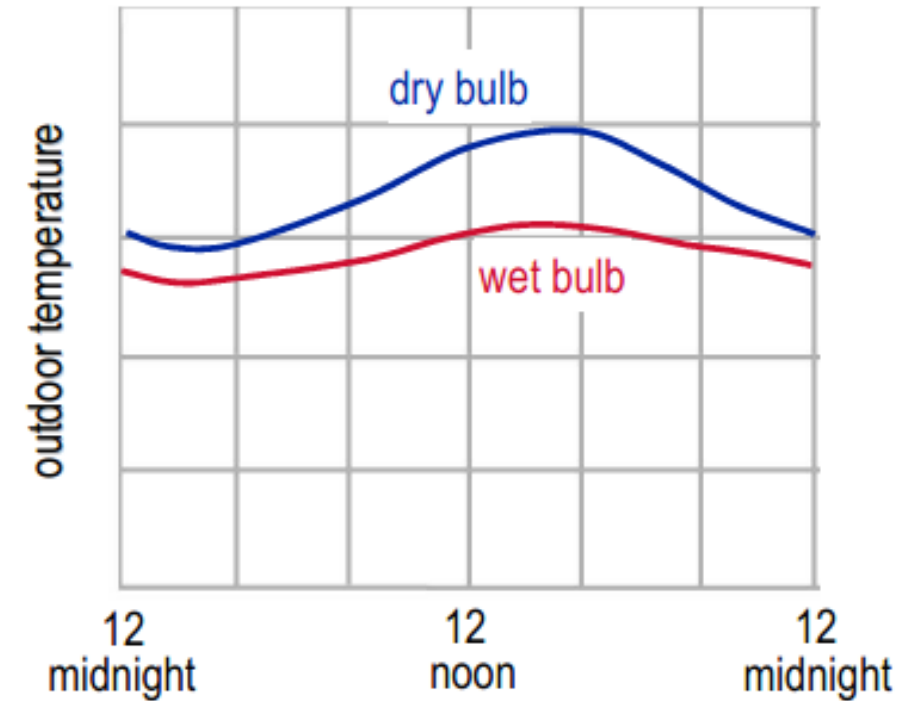


Image courtesy Trane Technologies

Agenda

**Why Evaporative Cooling
Selection & Design**

Tower Type Effects

Sound Mitigation Effects

Making it Fit - How Manufacturers can Help

Product Selection Tool

Piping Layout Options

Tower Space Requirements

NC - Crossflow



Tonnage	Crossflow
100 – 750	80 – 315 sf
>750	270 – 315 sf
Multi Cell (ex 6000)	1350 sf

MD - Counterflow

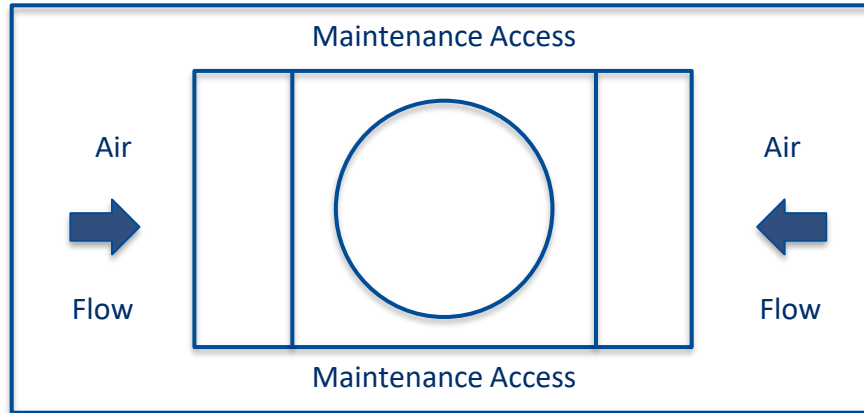


Tonnage	Counterflow
100 – 750	50 – 220 sf
>750	290 – 430 sf
Multi Cell (ex 6000)	1650 sf

Crossflow Tower is Rectangular & Horizontal; Counterflow Tower is More Square & Vertical

Total Tower Space Requirements

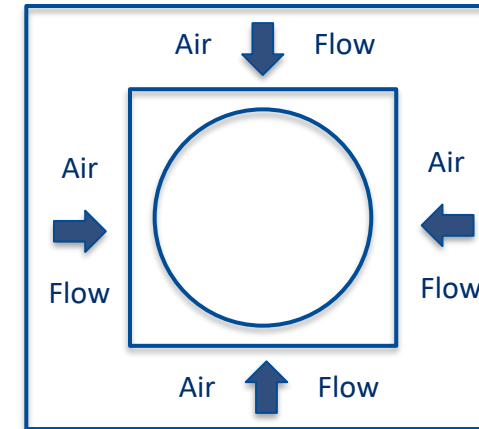
NC - Crossflow



Tonnage	Crossflow
100 – 750	250 – 850 sf
>750	850 sf
Multi Cell (ex 6000)	2800 sf

- + Air inlet space only required at the ends
- Space required on side to access the door

MD - Counterflow



Tonnage	Counterflow
100 – 750	200 – 990 sf
>750	990 – 1500 sf
Multi Cell (ex 6000)	4600 sf

- Air inlet space required on all 4 sides

Crossflow Requires Less Total Space

Tower Height

NC - Crossflow



Tonnage	Crossflow Ht.
100 – 750	10' – 12'
>750	18' – 22'
Multi Cell (ex 6000)	10' – 22'

- Add ~3' for Guardrail

MD - Counterflow



Tonnage	Counterflow Ht.
100 – 750	10' – 17'
>750	16' – 19'
Multi Cell (ex 6000)	10' – 19'

- Some manufacturers up to 22'



Advantage Depends on Job Requirements

Agenda

**Why Evaporative Cooling
Selection & Design**

Tower Type Effects

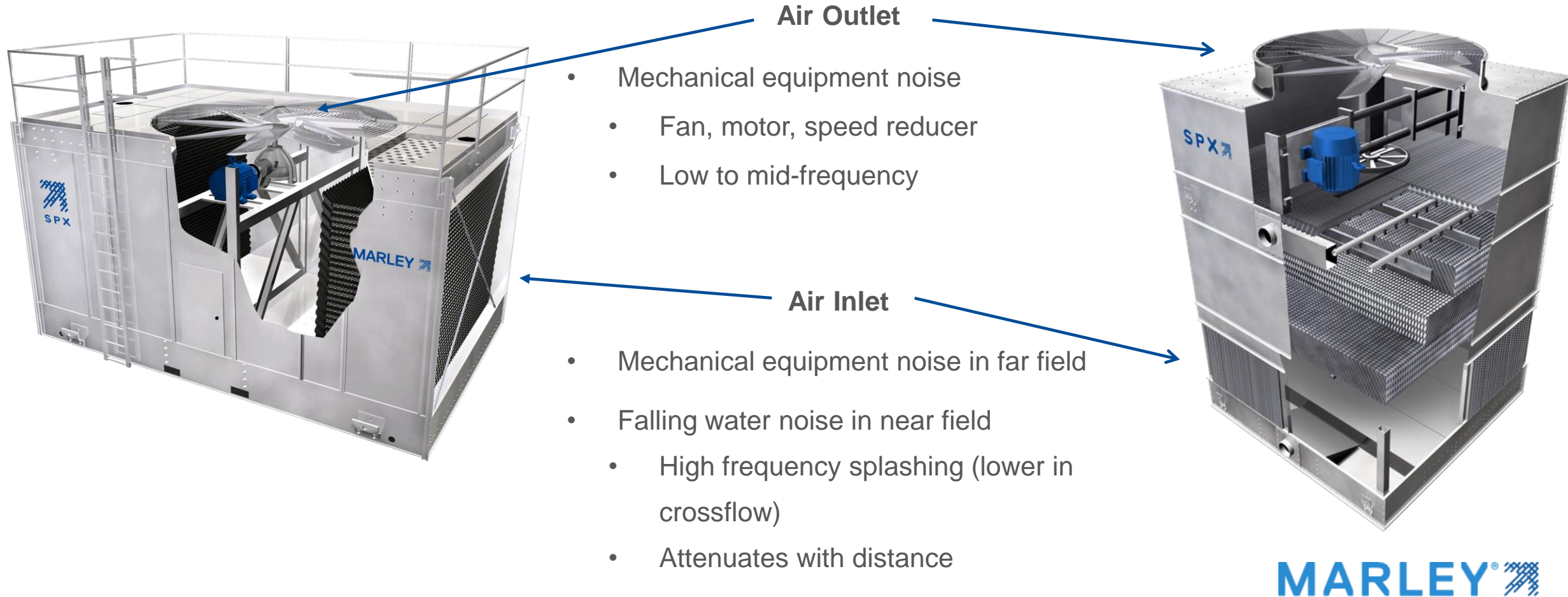
Sound Mitigation Effects

Making it Fit - How Manufacturers can Help

Product Selection Tool

Piping Layout Options

Sound: Primary Sources

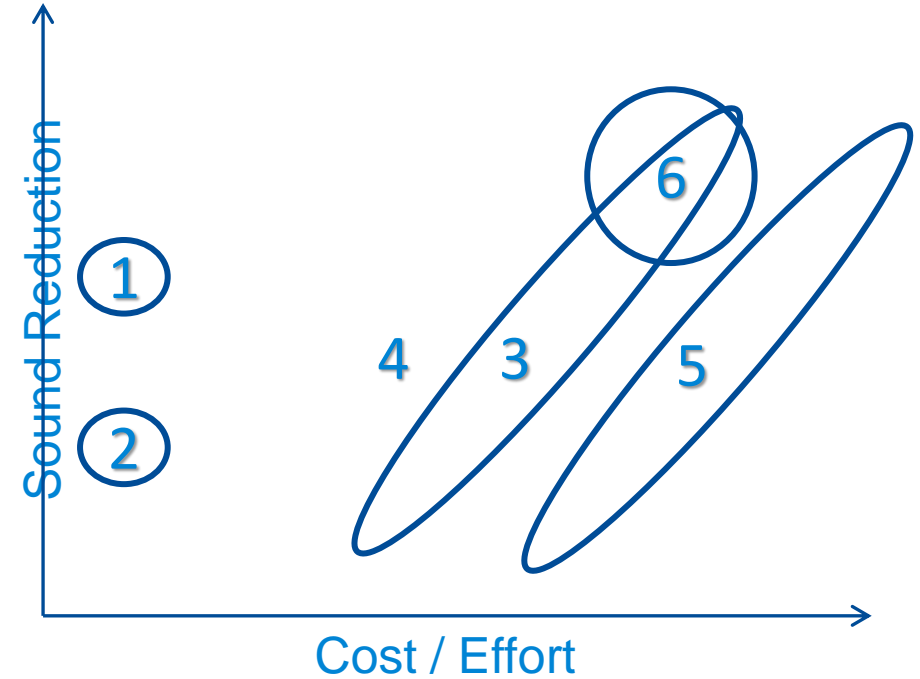


Orient Cased Face Toward Critical Sound Measurement Locations

Sound Mitigation Techniques



1. Orient the cased face toward receiver (crossflow tower)
2. Locate the tower farther from receiver
3. Oversize the tower and run at reduced fan speed
4. Low Noise Fan Options
5. Attenuation Options
6. Place a barrier between the tower and receiver



**Move the tower
before changing
the tower**



Agenda

**Why Evaporative Cooling
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Sound Mitigation Effects

Making it Fit - How Manufacturers can Help

Product Selection Tool

Piping Layout Options

- Sizing and Selection tool for cooling towers, fluid coolers and evaporative condensers
- Guided selection / recommendations based on System, Application, and User Priorities
- Compare functionality
- Filter functionality to limit key criteria
- Minimum enclosure clearances provided

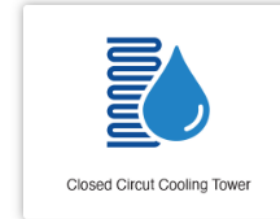
Minimum Enclosure Clearance

Clearance required on air inlet sides of tower without altering performance. Assumes no air from below tower.

Solid Wall	7 ft
50 % Open Wall	5 ft

Select Product Type

Confirm selection of product type below



Confirm Priorities

We've suggested the following recommendations based on patterns from similar users
 Drag and drop the items below to sort by importance

Very Important	Important	Somewhat Important	Not Important
First Cost ⓘ	Operating Cost ⓘ	Installation Ease ⓘ	Indoor-Ducted Installation ⓘ
Energy Efficiency ⓘ	Corrosion Resistance ⓘ	Redundancy ⓘ	
Footprint ⓘ		Cold Weather Operation ⓘ	
Height ⓘ			
Weight ⓘ			
Sound ⓘ			
Maintenance Ease ⓘ			

Register at <https://coolspec.com/>

Single flow Crossflow – Marley AV



125 – 772 tons/cell



- Induced draft single flow cooling tower
- Crossflow features in less space than a double flow NC
- Great for less than 750 ton
- Used on rooftops with limited space
- Great cold weather operation
- Low perimeter sound
- Low pump head
- Superior variable flow capabilities

Great alternative to counter-flow in small capacity applications

Forced Draft Counterflow – Marley MCW



25 – 600 tons/cell



- Forced draft counter-flow design
- Typically HVAC replacement market applications
- Low sound levels above the tower
- High sound levels around perimeter
- High static pressure fans good for indoor ducted applications
- Typically double the fan power of induced draft cooling towers

Niche market applications – indoor ducted fan outlets

Plume Abated Crossflow – Marley NCWD



546 – 921 tons/cell



- Induced draft double flow cooling tower
- Parallel path plume abatement
- Coil section in upper module uses inlet water to warm the discharge air
- Applications for airports, urban environments, roadway safety, visual pollution concerns, environmentally conscious building



- Sizing and Selection tool for cooling towers, fluid coolers and evaporative condensers
- Guided selection / recommendations based on System, Application, and User Priorities

Select Product Line

Select up to 3 products to consider

Selected:

 <p>NC Steel Crossflow Induced Draft Double-Flow Open Cooling Tower</p> <p>Best Maintenance Access Highest Capacity per Cell Flow Turndown Capability</p> <p>101 - 2189 Nominal Tons per Cell 132 - 7746 gpm</p> <p>Brochure Engineering Data Specifications Installation/Operation Manual Product Site</p> <p>Best fit score 95%</p>	 <p>MD Counterflow Induced Draft Open Cooling Tower</p> <p>Space-saving footprint Flexible layout arrangements Superior water management</p> <p>89 - 756 Nominal Tons per Cell 240 - 8537 gpm</p> <p>Brochure Engineering Data Installation/Operation Manual Product Site</p> <p>Best fit score 87%</p>	 <p>AV Crossflow Induced Draft Single-Flow Open Cooling Tower</p> <p>Orientation flexibility Easy maintenance access Ideal for tight spaces</p> <p>125 - 772 Nominal Tons per Cell 375 - 2316 gpm</p> <p>Brochure Engineering Data Installation/Operation Manual Product Site</p> <p>Best fit score 85%</p>	 <p>MD Everest Counterflow Induced Draft Open Cooling Tower</p> <p>Highest Capacity per Cell Modular Construction</p> <p>1227 - 3790 Nominal Tons per Cell 1555 - 12602 gpm</p> <p>Brochure Installation/Operation Manual Product Site</p> <p>Best fit score 80%</p>	 <p>NCWD (Plume Abated) Crossflow Induced Draft Double-Flow Hybrid Cooling Tower</p> <p>Plume Abatement coils Long Life Construction</p> <p>546 - 921 Nominal Tons per Cell 1180 - 3100 gpm</p> <p>Brochure Installation/Operation Manual Product Site</p> <p>Best fit score 79%</p>
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Agenda

**Why Evaporative Cooling
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Sound Mitigation Effects

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Piping Layout Options

Piping Layout – Why Discuss?



SPX Photo

Inlet Configurations: Dual Top Inlet



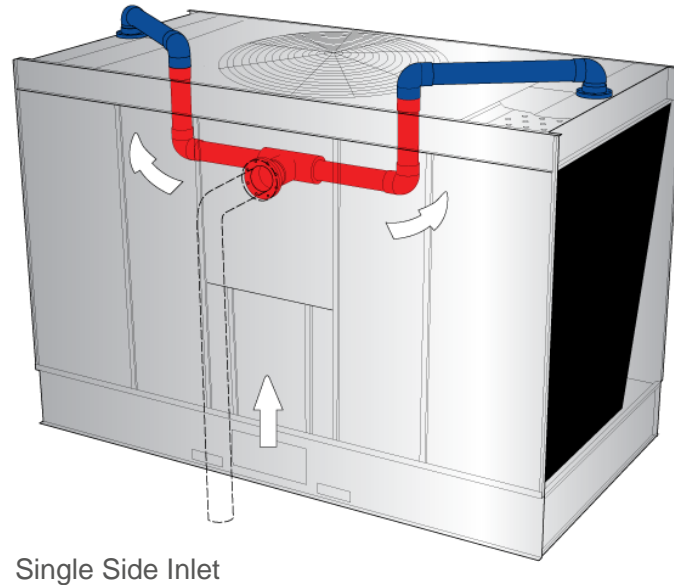
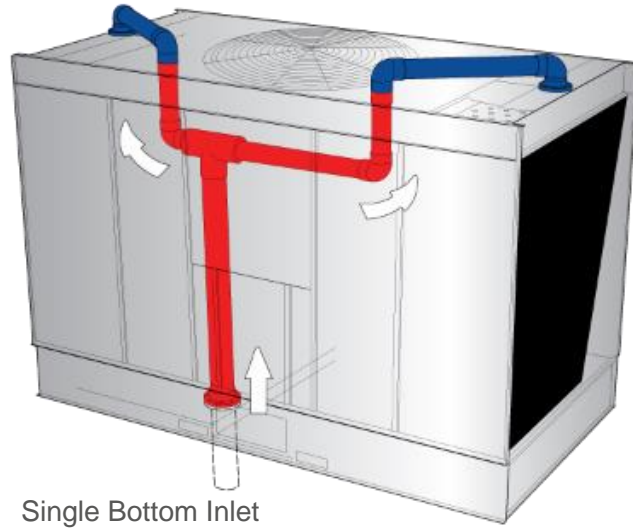
- Typically provides lowest pump head option (vs single inlet)
- Optional Horizontal Control (HC) Valves provide economical hydraulic control



HC valve

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Inlet Configurations: Single Inlet



- Reduces piping design and installation costs
- Eliminates the need for additional piping and supports
- Auto balance feature (orifice plates) balances flow between hot water basins

Installed at SPX factory
Ships Separately for Field Install
 Designed & installed by others



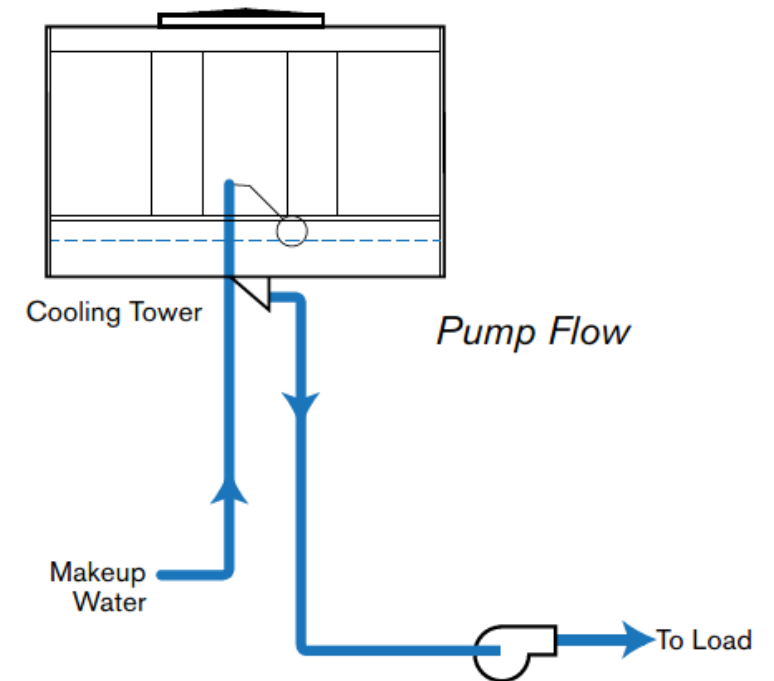
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Convenient Piping Solutions

Outlet Flow Types: Pump Flow

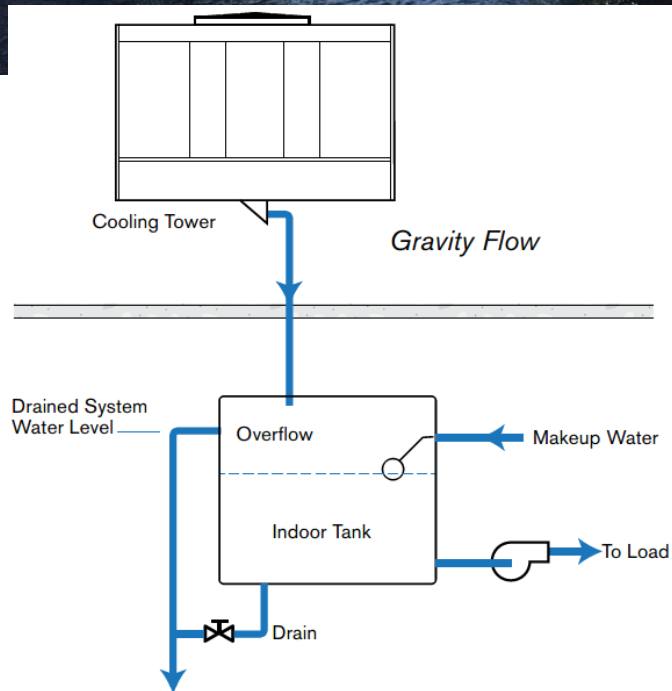
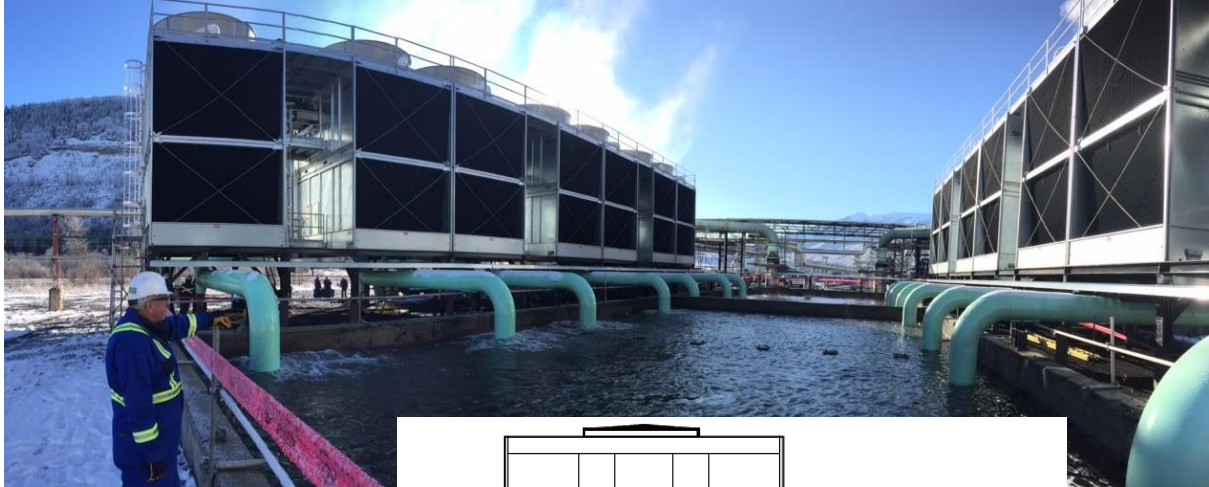


- Pump suction piped directly to the tower basin
 - Pump draws water directly from the basin
- Water remains in basin upon shutdown
- Freezing climates require basin heaters if basin not drained
- Predominant design



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Outlet Flow Types: Gravity Flow



- Basin drains by gravity to a separate basin or remote sump below the tower
 - Pump draws water from separate basin
- No water remains in cold water basin
- Fail-safe
- Trades energy for real estate
- Simplifies water treatment on fluid cooler applications
- **Must** be properly sized
- Less common

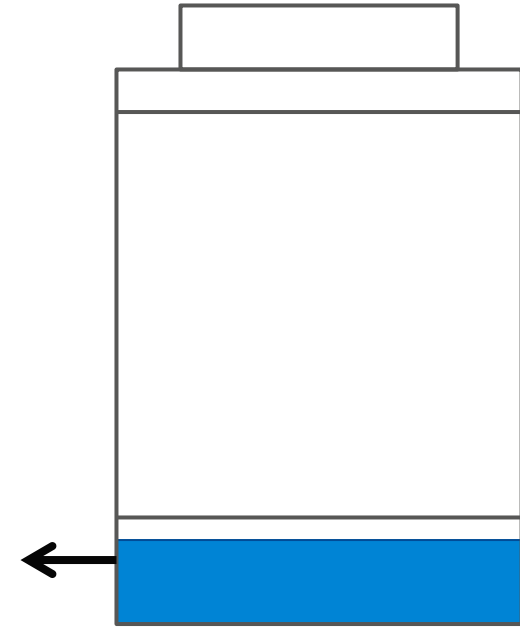
Outlet Configurations



**Bottom
Outlet**

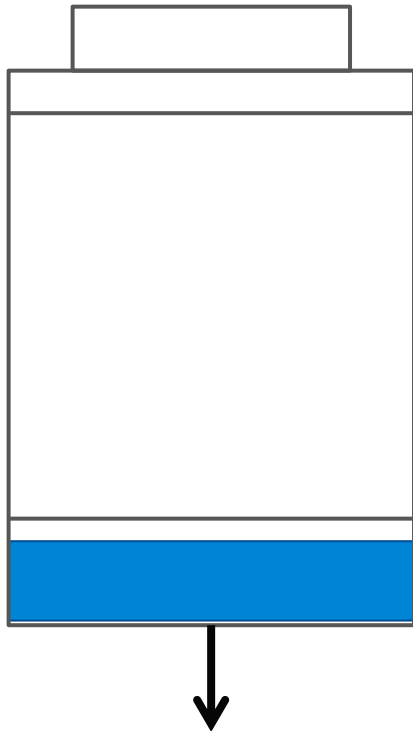


Sump



**Side
Suction**

Outlet Configurations – Bottom Outlet



Used on pump or gravity flow

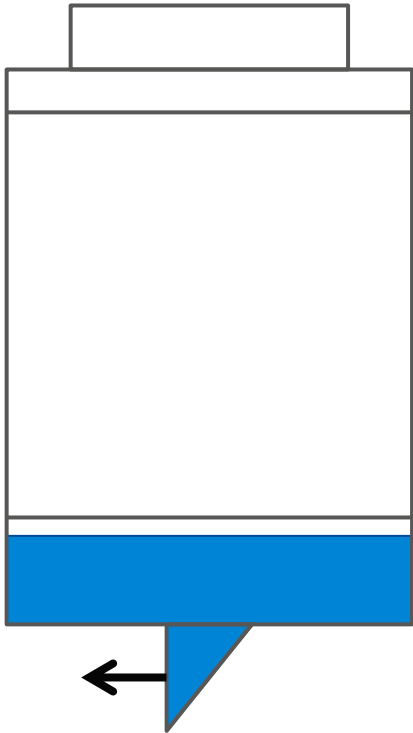
Advantages

- Simple
- Lowest tower cost
- Handles highest flow rates

Disadvantage

- Requires larger outlet diameter
 - Typically higher piping cost

Outlet Configurations – Sump



Used on pump or gravity flow

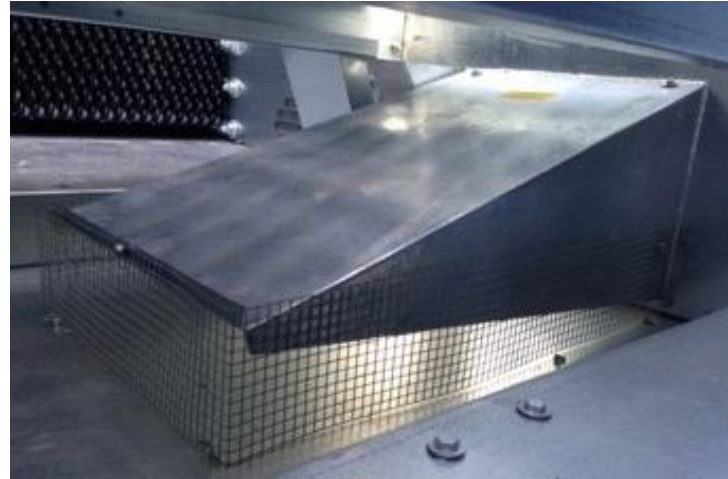
Advantages

- Reduces chance of cavitation
- High flow capability
- Replaces 90° elbow

Disadvantages

- Higher tower cost
- 1 additional joint to potentially leak

Outlet Configurations – Side Suction



Used on pump flow only

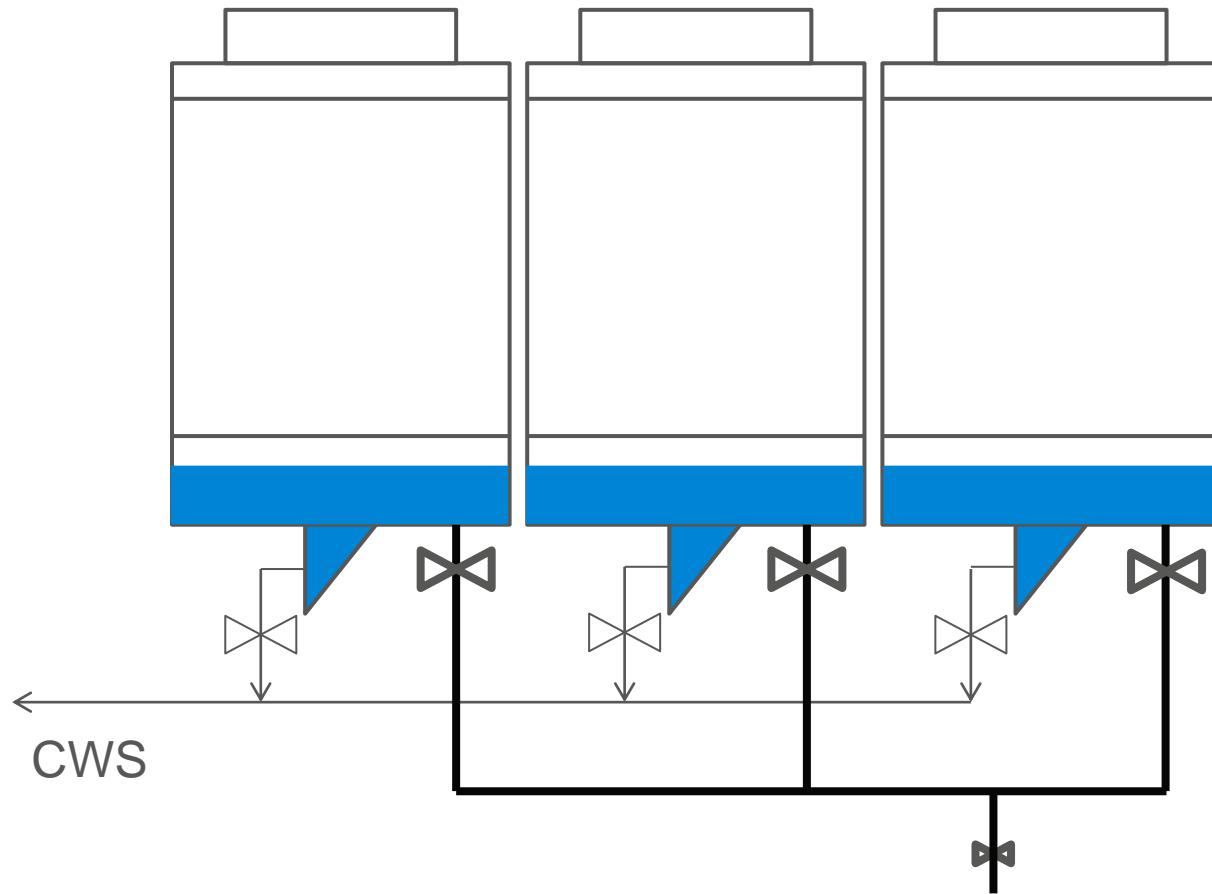
Advantages

- Can be used on slab
- High flow capability
- Does not compete with sweeper system

Disadvantage

- Can only be used on:
 - pump flow
 - 2 cells or fewer
- 1 additional joint to potentially leak
- Basin must be flooded for initial startup

Equalizers – Bottom Equalizers



Used to promote equal operating water levels between cells

Advantages

- Pipe runs full of water
- Most forgiving design – provides operational flexibility during wider range of flow rates

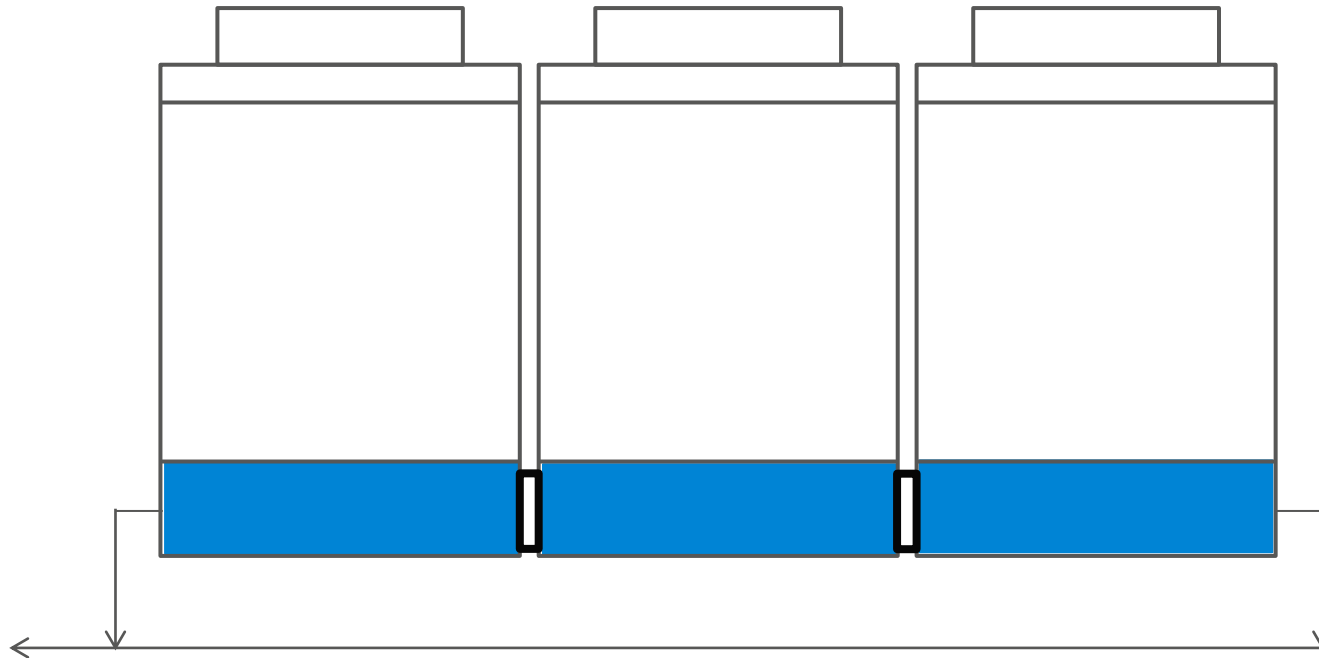
Disadvantage

- Requires space under the tower
- Potential dead leg

Recommended Design

Equalizers – Flumes

Used to promote equal operating water levels between cells



Advantages

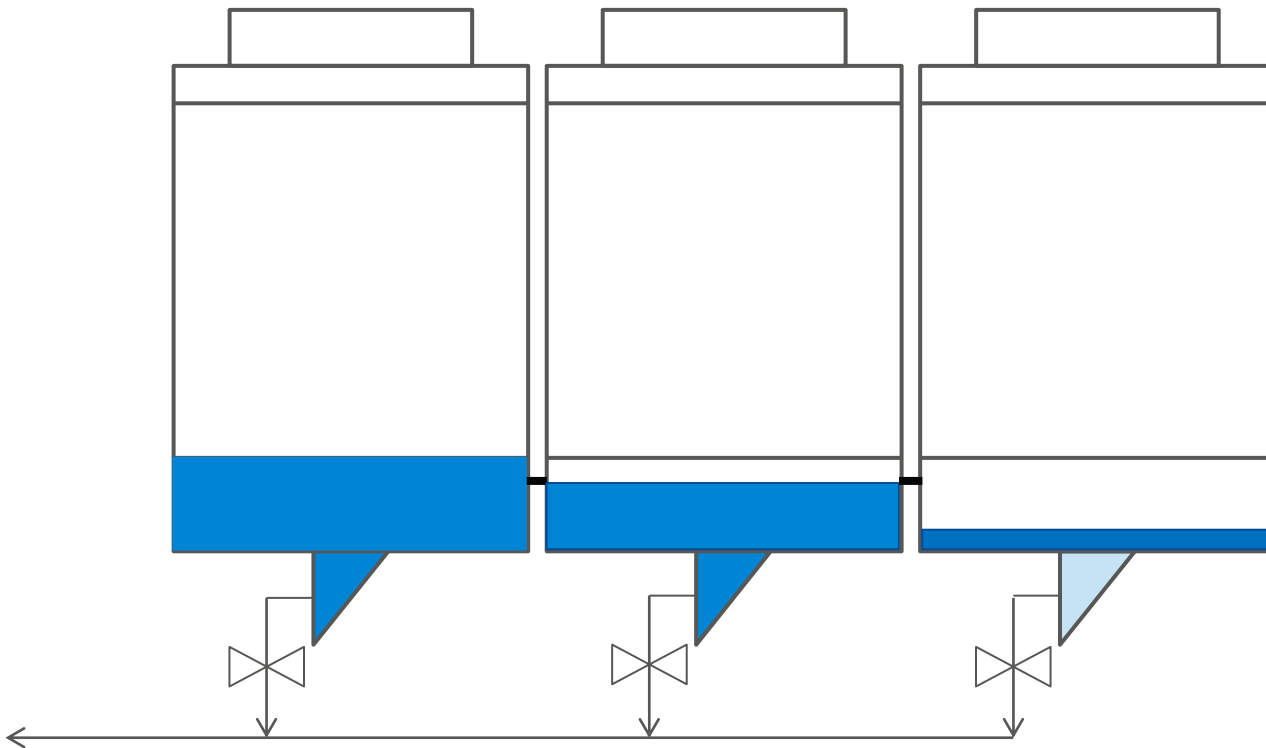
- Can set tower on slab
- Less piping
- Handles highest imbalance between cells
- Avoids potential dead legs

Disadvantage

- Cell isolation with weir plate tedious
- Increased leak potential

Bottom Equalizers recommended over Flumes

Equalizers – Non-conforming



Examples

- Smaller equalizer diameters
- Side equalizers

Advantages

- Often used on proven applications
- Re-uses existing pipe

Disadvantages

- Reduces operational flexibility
- Increases risk of overflow and pump cavitation

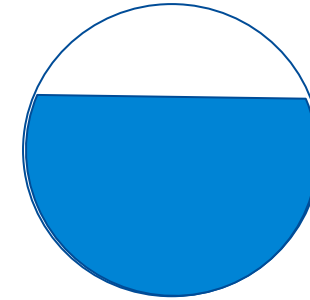
Not Recommended

Equalizers – Non-conforming

Which flows more water?



Flume



Side Equalizer

Side equalizers have limited capability

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