Hygroscopic Cooling Tower for Reduced HVAC Water Consumption

Christopher Martin, Ph.D.

Senior Research Engineer

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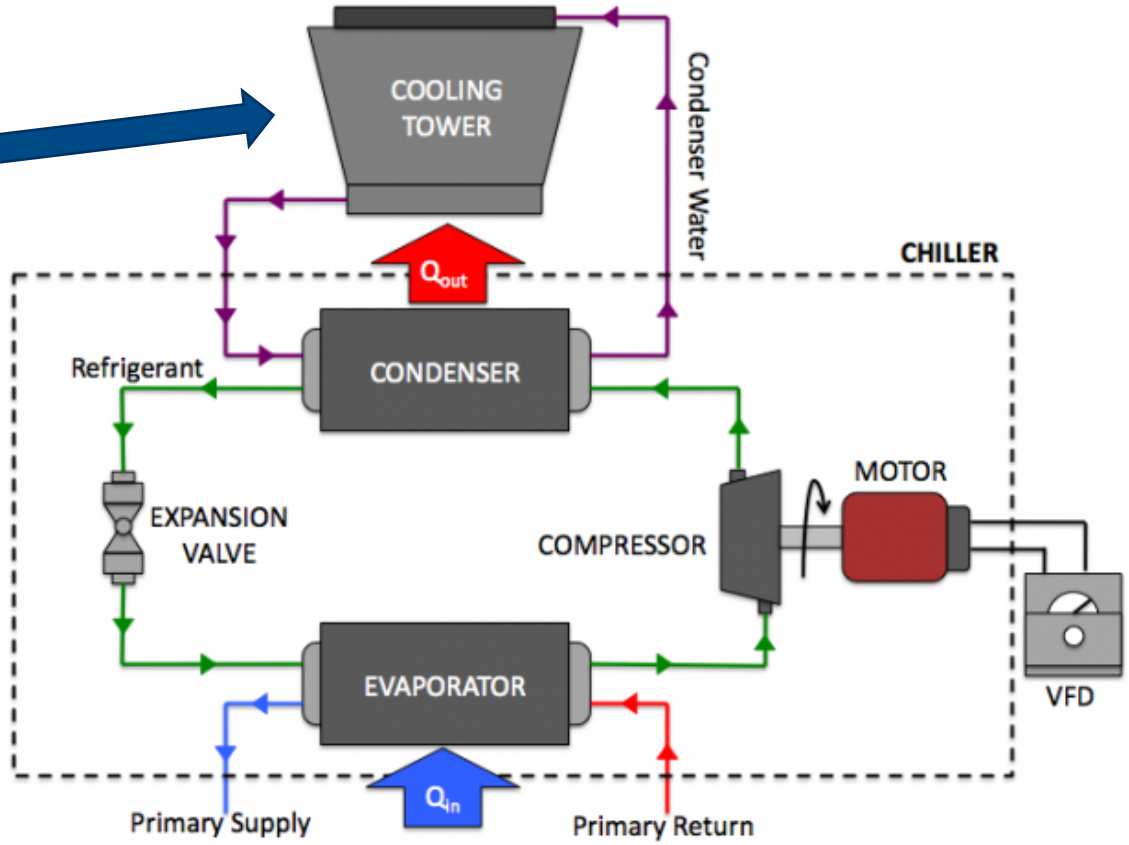
- Technical Contributor
  - Mr. Kenneth Mortensen; SPX Cooling Technologies, Inc.

HVAC System Cooling



Building Cooling Load Interface

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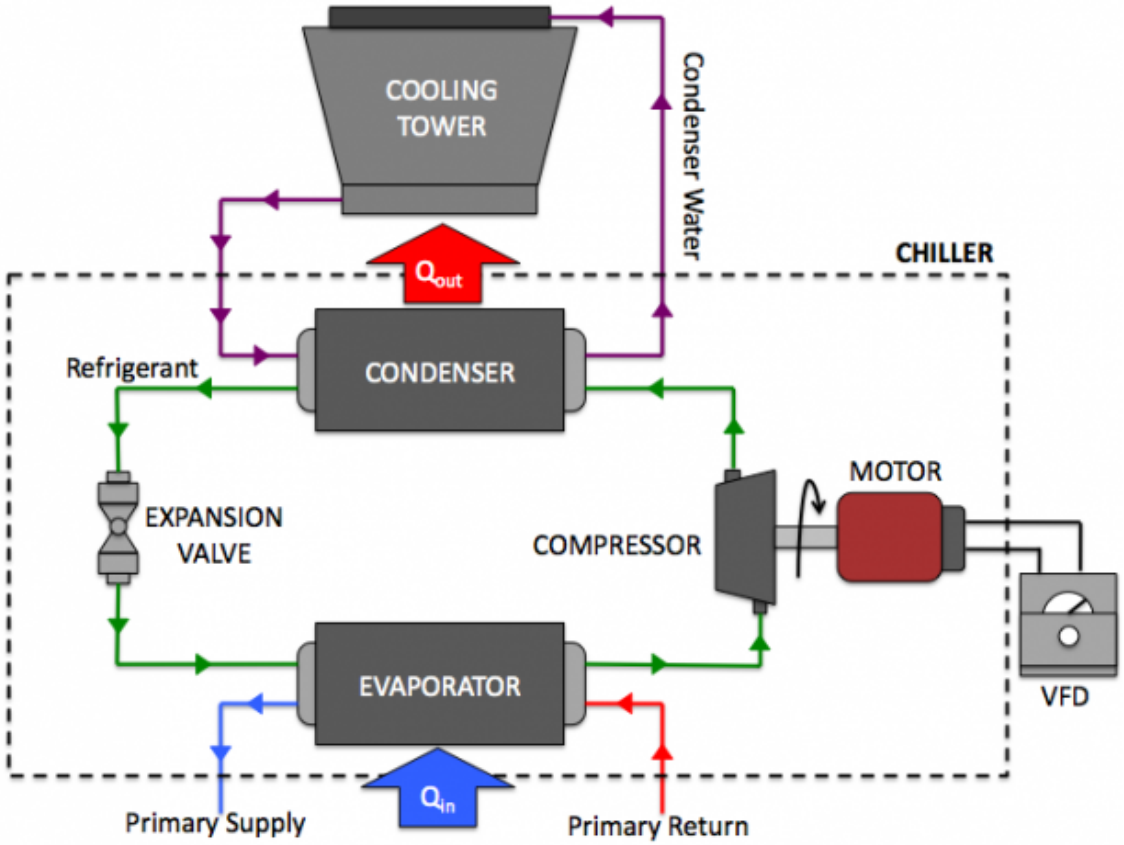
Efficiency Comparison

Example Component Efficiencies

Device	ASHRAE 90.1 Standard; >150 tons	Common Basis, kWth/kWe
Air Cooled Chiller	10.10 Btu/W-hr	3.0
Water Cooled Centrifugal Chiller	0.610 kW/ton	5.7
Free Cooling with Cooling Tower	40.2 gpm/hp*	79

**Based on a 10°F temperature range and a 10°F wet bulb approach*



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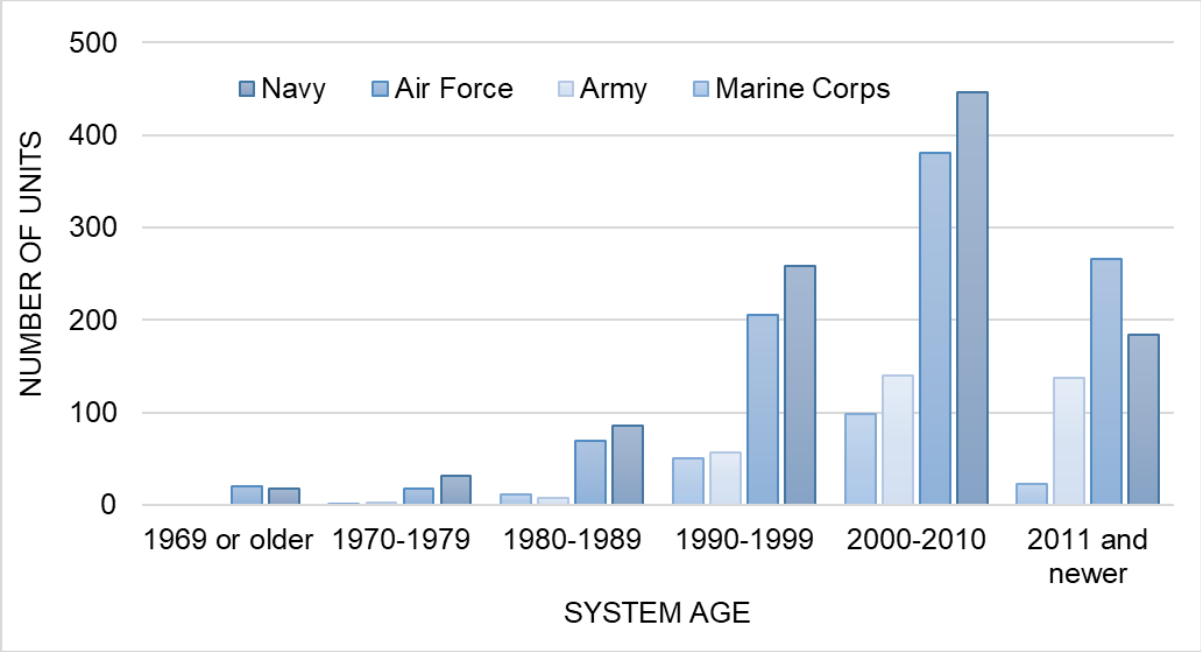
Existing DoD Cooling Towers

CERL's BUILDER™ Sustainment Management System (SMS) used to gage DoD's cooling tower inventory

Rounded cooling tower totals for each service

Air Force	1400
Navy	1200
Marines	200
Army*	1300
Approximate Total	**4200**

** Inventory of Army units is ongoing; 1300 estimated from known numbers at individual sites*



- 80% of the known towers are newer than 1990
- Replacement rate of ~130 towers per year assuming a 20 to 25 year service life
- Unit sizes range from 60 to 1000 tons

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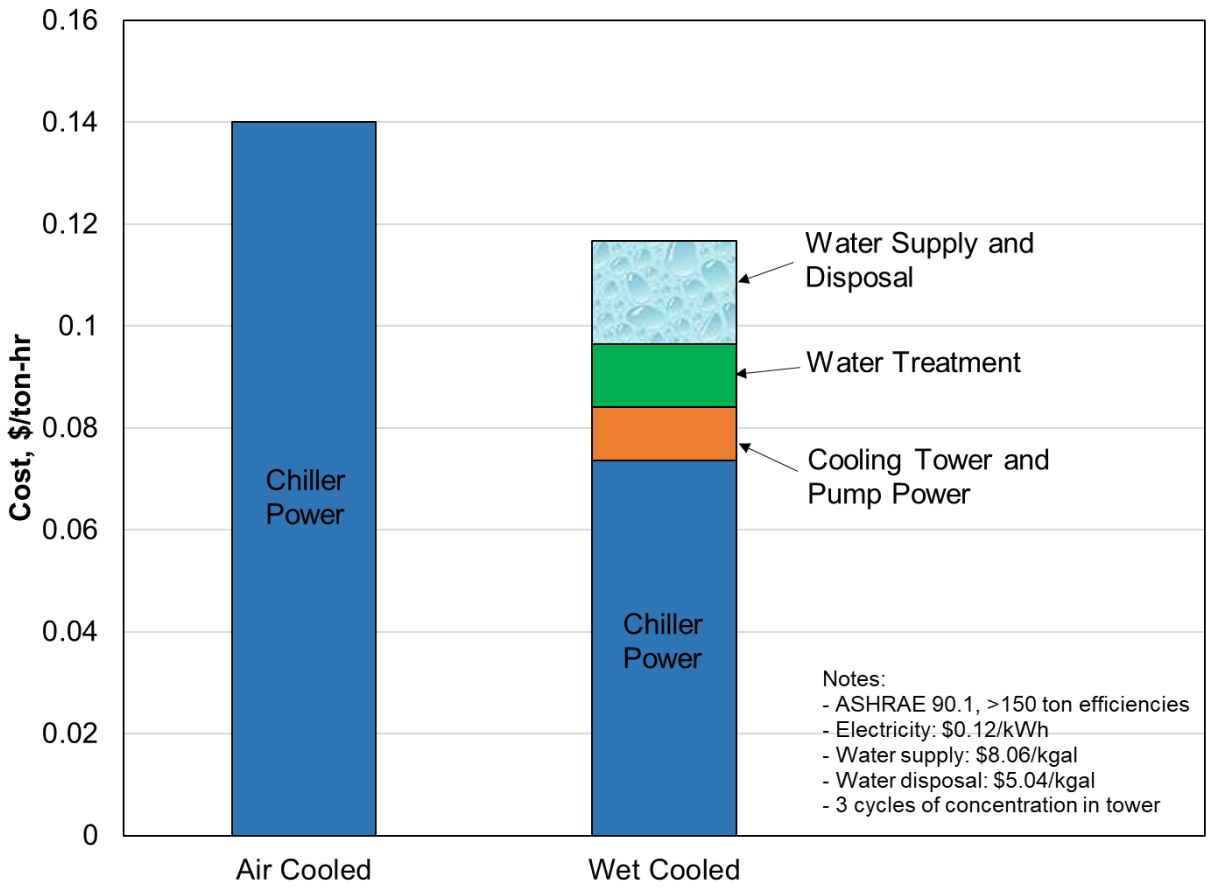
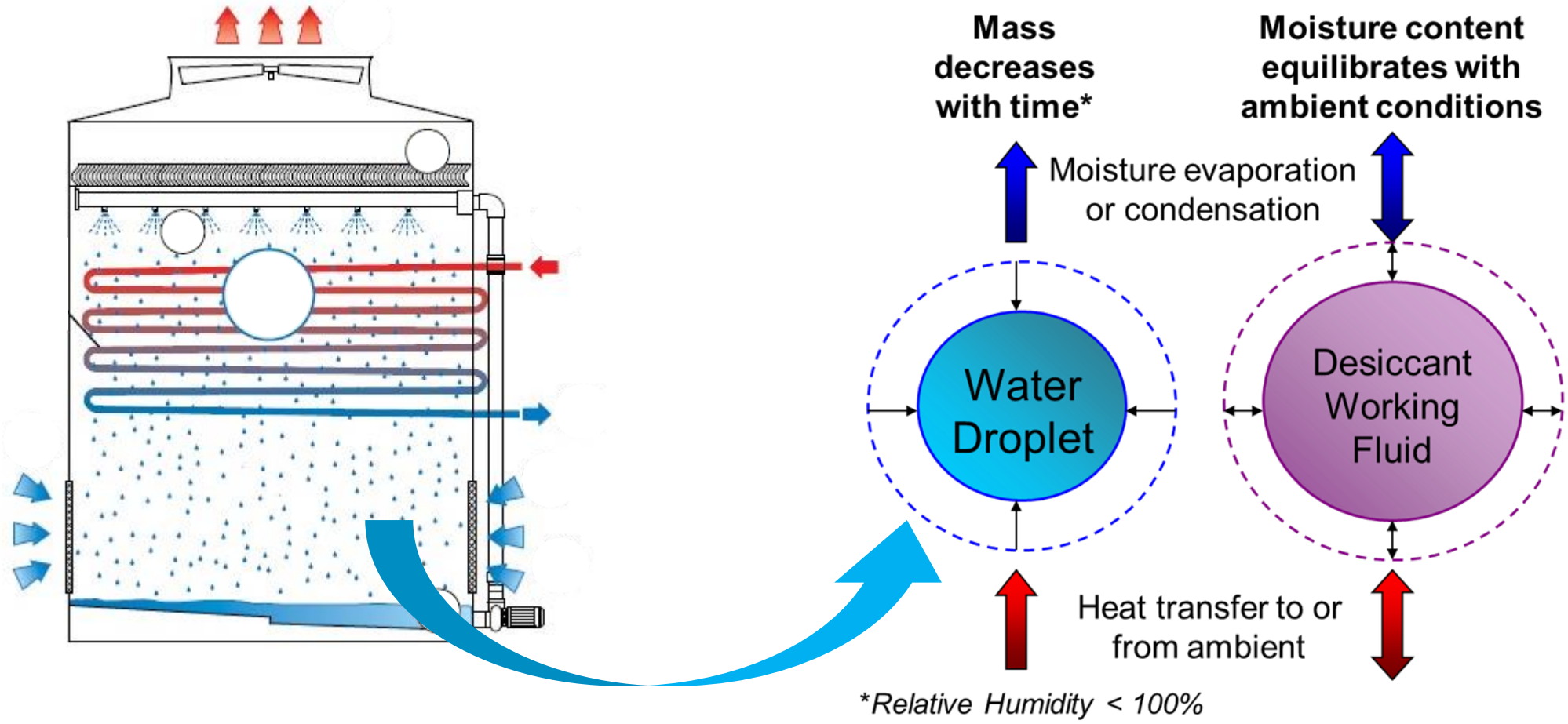
Wet Cooling Deterrents

- Rising water supply and wastewater costs
  - 41% increase in average General Services Administration (GSA) water cost between 2014-2017*
- Ongoing maintenance of water quality (fouling, corrosion, biological)
- Potential liability from microbial growth



* Tomberlin, G.; Dean, J.; Deru, M. *Electrochemical Water Treatment for Cooling Towers*; National Renewable Energy Laboratory, December 2018, https://www.gsa.gov/cdnstatic/DWT%20Final%20Report%206-28-19.pdf.

Hygroscopic Cooling Technology

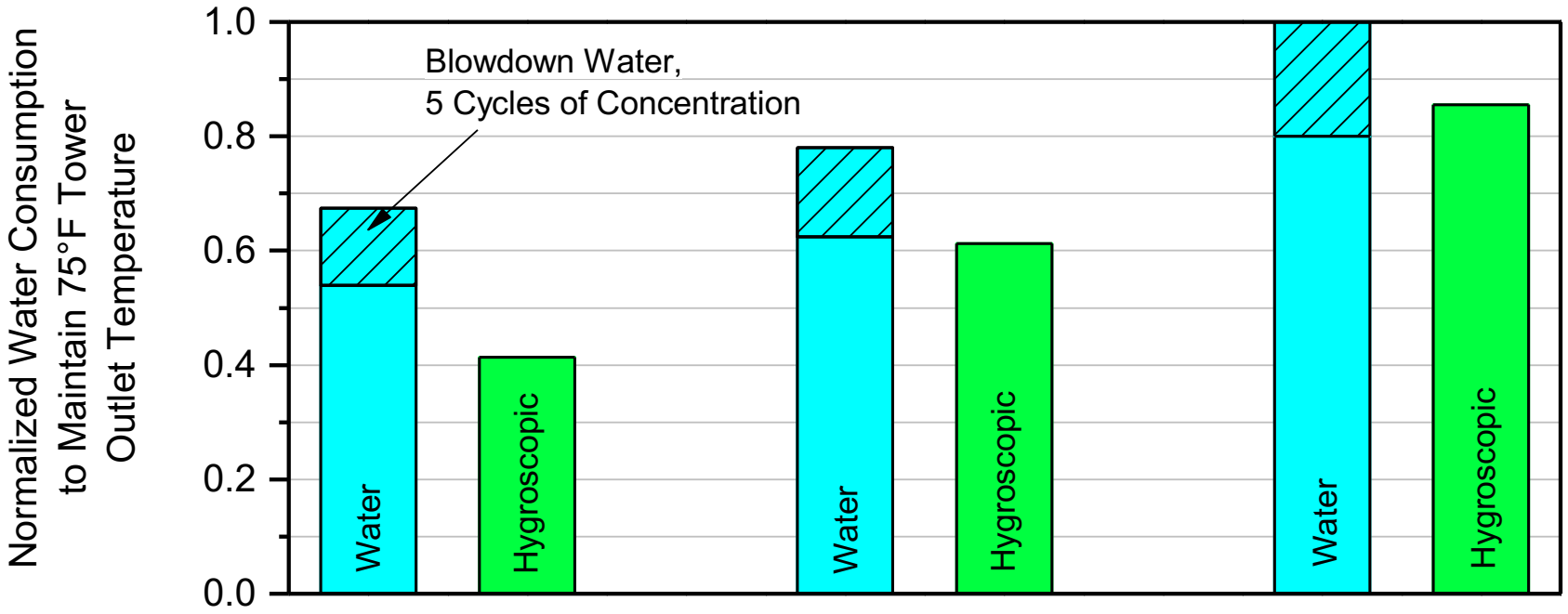


Hygroscopic Operation

- Water conserved via two mechanisms:
  - Increased sensible heat transfer with cool temperatures
  - Blowdown eliminated, all makeup water is evaporated for cooling
- Preferred working fluid is a solution of $CaCl_2$ and water.
  - Tolerant of poor quality makeup water
  - Virtually freeze proof for year-round operation
  - Microbe inhibiting
- $CaCl_2$ is also non-toxic, inexpensive, and widely available

Natural $CaCl_2$ brine concentration; Amboy, CA; Peter Thody

Water Saving Trends



Conditions	**Cool**	**Neutral**	**Hot**
Dry Bulb Temp.	60°F	75°F	90°F
Wet Bulb Temp.	54°F	63°F	67°F
Relative Humidity	70%	50%	30%

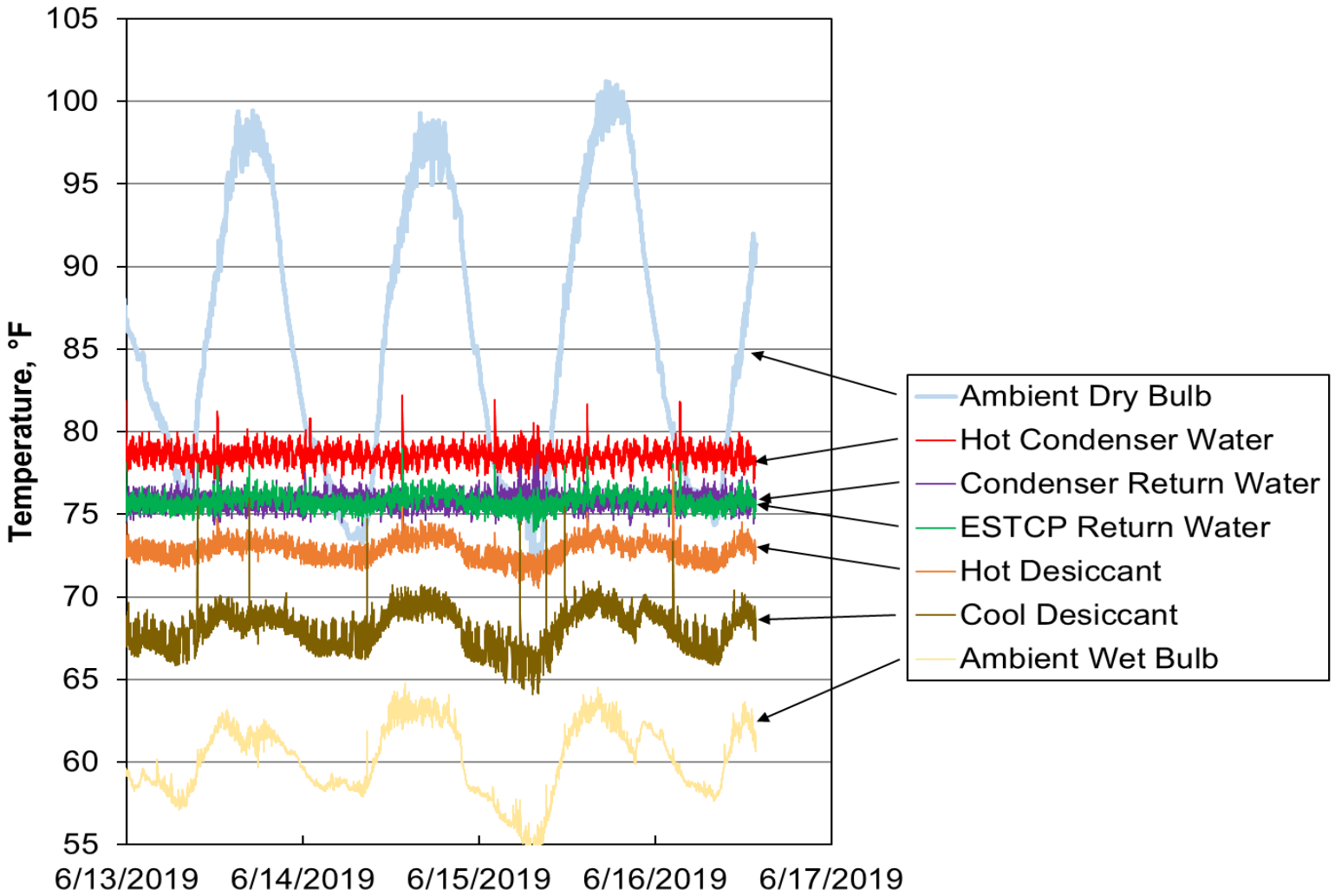
ESTCP Demonstration Sites

- National Training Center, Fort Irwin
  - Central heating and cooling plant
  - Existing tower cools a 325 ton chiller
  - Demonstration started July 2018
- DoD Center Monterey Bay
  - Existing tower cools 190 and 120 ton, staged chillers
  - Demonstration started March 2019

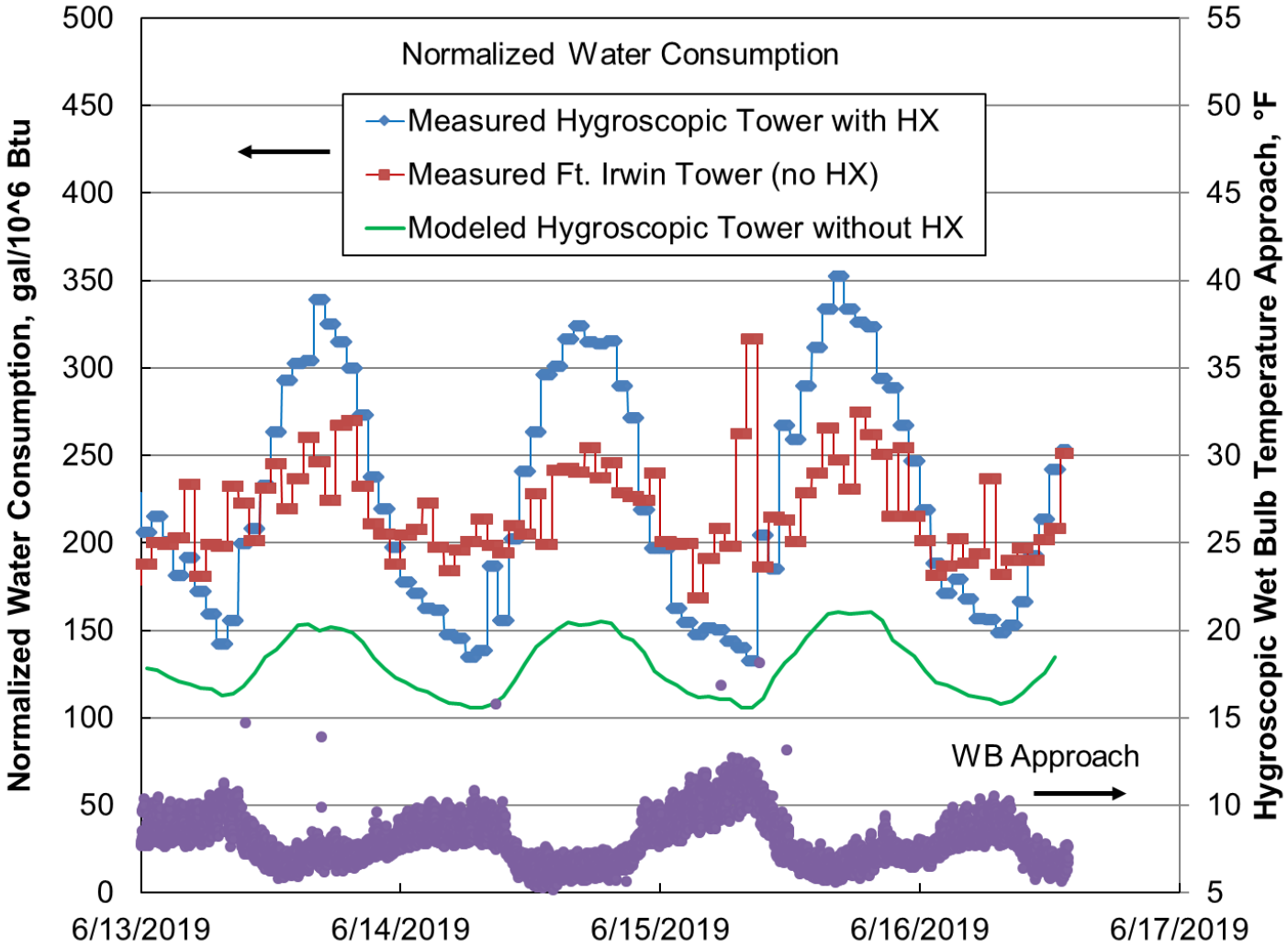
DoD Center Monterey Bay

National Training Center, Fort Irwin

Fort Irwin Operating Temperatures



Fort Irwin Normalized Water Consumption



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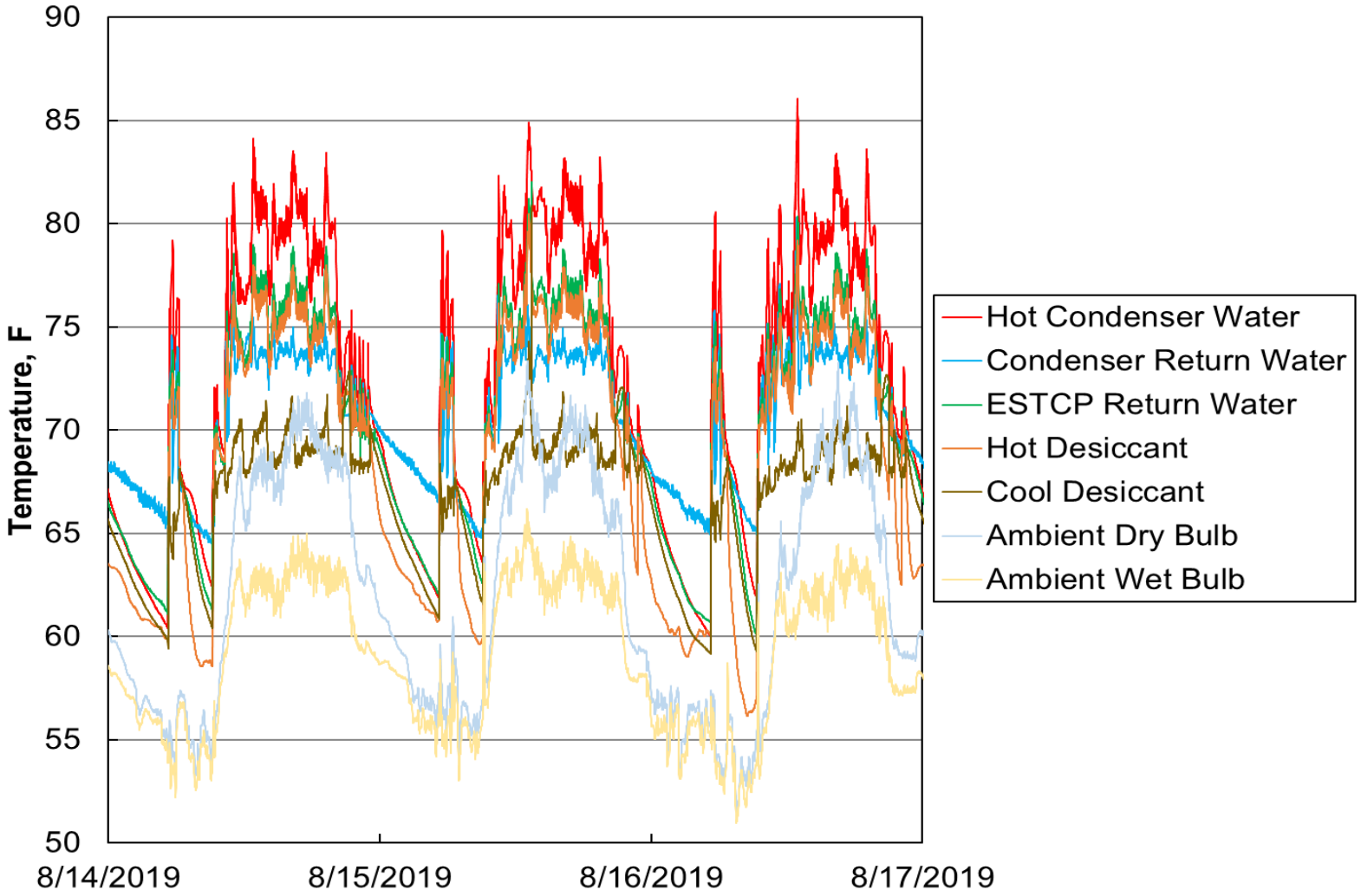
Monterey Operating Temperatures



Monterey Normalized Water Consumption

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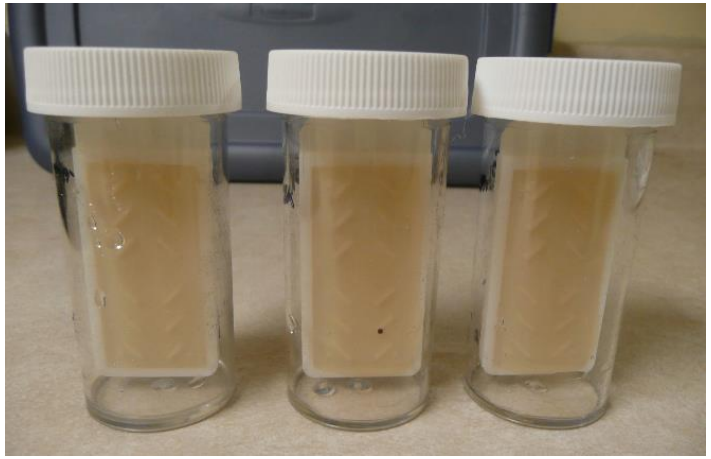
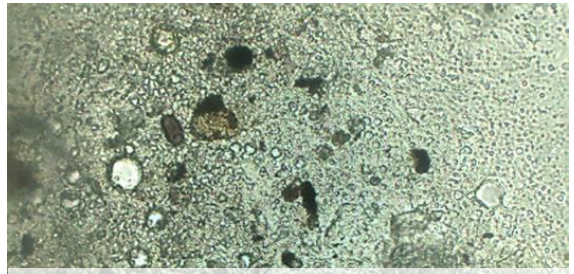
Microbial Control

- **Reduced water activity of the desiccant inhibits microbe growth**
- Bacterial dip slides
  - Readings <100 to 100 cfu/ml for the hygroscopic fluid
  - Indicates “system under control”
- Microbiological examination
  - Floating debris submitted for optical microscopy
  - No signs of single cell bacteria, algae, or higher life forms

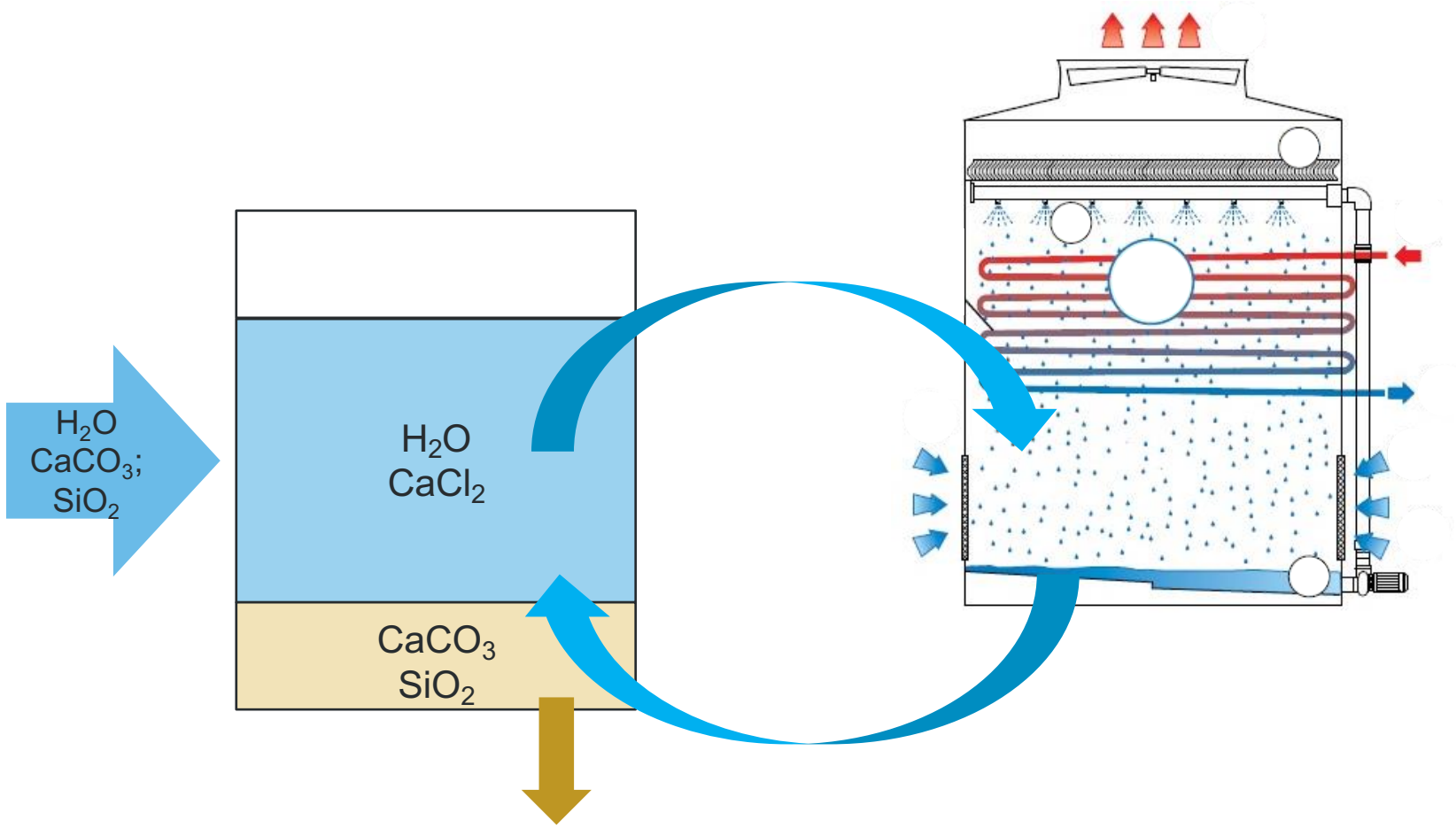


Sani-Check B slides after 48 hr incubation period. Ft. Irwin hygroscopic samples, 8/27/18



Sample microscopy image of material collected at Fort Irwin, 6/7/19

Dissolved Solids Control



- Towers have operated without blowdown; solid precipitates produced for disposal.
- One shortcoming has been with limiting precipitates to the makeup water circuit.
- In-field modifications were made to increase the effectiveness of the makeup water circuit.

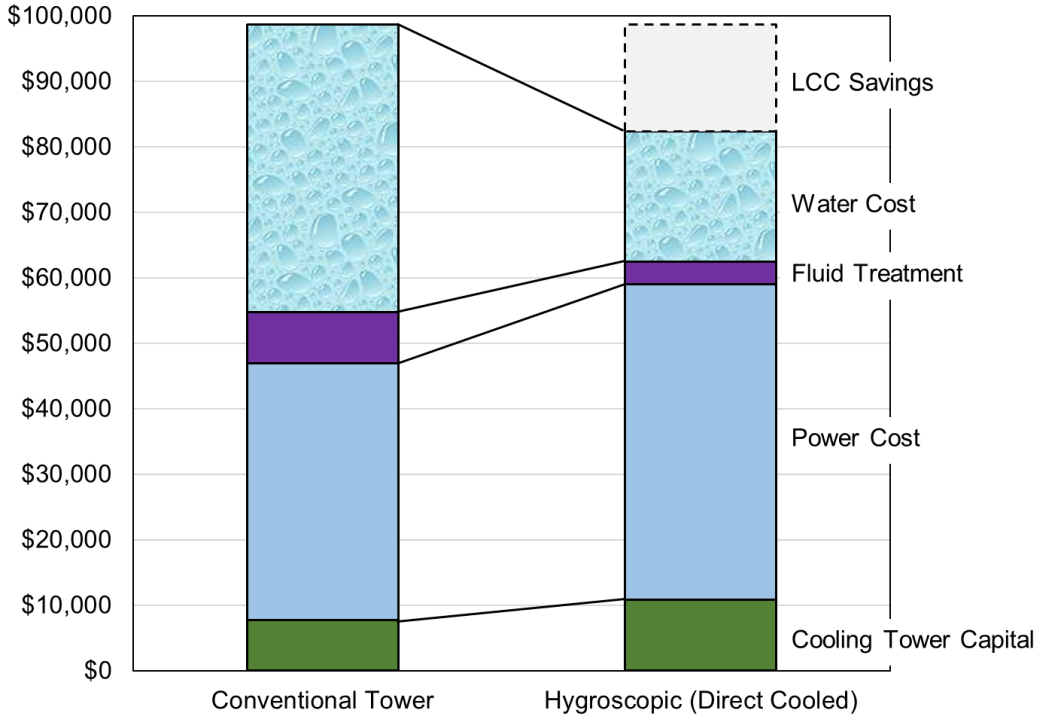
Mineral Precipitates

RCRA Metals	California Regulatory Basis: Measured Solid Conc. mg/kg	California Regulatory Basis: Total Threshold Limit Conc., mg/kg	Federal Regulatory Basis: Maximum Leachate Conc. mg/L (20:1 dilution)	Federal Regulatory Basis: Regulatory Leachate Limit, mg/L (20:1 dilution)
As	5.76	500	0.288	5
Ba	57.5	10,000	2.88	100
Cd	<0.05	100	0.0025	1
Cr	16.9	2500	.845	5
Pb	1.58	1000	0.079	5
Hg	0.0082	20	0.0004	0.2
Se	0.37	100	0.02	1
Ag	<0.05	500	0.0025	5

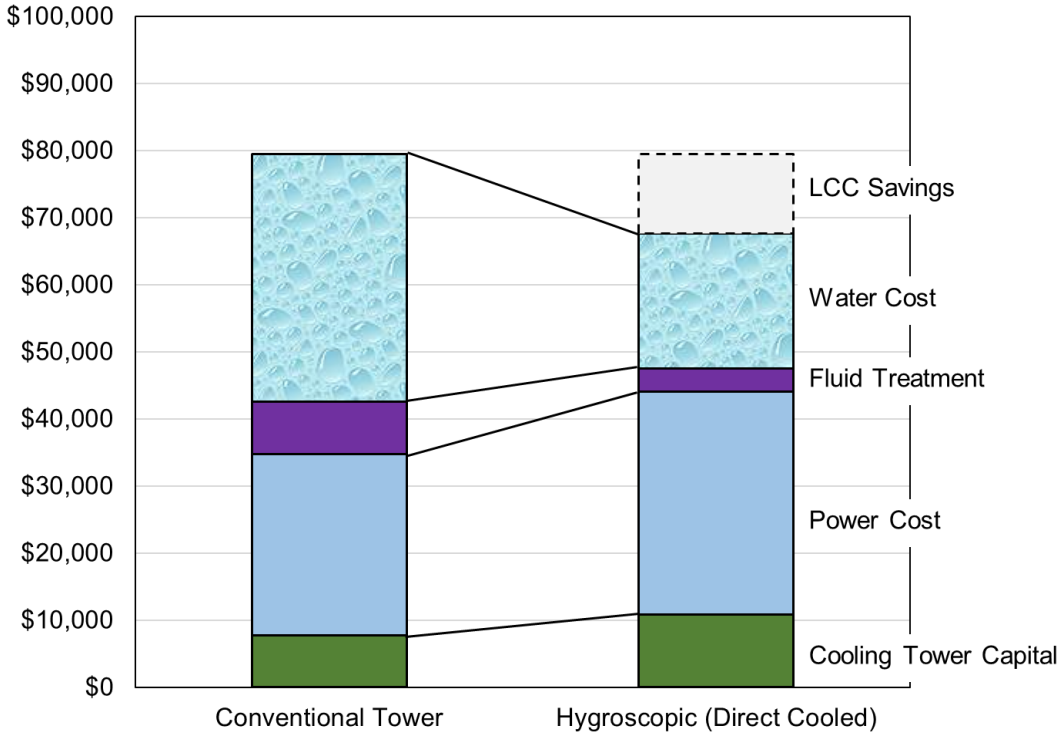
- Non-hazardous determination; material can go in conventional solid waste stream.

Preliminary Payback Potential

Fort Irwin



DoD Center Monterey Bay



	Combined Water and Sewer Rate, $/kgal	Estimated Savings to Investment	Simple Payback
Fort Irwin	$14.00	6.2	3
Monterey	$11.80	4.7	4

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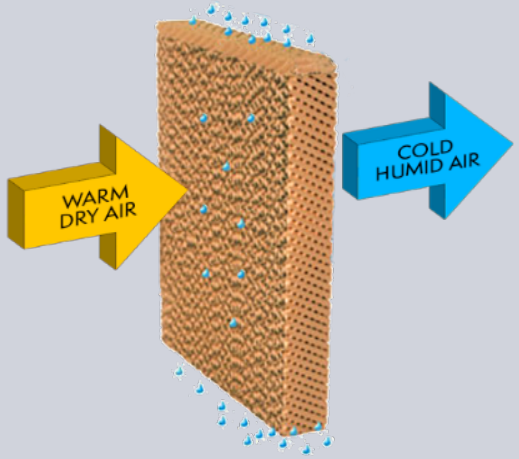
Framework for Cooling Water Cost Reductions



Increase Water Utilization

- Feedback COC control
- Cut adiabatic evaporation with a fan VFD
- Advanced water treatment*

Switch Water Source

- Municipal recycled/reclaimed
- Reuse local process water

Change Cooling Tower

- Hybrid fluid cooler
- Adiabatic condenser
- Hygroscopic cooling

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* Resource for advanced water treatment testing: https://www.gsa.gov/governmentwide-initiatives/sustainability/emerging-building-technologies/published-findings/water

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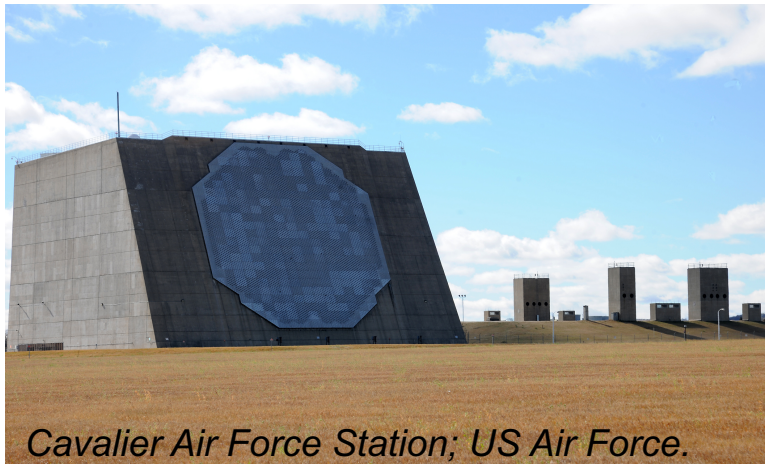
Water Cost Reduction Examples

Method	Baseline	Use Reclaimed or Recycled Water	Increase Cycles of Concentration (COC)	Hygroscopic Cooling
Considerations	Existing system	Availability and quality of supply	Impacted by starting water quality	New system, not a retrofit
Key Cost Elements	None	Added piping infrastructure to reach tower	Feedback controller; added water treatment	New tower investment
Comparison Basis	Baseline, 500 kgal/yr with 3 COC	Substitute lower cost reclaimed water	Increase COC from 3 to 5 (to 20)	30 to 50% water savings; with reclaimed
Makeup Water, kgal/year	500	500	417 (351)	250 – 350
Water to Sewer, kgal/year	167	167	83.3 (17.5)	0
Total Water Charge*, $/year	$4870	$2000	$3778 ($2916)	$2015 – $2821 $580 – $812
Reduction, %	**0**	**58.9**	**22.4 (40.1)**	**42.1 – 58.6** **83.3 – 88.1**

* Water costs based on City of San Diego posted rates for industrial and irrigation customers (https://www.sandiego.gov/public-utilities/customer-service/water-and-sewer-rates/): Potable water supply: $8.06/kgal; reclaimed water supply: $2.32/kgal; sewer charge: $5.04/kgal

Conclusions

- Key aspects of hygroscopic cooling operation have been shown:
  - Water savings potential
  - Inherent biological control
  - Blowdown elimination
- Long-term performance of precipitate control not conclusive.
- Favorable applications
  - Year-round operations
  - Poor quality makeup water
  - Costly water supply and disposal
  - Improved resilience from optimized water use



Cavalier Air Force Station; US Air Force.

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For additional information, please visit

https://www.serdp-estcp.org/Program-Areas/Installation-Energy-and-Water/Water-Conservation/EW-201723

Speaker Contact Information

cmartin@undeerc.org; 701-777-5083

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