TOPICS: Cooling Tower Basics, Water Use in Evaporative Cooling, Make-up Quality, Energy/Water Conservation, and the Value of Evaporative Cooling

Ken Mortensen and Chris Kapp

SPX®
COOLING TECHNOLOGIES

MARLEY®

RECOLD®

VENUE: TIEPP March 3, 2022
Houston TX

Agenda

1. ***Speaker & Author Biographies***

2. **Introduction SPX Cooling**

3. **Evaporative Cooling**
   - Basics
   - Water Use in Evaporative Cooling
     - Make-up
     - Blow Down/Cycles of Concentration
     - Blowdown Reduction
   - Make-up Water Quality – Is Water Reuse in your Future?
     - Types of Water
     - Examples of Reclaimed Water Use
   - Water Conservation Technologies
   - Value of Evaporative Cooling

SPX

Author & Speakers

Author: Kenneth P. Mortensen

Ken is Senior Manager Research and Development for SPX Cooling Technologies. Ken has been with SPX/Marley for more than 40 years.

Ken graduated in 1977 with a Bachelor of Science Degree in Chemical Engineering from Massachusetts Institute of Technology and completed an MBA at Rockhurst University in Kansas City, Missouri in 2000.

Ken has authored a number of technical papers and holds a number of Patents for Fire-resistant Cooling Tower Design, Film Fills, Water Filtration, and Water Conservation. He is a registered engineer in the State of Kansas.

Ken became the President of the Cooling Technology Institute [CTI] in February.

Speaker: Chris Kapp

Chris Kapp is General Manager SPX Cooling for the Gulf Coast Region, located in Deer Park, TX. He has worked in the turbomachinery world for companies such as Siemens and Rolls-Royce in all areas of Power and Oil & Gas.

Chris graduated in with a master's degree in aerospace engineering from RWTH University in Aachen, Germany and studied Finance with KIAMS in India.

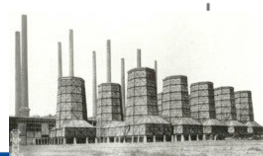
Chris is the author of several technical papers and has worked with API taskforces writing specifications, the Dept. of Energy (DoE) and the Environmental Protection Agency (EPA) on efficiency and emission projects. He is a co-organizer of the Gas / Electric Conference in Houston.

SPX

SPX Cooling & History

1922 – Company Formed
Leon T. Mart and Chester E. Smiley form the Power Plant Equipment Company in Kansas City, Missouri

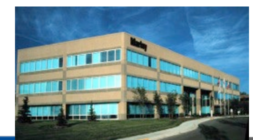
1924 – "Marley" Formed
Mart and Smiley combine elements of their last names to form the "Marley" trade name. The first Marley spray pond is installed.



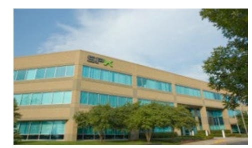
1928 – Incorporation
The Marley Company is incorporated.

1971 – Relocation
Marley relocates across the state line to Mission, Kansas

1980 – Acquisition
Marley is acquired by private equity firm, KKR



1993 – Sale
KKR sells Marley to United Dominion Industries, Charlotte, NC



1996 – New HQ
Marley moves to a new world headquarters in Overland Park, Kansas

2001 – SPX Cooling Technologies
SPX Corporation acquires Marley & changes the name to SPX Cooling Technologies.

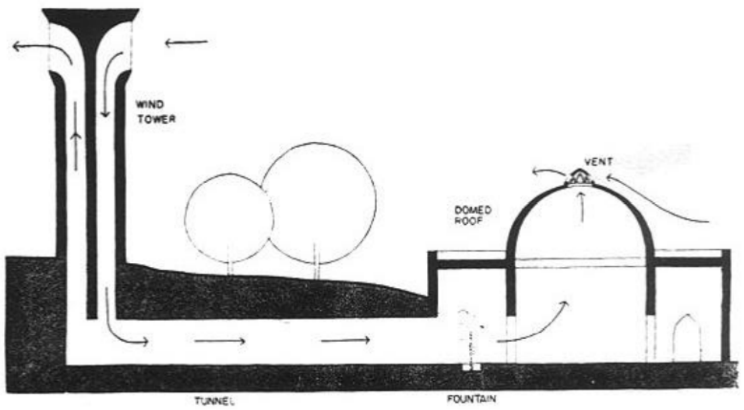
2016 – SPX Corp
SPX Company Spin Off – creates the New SPX Corp

- SPX is a $1.5 Billion company with more than 3,500 employees

History of Evaporative Cooling

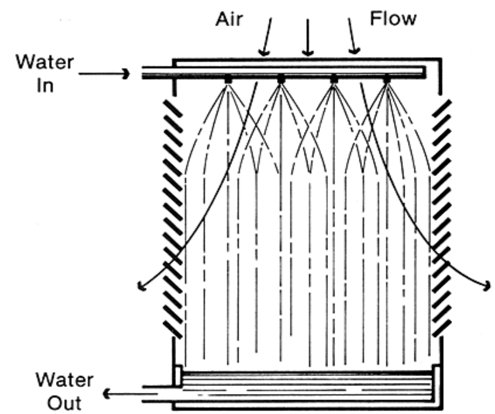
- Evaporative Cooling dissipates up to ¾ of our body heat up to two liters of water per hour.

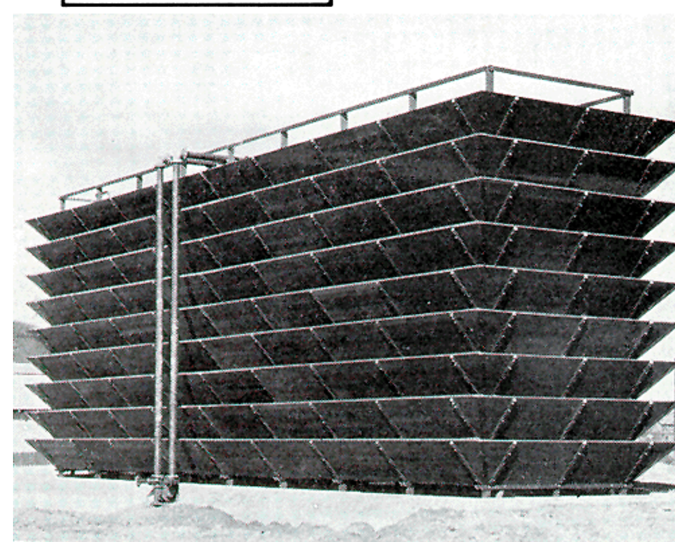
- Rate of heat loss is determined by the surrounding.
- Evaporation cools our environment.
- Water absorbs a large amount of heat with small change in temperature.
- Some Ancient Cultures such as Persia and India have used evaporative cooling concepts for hundreds of years.



Modern History of Cooling Towers

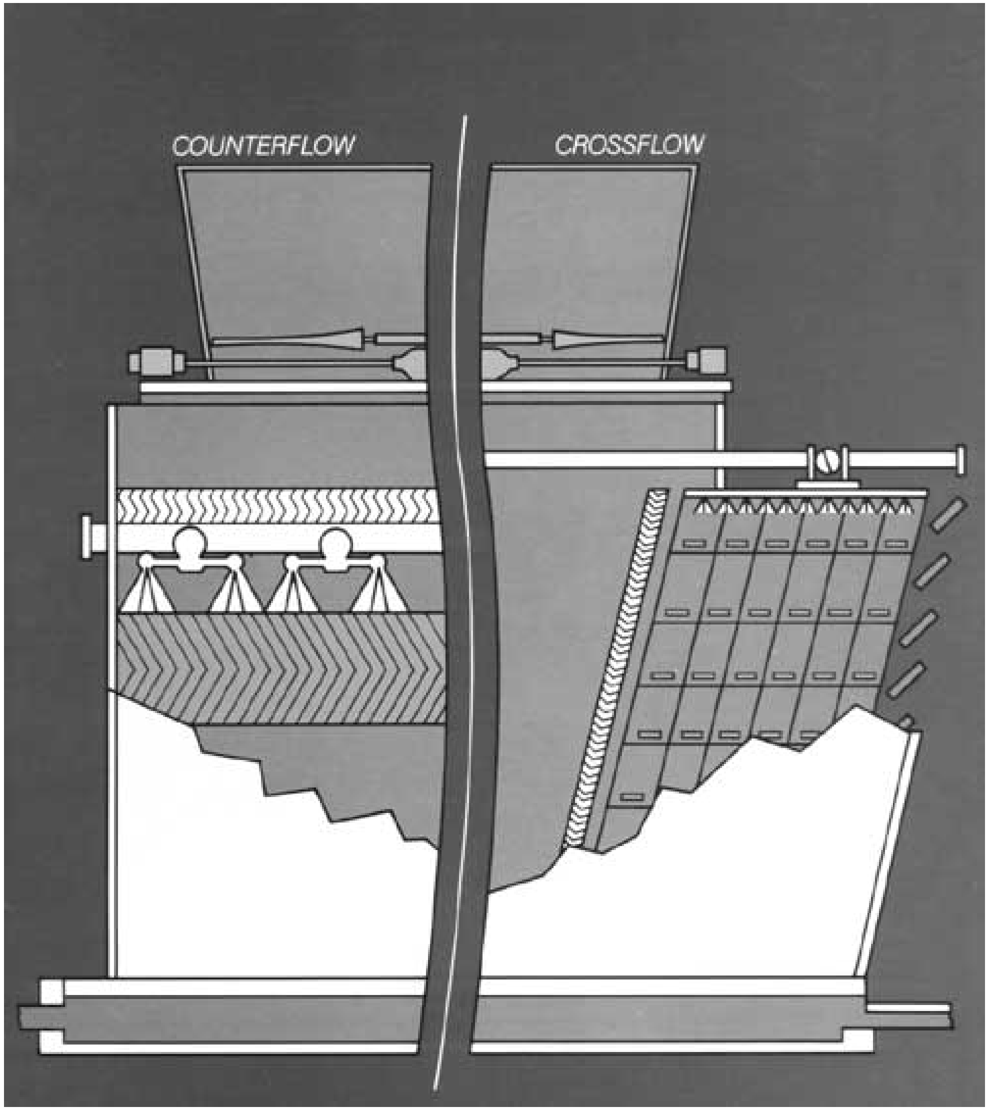
- Right Angle Spray Nozzles increased water surface area exposed to the air.
- Spray Tower developed in 1926-1927.
- Decreased temperature by increasing the time the water is in contact with air.
- Enclosure resulted from undersized spray pond.
- Spray pond could not be enlarged.
- Marley designed and built a deck tower to enclose.
- 110 atmospheric deck towers, 1931 - 1942.



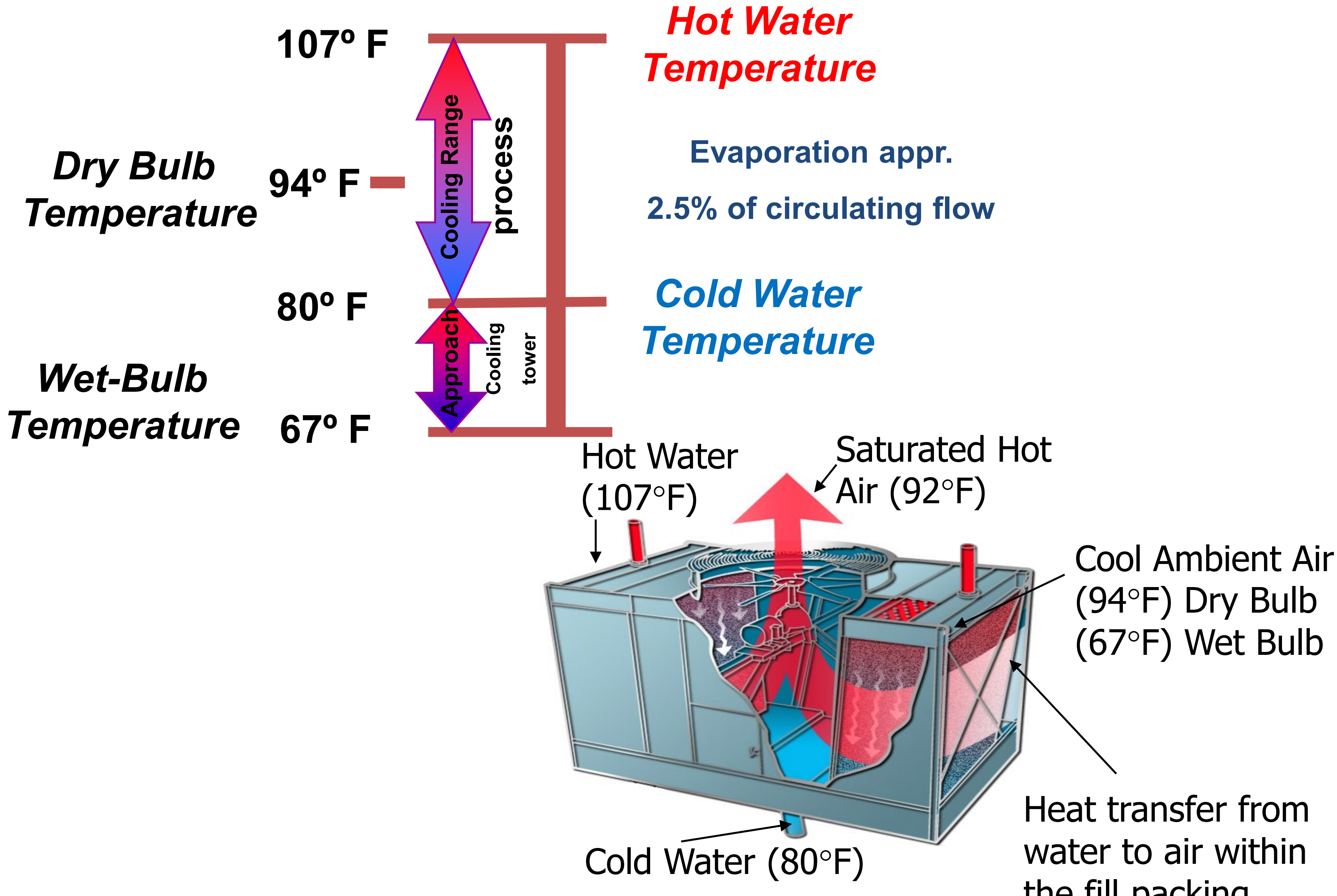


Cooling Tower Structure

- A Cooling Tower is made up of 4 systems:
    - Fill
    - Water Distribution [Nozzles]
    - Air Movement [Fan]
    - Structure
- A heat exchanger in which air & water are brought into close contact.
- Heat is rejected from circulating water through sensible and latent (evaporative) heat transfer.
- Water evaporated at 0.85% of the circulating water for each 10ºF of range.
- A Cooling Tower is an Air Scrubber.



Evaporative Cooling Requires Water



Water Use in Evaporative Cooling

$$W_m = W_e + W_d + W_b$$

$$W_e = 0.00085\ Wc\ (T1 - T2)$$

$$W_d = \text{drift loss} = 0.00005\ W_c$$

$$W_b = \text{blow down}$$

Where:

W_m = makeup water

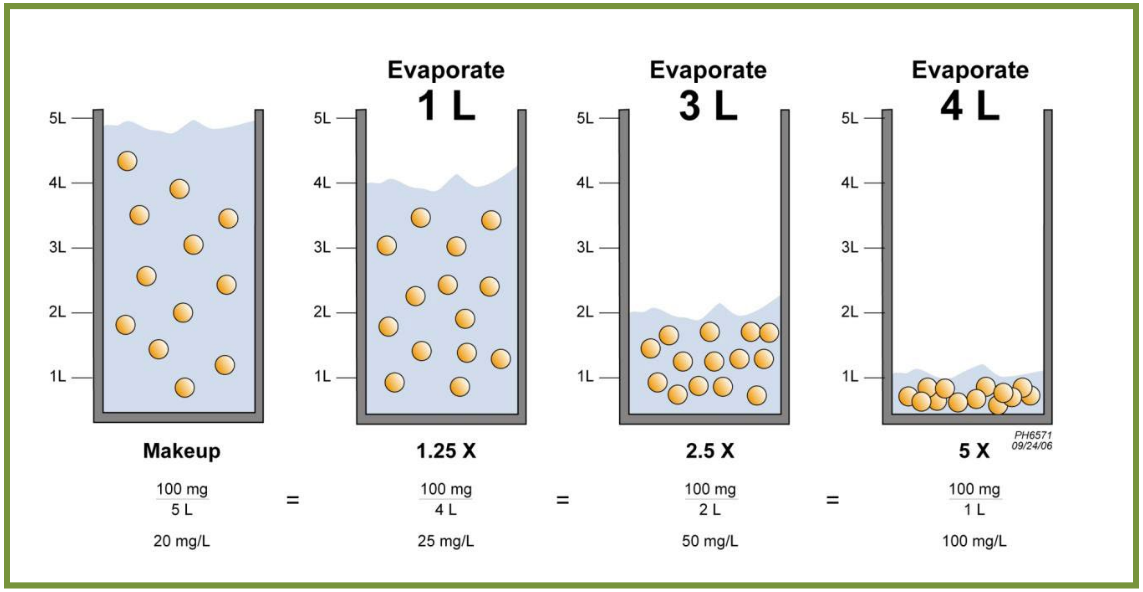
W_c = circulating water flow

T1 - T2 = inlet – outlet water temperature, °F

0.00085 evaporation constant is " rule of thumb" value. Varies by season and climate.

Water Use in Evaporative Cooling

As Pure Water Is Evaporated, Solids Concentrate



$$COC = \frac{MU}{BD}$$

COC = Cycles of Concentration

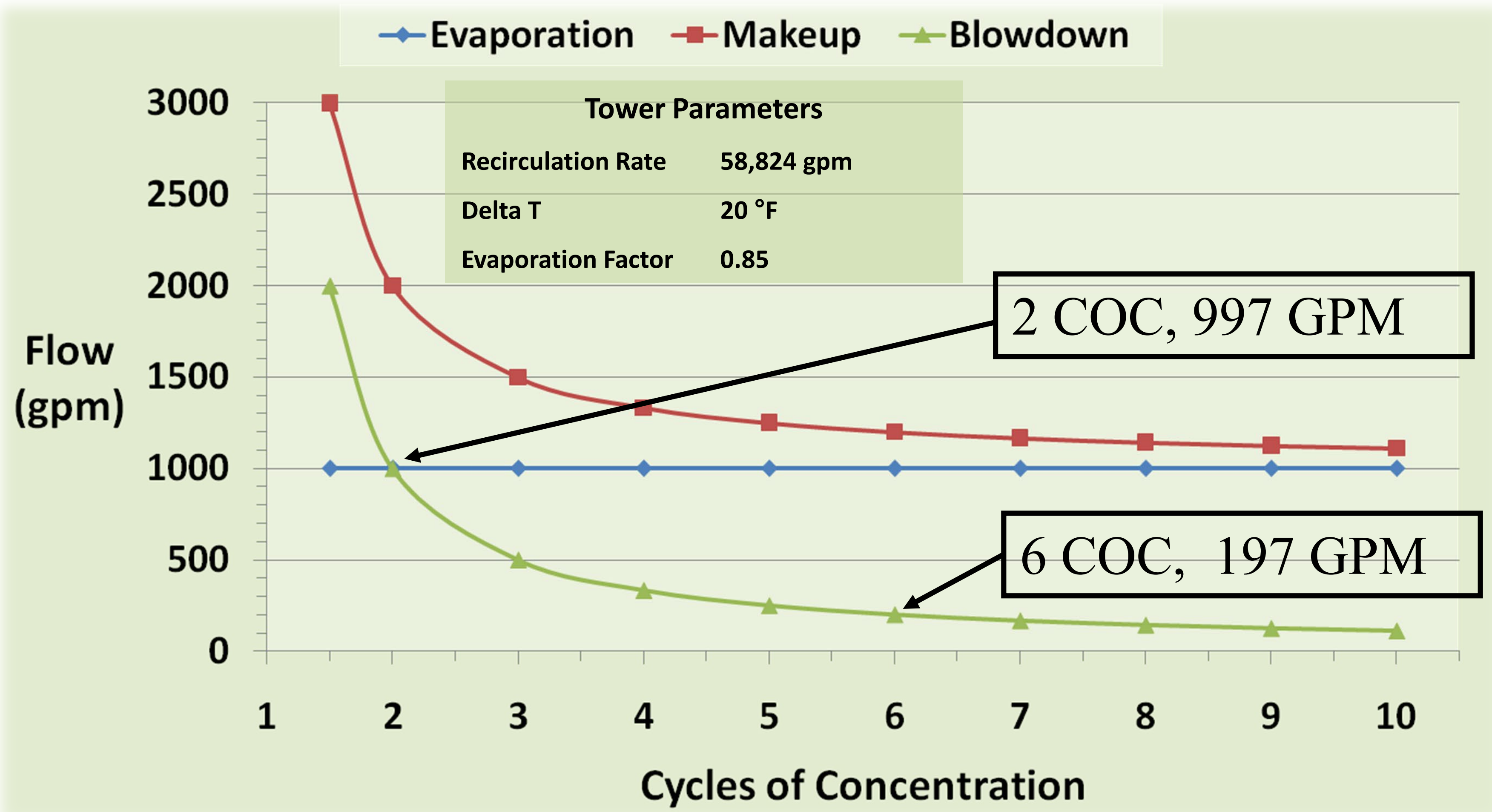
MU = Makeup flow

BD = Blowdown flow

$$W_{bd} = (W_{evap} - ((\text{cycles} - 1) \times W_{drift}))/(\text{cycles} - 1)$$

Source: Ray Post, Cooling Water Technology, ChemTreat

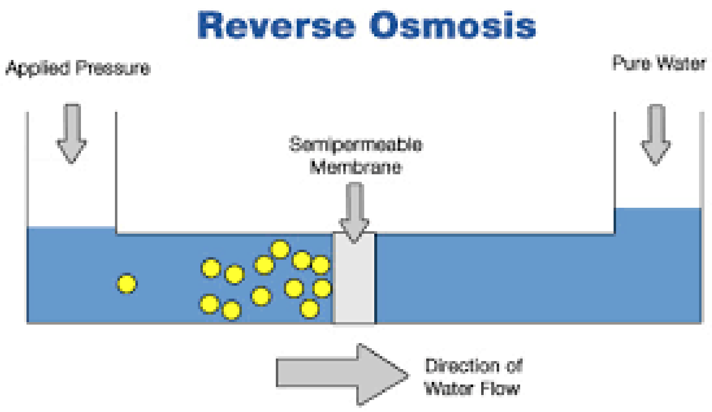
Effect of Cycles on Makeup & Blowdown Flow

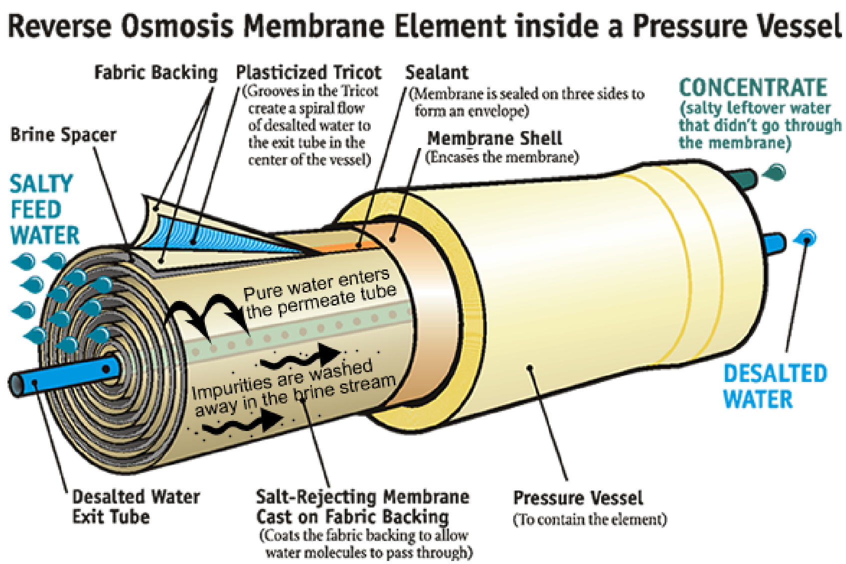


At what Cycles do you operate your tower at? What limits the COC?

Water Treatment Calcium Reduction - RO

- High Purity
- High Pressure





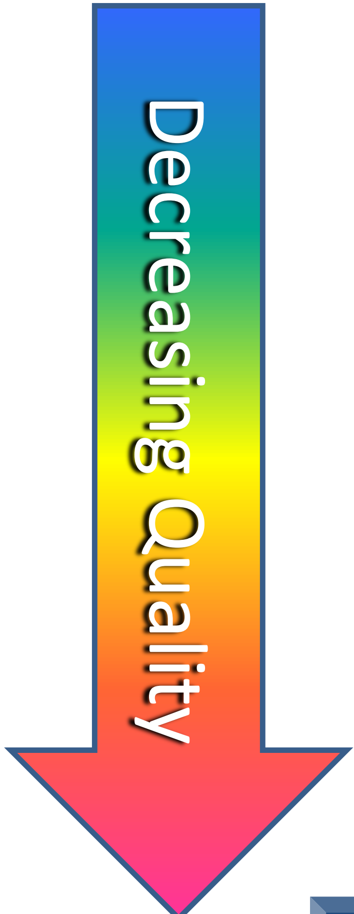
You may have to filter components out

Is Water Reuse In Your Future?

"When the well's dry, you *know the worth of water.*"

- Ben Franklin

Potential Plant Water Sources



- City water
- Well water
- Lake water
  - Storm or Runoff Ponds
- River water
- Desalination water
- Grey/Reclaimed/Reuse water
  - Municipal effluent
  - Industrial process water
  - Industrial effluent
- Saline water
  - Brackish water
  - Sea water

What Source(s) of Water Do You Use At Your Plant?

What Challenges Does It Present?

Evaluating Alternative Water Sources

- Many alternative water sources can be used successfully with proper pretreatment

- Determine the chemistry, avg., min, max.
  - Specify the water quality in the contract!

- Determine the quantity available

- Evaluate system constraints
  - Stainless steels – chlorides
  - Copper alloys – ammonia
  - Carbon steel - corrosion
  - Plastic fill – organics, fibrous materials, biofouling
  - Heat exchanger type (plate and frame, tube diameter)

- Evaluate impact on discharge constraints
  - BOD, COD, ammonia, metals, priority pollutants,
  - sulfates, chlorides, phosphate, etc.

Water Reuse May Increase CAPEX and OPEX but reduce Environmental Footprint

Averaged Reuse/Grey Waters

Constituent	Reclaim, Makeup	Comment on Reclaim Usage
TAB aerobic, cfu/ml	0 –5	Low Bacteria initial count
TOC, mg/l	16	Moderate, biogrowth
TSS, mg/l	9	OK
Ammonia, mg/l	13	Moderate/high, biogrowth
Phosphate, mg/l	4	Moderate, scale & biogrowth
Nitrate, mg/l	11	Moderate/high, biogrowth
Chlorine mg/l	5	High, wood and corrosion
Chloride, mg/l, Cl^-	375	Moderate/high, corrosion
Ca Hardness, mg/l	161	Moderate, cycles or scale
Tot.Hardness,mg/l	253	OK
Alkalinity, mg/l,$CaCO_3$	191	OK
Silica, mg/l	18	OK
TDS, mg/l	1088	High, various effects
pH	7.3	OK

Differences Water Quality and Likely Effects

- Organics and Nutrients UP
  - TOC, Ammonia, Phosphate, Nitrate
  - Bio growth increases
- Corrosives UP
  - Chlorides (most common)
  - Corrosion rate increases
- Scalants UP
  - Calcium Hardness, TDS
  - Scale formation increases

What happens when certain components increase?

POTENTIAL REMEDIAL ACTIONS

- Tower Materials and Component changes
  - SS
  - FRP
  - Nozzle, orifice size increase
  - Fill, low-clog film fills

- Water Treatment
  - Bio growth - increase biocide, perhaps continuous feed
  - Corrosion Rate [chloride increase, pH decrease] - inhibitor types, level
  - Scale/Calcium control - cycles decrease and/or inhibitor modification

What can I do about it?

Specific Case Of Waste Water Effluent Use

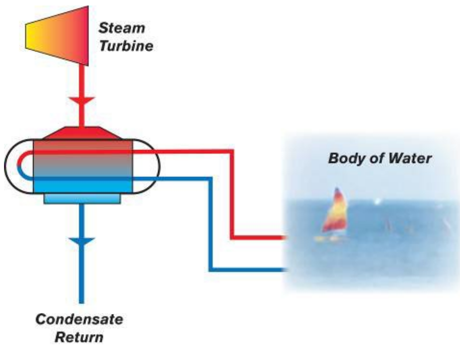
- A pilot cooling tower was used to evaluate the impact of the various makeup water blends on cooling system corrosion
- The existing stabilized phosphate program provided acceptable mild steel corrosion rates up to a cooling water conductivity of 3,000 umhos
- Zinc / orthophosphate treatment provided acceptable mild steel corrosion rates up to a cooling water conductivity of 8,600 umhos
- Yellow metal corrosion rates were consistently <0.2 mpy

Case Study

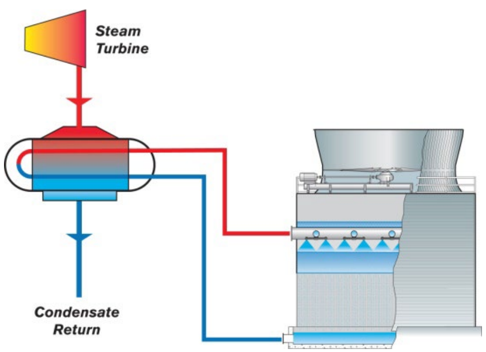
- Using zinc /orthophosphate treatment, the refinery cooling systems could safely be operated using 100% waste plant effluent at a maximum of 2.6 cycles of concentration
- Eliminating City Water as the makeup water source for the cooling systems at this refinery would reduce water costs by $1,287,045 annually
- Due to higher blowdown rates, cooling system treatment costs would increase by $249,123 annually
- No pretreatment equipment required for the conversion
  - Avoided $4 million UF/RO alternative solution
- The use of waste treatment plant effluent as the sole source of cooling tower makeup would reduce the total water and treatment costs by $1,037,922 annually

Water Conservation Technologies -Other Options for Power Plants

Wet Cooling

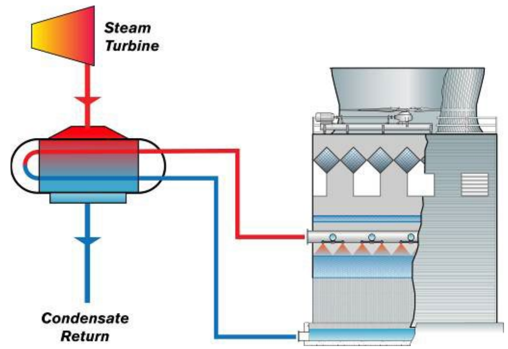


Once Through

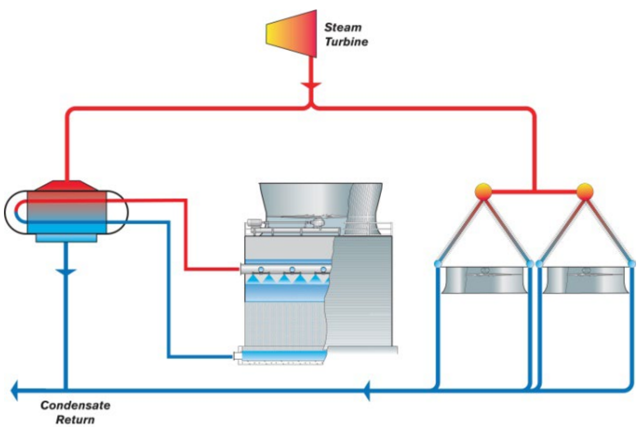


Evaporative Cooling Tower

Hybrid Cooling

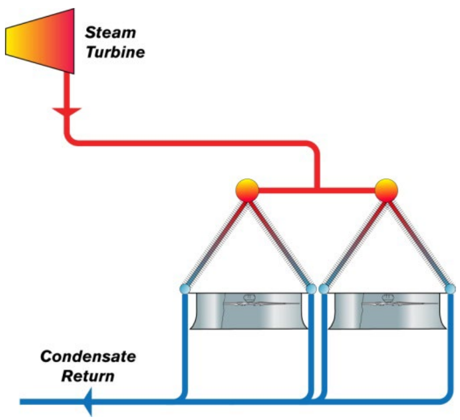


Wet Hybrid Cooling Tower



Parallel Condensing

Dry Cooling

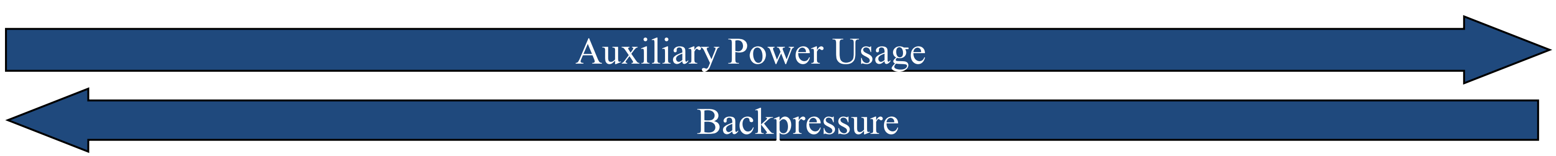


Air Cooled Condenser

Depending on site needs, there are a wide range of cooling solutions

Water Savings Options – Alternatives to Wet Evaporative

	Wet evap with high cycles of conc.	Condensing	Coil Hybrid	Parallel Condensing	Air Cooled Condensing
Water Savings	0-10%	10-30%+	10-30%+	30-90%*	100%
Other Pros and Cons	+ Relatively low up front costs - Most water usage	+ Plume abatement - Higher fan power - Some damper maintenance	+ Plume abatement - Limited back-to-back layout - Higher pump head - Coil, damper and valve maintenance	+ Flexibility to achieve precise water savings - Highest complexity - May still have plume - cost	+ Fully dry + No water costs + No water treatment cost - Highest backpressure - Highest upfront cost



Different options require different amounts of water

* Parallel condensing theoretically can reach any water savings required between 0-100%

The Value of Evaporative Heat Rejection

Evaporative vs. Air-Cooled

Highest energy efficiency
- 50% less energy usage on typical application

Lower GHG Emissions
- Significantly lower; less than half of the CO_2 footprint

Comparable or lower water usage
- Up to 40% less water consumption (high water usage in power production)

Other User Benefits
- Less noise – 2 fans vs. 20 fans, typical
- Environmentally friendly materials – recycled PVC, less metal usage
- Space – 2 - 5X less space for heat rejection

Typical Application – 400 ton in California

Annual	Air Cooled	Water Cooled	% Delta
Energy Consumption	440 MWH	190 MWH	(56.8%)
GHG Emission(2) lbs. of CO_2	682,000	294,500	(56.8%)
Total Water Usage In 0000s Gallons (on-site(3) + power generation(4))	1,944	1,530	(21.3%)

1. Assumes $0.1358/KWH.
2. Average US energy plant emits 1.55 lbs. of CO_2 for each KWH generated.
3. Site water includes water for blowdown, assuming 6 cycles of concentration, and make up.
4. In CA and many Western states each KWH produced consumes 4.42 gallons of water. On average in US each KWH produced consumes 2 gallons of water.

Source: *Buildings Magazine* 2008 quoting Pacific Gas & Electric Co. study including NREL data.

- Evaporative Cooling is Sustainable with Significant Environmental and Water Usage Benefits

Questions?

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Proof In Performance

SPX

Mission

Creating infrastructure solutions for a smarter, more productive future.

Vision

We deliver highly valued products, services, and solutions to the world based on a deep understanding of our customers' needs. Our businesses are leaders in their respective markets, our teams are collaborative and agile, and together we achieve sustainable growth and exceptional results.

Our Values...

Integrity
Do what's right, the right way. Both the "what" and the "how" matter.

Accountability
Take ownership. Create understanding and develop solutions by communicating with data and transparency.

Excellence
Exceed customer expectations through active engagement, relentless focus, and a passion for innovative solutions. Drive constant improvement in everything we do.

Teamwork
Engage. Have fun. Make others successful. Our strongest asset is the power of "we."

Results
Make an impact. Focus on what matters. Deliver on commitments.