Thermal Performance of Evaporative and Dry Cooling Systems

Clayton Penhallegon, Jr., PE
Integrated Services Group
Keynote Speaker

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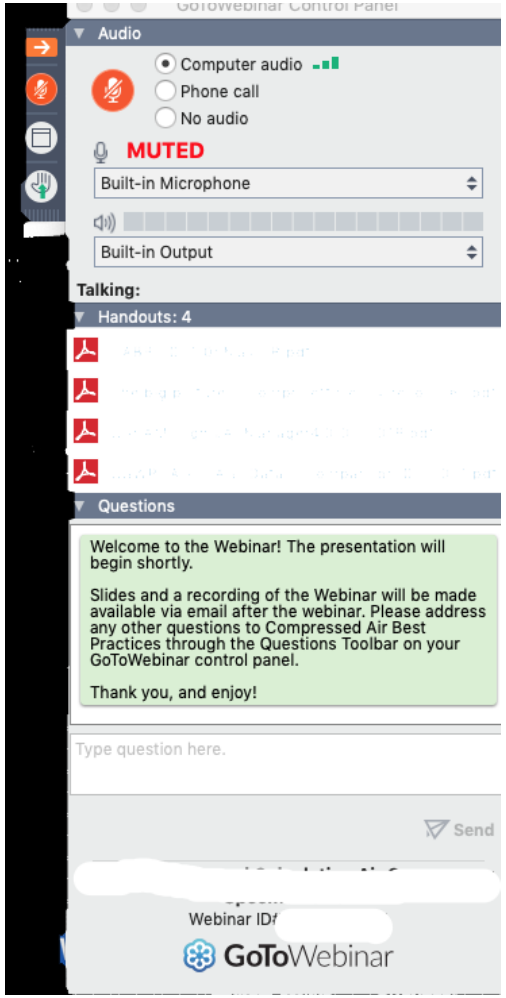
Q&A Format



- Panelists will answer your questions during the Q&A session at the end of the Webinar.
- Please post your questions in the Questions Window in your GoToWebinar interface.
- Direct all questions to Chiller & Cooling Best Practices® Magazine

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Handouts

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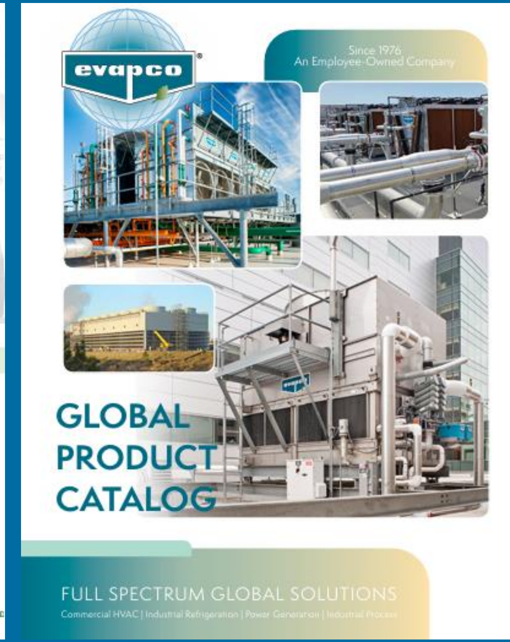
Providing over 20 years of industrial cooling system expertise
WHY WATER SYSTEMS?
Cooling water systems are one of the most overlooked, yet essential, portions of the manufacturing process. Water systems are almost always:
Engineered very conservatively, using designs and concepts 20, 30, or more years old
Production-critical, but frequently operated within a broad performance envelope
Not controlled to take advantage of seasonal conditions and load reductions
Consequently, systems typically run well below capacity and at significantly lower efficiencies than are possible. Hallmarks of these conditions include constant water flows pumped year-round, temperature control by cycling tower fans and part loading of chillers, and resolving system performance issues by blindly adding towers, pumping horsepower, etc. Operating in this manner negatively impacts EBITDA while simultaneously increasing capital.



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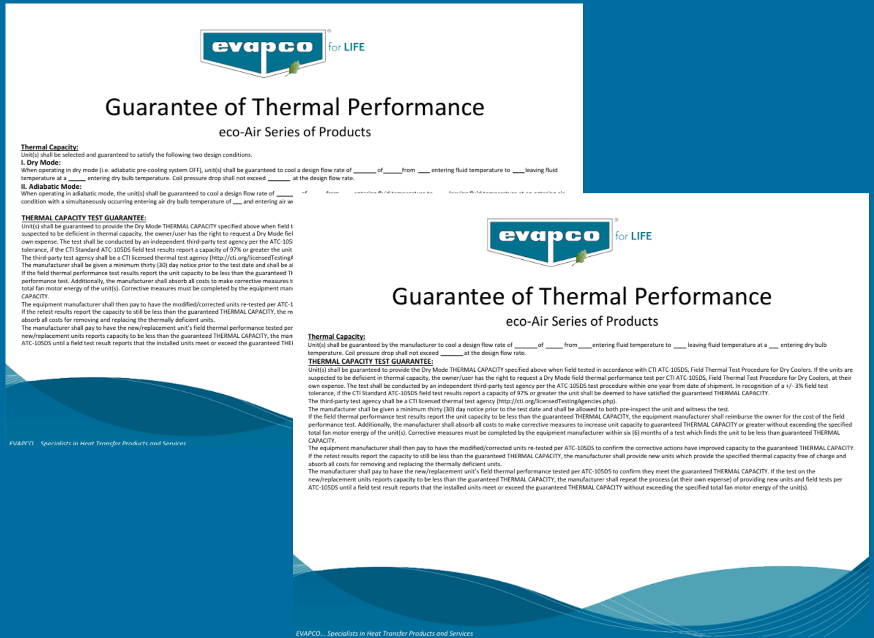

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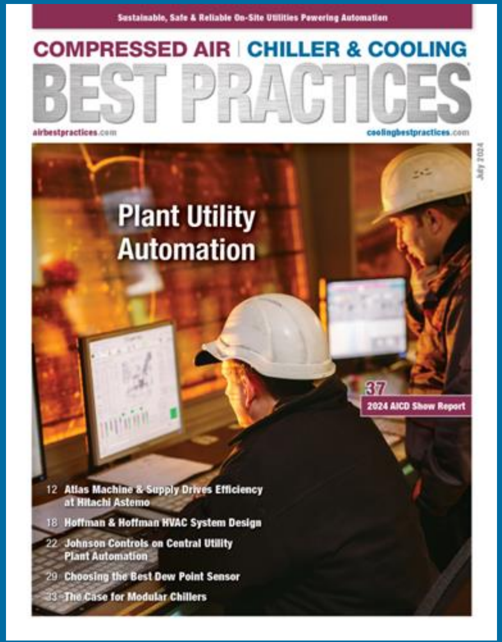

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33 The Case for Modular Chillers

Disclaimer

All materials presented are educational. Each system is unique and must be evaluated on its own merits.

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The Plenary Session welcomes all EXPO, Exhibitor and Conference Attendees! Attendees will earn 2 PDH credits.

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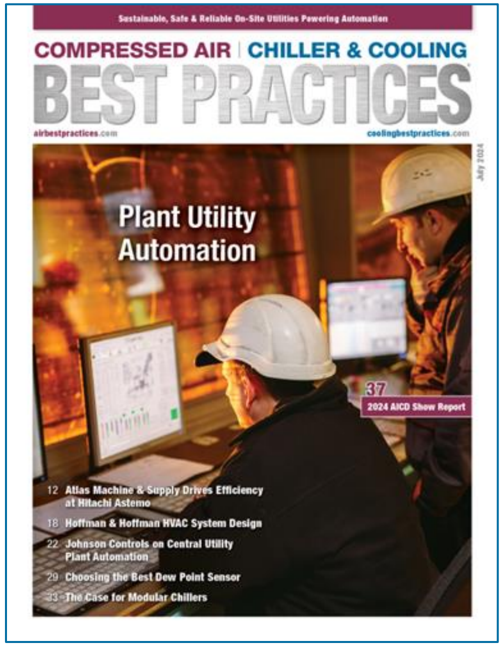
Thermal Performance of Evaporative and Dry Cooling Systems

Introduction

Chiller & Cooling Best Practices® Magazine



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About the Speaker

Clayton Penhallegon, Jr.
Integrated Services Group

- Principal Engineer, Integrated Services Group
- >25 years of experience in industrial energy efficiency
- Bachelor of Mechanical Engineering from Georgia Tech
- Registered P.E. for >30 years

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Overview

- Evaporative and dry cooling (EDC) systems are a subset of general process cooling systems
- These systems are often energy-efficient and / or water-efficient when compared to chilled water systems
- Use of EDC systems require cooling loads that can satisfactorily operate at higher temperatures than typically provided from chilled water systems
- Presentation will cover distinctions between these alternatives and typical chilled water systems and how to assess applications

Cooling Systems Context

- Many industrial processes require liquid cooling systems
  - Remove more heat in given space than air heat rejection
  - Highly flexibility locations of heat capture and rejection (e.g. outside the plant)
- Systems over a certain size (≈ 1000 tons ±) typically use open loop cooling towers
  - Evaporative towers can reject very large amounts of heat in relatively small space
  - Common & familiar applications:
    - Chiller condensers for chilled water systems, e.g. air conditioning and mold cooling
    - Large scale air compressor cooling
    - Injection molding machine hydraulics
    - Very large applications like refineries, chemical plants, power generation

Need for Cooling Systems Alternatives

- Open towers evaporate ≈ 1% of the circulated water, which can be a significant issue in various locations due to water cost and / or availability

  → *Nearly all heat removal is by the evaporation, not direct water (sensible) cooling*

- Open systems often introduce dirt and other contaminants into equipment
- Air-cooled chillers are an option but they are high energy users (refrigerant cycles), typically 6 – 8X more energy vs. towers for same heat removal
- For selected applications, Dry Cooling systems and “Adiabatic” evaporation-assisted systems can be efficient alternatives

Dry Cooling Systems Introduction

- Dry Cooling systems refer to circulating liquid cooling systems using coil-to-air heat rejection with a closed loop of water or oil going back to the machines
- Car radiator is familiar dry cooling system

Example Dry Cooling Systems

Vertical “V” Style Dry Cooling Unit

Horizontal Dry Cooling Unit

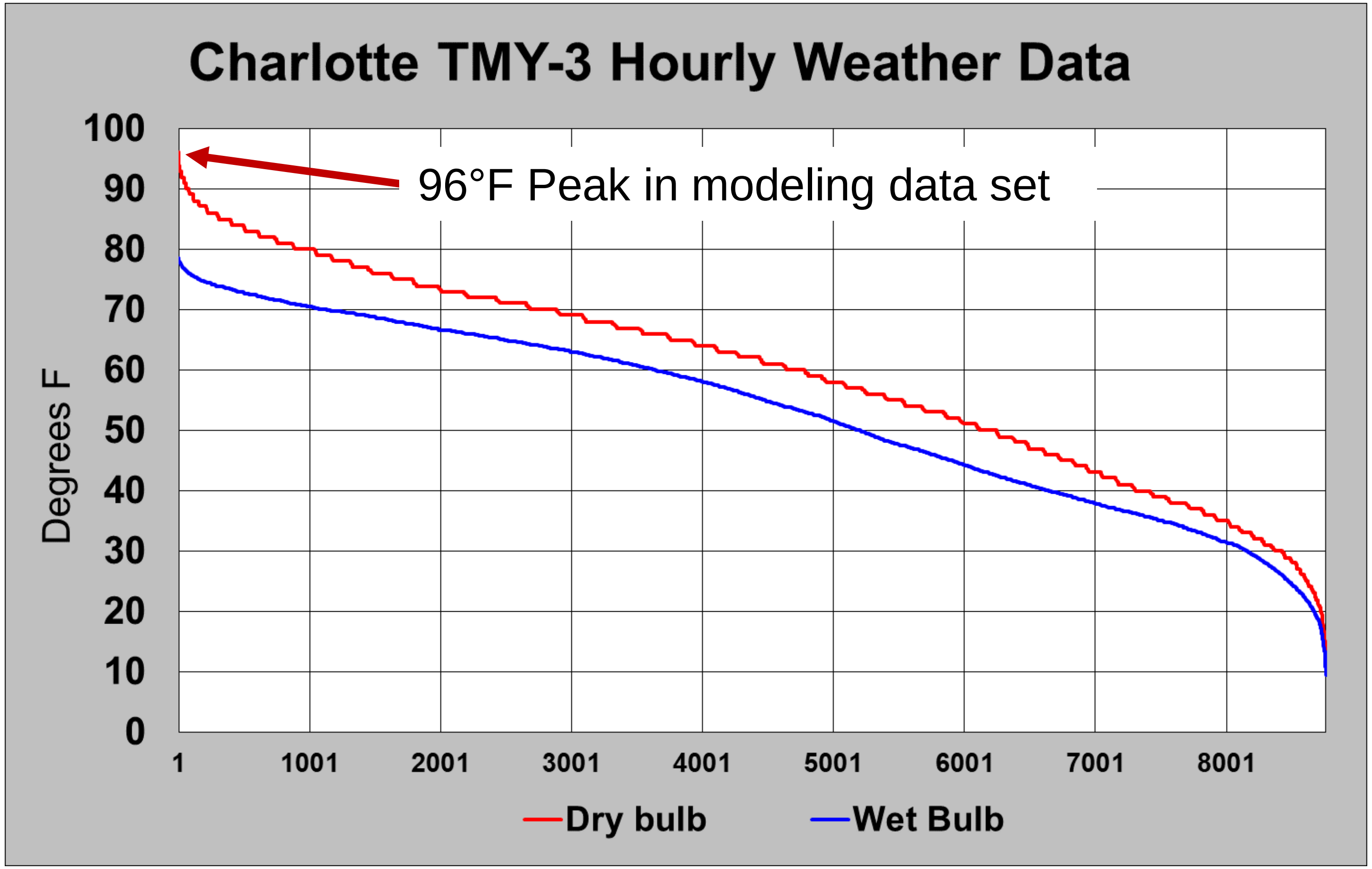
Dry Cooling Systems Introduction

- Dry Cooling systems refer to circulating liquid cooling systems using coil-to-air heat rejection with a closed loop of water or oil going back to the machines
- Typically more efficient than refrigerant cycle systems,

But…

- Applications require cooling loads that can operate satisfactorily at higher temperatures than commonly provided from chilled water systems
  - Common coil approach temperatures are ***15 – 20°F***
  - Supply In water temperatures of ***110 – 115°F*** @ 95°F air temp (higher at higher ambient)
- Require significantly more space for cooling units of equivalent rating
- Typically higher purchase and fan energy cost, lower overall operating cost due to water savings and associated other cost savings (chemical treatment, etc.)

Dry Cooling Temperature from Typical Weather Data



DC system could provide appx. 110°F LWT year round

875 Ton-R Process Custom Dry Cooling Tower

Dry Cooling Tower Erection

60 HP Fan Dry Cooling Tower

600 GPM @ 160 °F In, appx. 125°F Out with 100°F air temp

Dry Cooling Systems Potential Applications

- Air compressor gear lubrication cooling, e.g. high HP, multi-stage centrifugal (with separate, lower temperature aftercooler cooling)
- Hydraulic system cooling (sawmills, auto crushers, high temperature hydraulic presses, etc.)
- Warm temperature plastics cooling (polypropylene film, EPS cup molds)
- Rolling mill bearing cooling

Dry Cooling Systems Performance Maintenance

- Cooling effectiveness depends on several factors:
  - Original design temperature-approach capability
  - Liquid selection – glycol solutions or oil do not perform identically to water
  - Coil exterior condition – fin surface not excessively oxidized or corroded

    → *Surface treatments to help AL or SS fins, exposure to accelerants (exhausts from plant, etc.)*
  - Air flow through coils – surface blockage (debris), fouled screens*, fan failure
- Internal surfaces usually not the cause of problems but circulating liquid must be treated properly for closed loop system
- Cooling efficiency enhanced by fan control – speed control (VFDs) better than staging, but either approach better than constant on, liquid-bypass operation

Air Flow Obstruction Example

- Screens to protect coils very prone to fouling
- Aggressive maintenance (cleaning / replacement) can provide air flow benefits
- Site selection critical to satisfactory performance of coil-based heat rejection systems
  - Don't use coils in the first place if environmental fouling potential too high – chicken vs. egg situation – if screens <u>required</u>, probably not a good location for coil application!

Chiller coil screen – L.A. Basin location

Dry Cooling Systems Drawbacks

- Many processes can’t run at the temperatures available from pure DC systems
- “Adiabatic” or Evaporative-Assist Cooling Systems can meet more needs

Adiabatic Process Definition

Thermodynamics: An adiabatic process (adiabatic from Ancient Greek ἀδιάβατος (adiábatos) 'impassable') is a type of thermodynamic process that occurs without transferring heat or mass between the thermodynamic system and its environment (credit Wikipedia).

In meteorology, the adiabatic process primarily describes the action of heating or cooling a body of air without any energy exchanged with the surrounding atmosphere. The temperature changes occur as a result of an air pocket's compression or expansion due to pressure changes in the surrounding air.

“Adiabatic” or Evaporative-Assist Cooling Systems

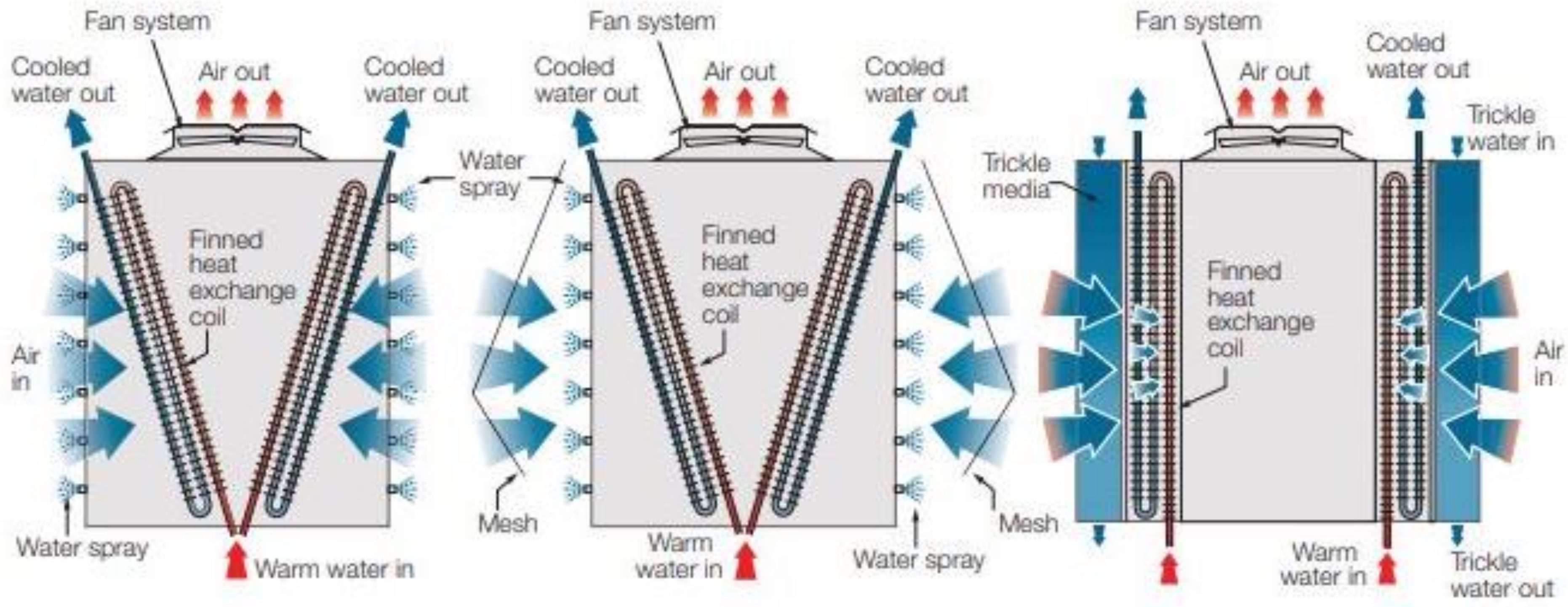
- Dry cooling systems can provide temperate water (<90°F) much of the year depending on location and climate
- Summer high temperatures result in Leaving Water Temperatures (LWT)(from coil, to process) of 115 – 120°F @ 100°F air temp
- So-called Adiabatic systems use an evaporating water spray or saturated pads to cool the air toward the wet bulb temperature

Example Adiabatic Cooling Systems

Vertical “V” Style
Pad Adiabatic
Cooling Units

Spray Adiabatic Cooling Unit

Adiabatic Cooling System Evaporative Types



(a) Hybrid cooler with sprays

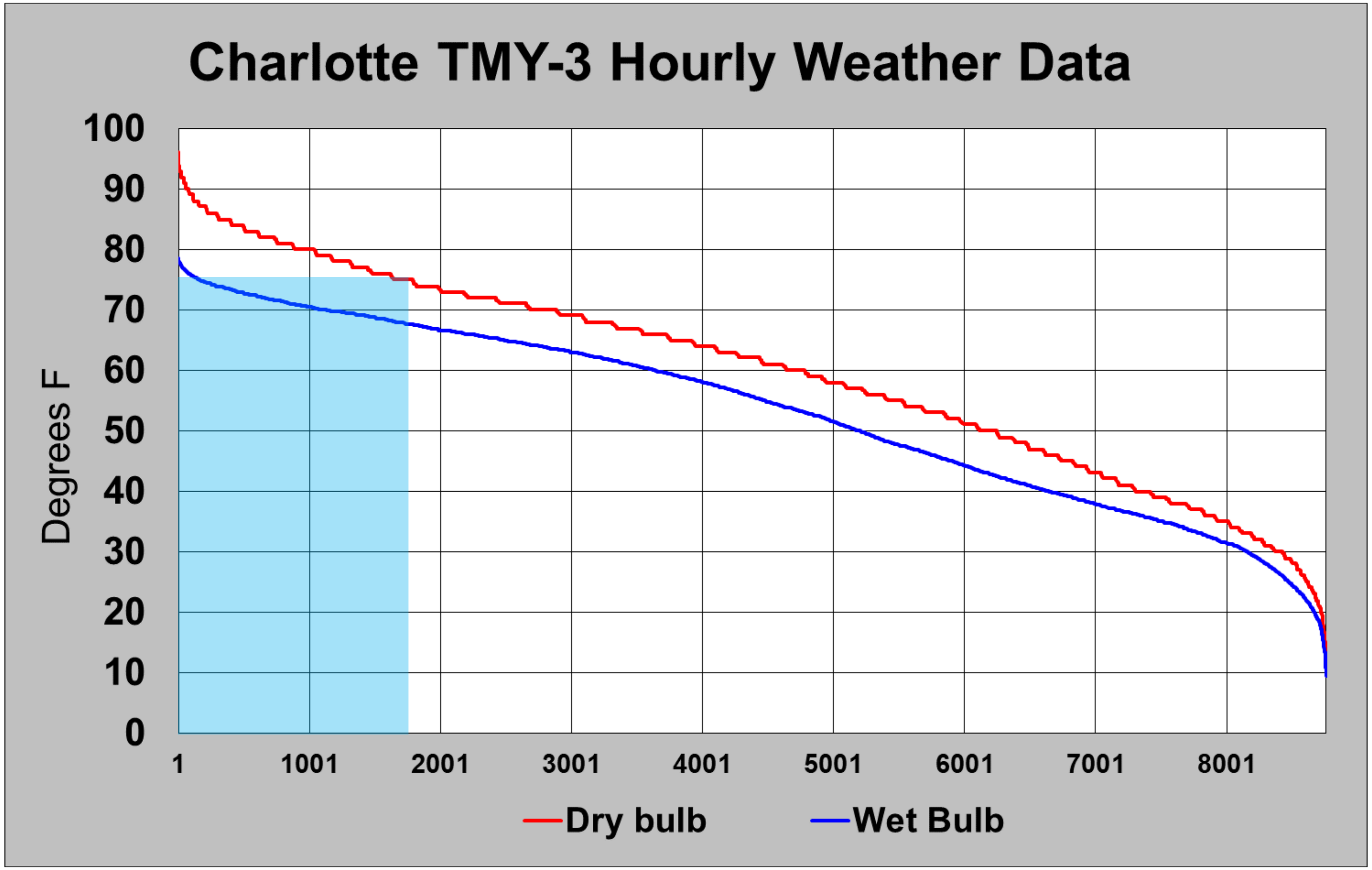
(b) Hybrid cooler with spray onto mesh

(c) Hybrid cooler with trickle onto media

“Adiabatic” or Evaporative-Assist Cooling Systems

- Dry cooling systems can provide temperate water (<90°F) much of the year depending on location and climate
- Summer high temperatures result in Leaving Water Temperatures (LWT)(from coil, to process) of 115 – 120°F @ 100°F air temp
- So-called Adiabatic systems use an evaporating water spray or saturated pads to cool the air toward the wet bulb temperature
- Evaporation-assist cooled air is usually around 10 – 15°F cooler at summer conditions than the dry bulb air temp, e.g. roughly 83 - 85°F for wet bulb of 78 °F
- Adiabatic systems can enable use of *non-refrigerant* cycle cooling on additional loads, LWTs of 95 – 90°F except limited number of peak hours

Typical Weather Data



*Approximately 1790 hours of spray to maintain ≈90°F LWT

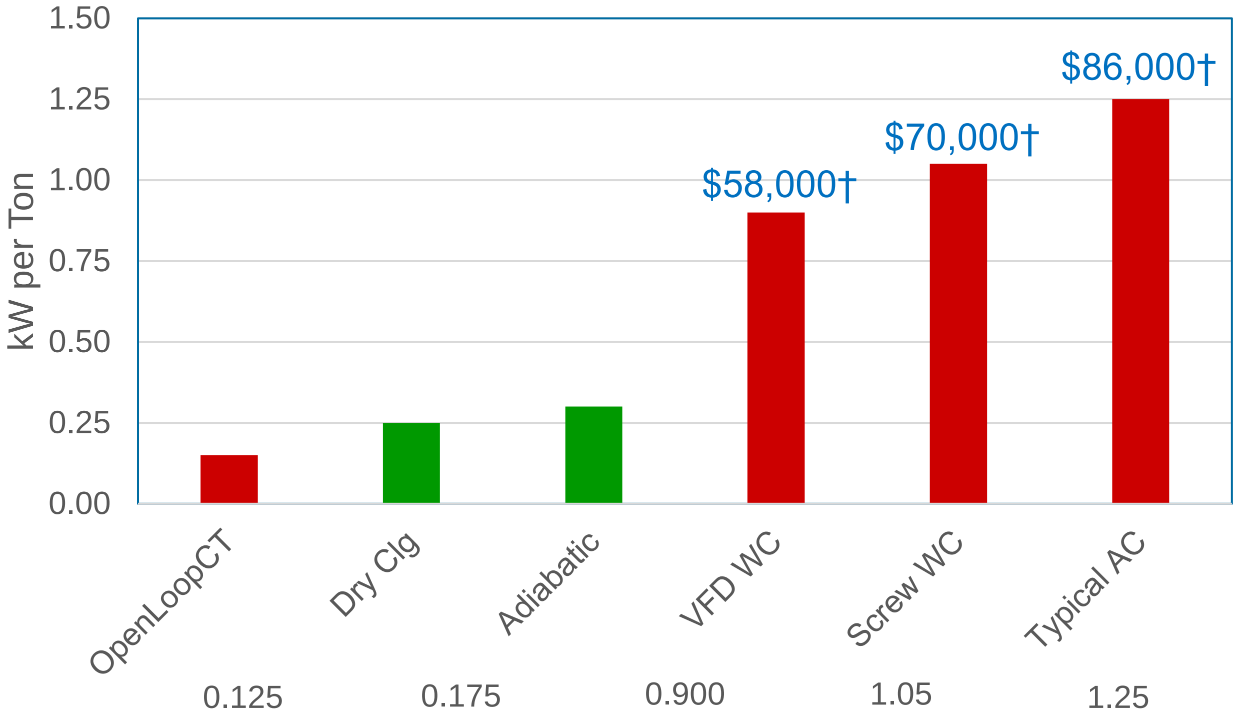
Adiabatic Cooling Systems Potential Applications

- Same as Dry Coolers except more of it:
  - Hydraulic system cooling
  - Packaged air compressors and vacuum pumps – including flooded screw, oil-free, aftercoolers before refrigerated dryers
  - High HP air compressors – gearbox cooling, interstage air coolers, aftercooler
- Rubber, synthetic rubber mold curing
- Medium temperature plastics uses – film cast rolls, injection molding, etc.

Adiabatic Cooling Systems Performance Maintenance

- Water spray effectiveness dependent on nozzle condition, water quality
- Pad system effectiveness dependent on uniform water distribution (no channeling)
- Most useful wetting completely evaporates leaving no water droplets to fall out of stream (wasted water), impinge on the coils (collects dirt), or drain off
- Pads and / or screens must be kept reasonably clean – *reduced airflow from fouling can more than offset benefit from evaporation*

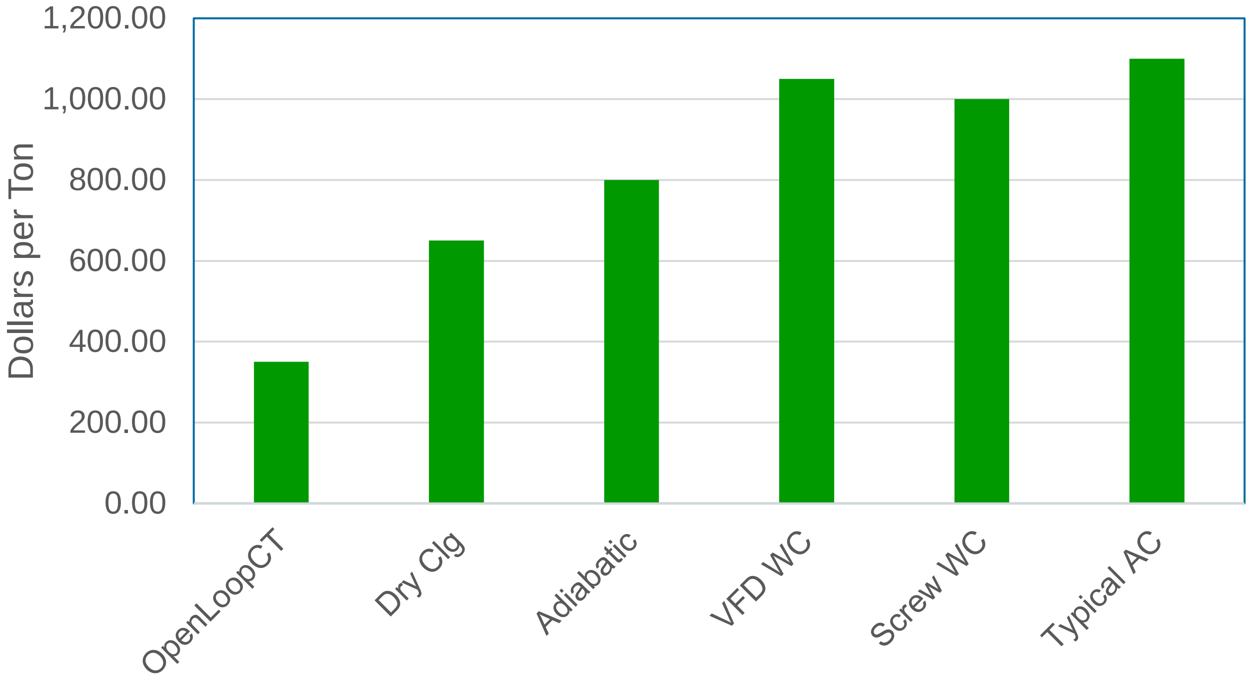
Dry Cooling & Adiabatic Systems Efficiency & Savings



VFD WC – centrifugal chiller with VFD , typical system, typical controls
Typical WC – standard water-cooled screw chillers, typical system, typical controls
Typical AC – air-cooled screw chillers, standard pumping and control

†Cost premium basis – vs. Adiabatic, 100 tons, 8000 hours / yr, 100% run factor, 10¢ / kWh power cost

Dry Cooling & Adiabatic Systems Cost Per Ton



Open Loop Cooling Tower – cooling tower, pumps, typical system, typical controls
VFD WC – centrifugal chiller with VFD , typical system, typical controls
Typical WC – standard water-cooled screw chillers, typical system, typical controls
Typical AC – air-cooled screw chillers, standard pumping and control

Basis – Heat rejection and required associated equipment (pumps, towers, etc.) – no sq. ft. costs included

Evaporative & Dry Cooling Systems Summary

- EDC systems are great options for process cooling
  - Significant water savings vs. cooling tower systems
  - High efficiency compared to chilled water systems, whether air-cooled or water-cooled
- Application of EDCs requires care to ensure that the processes can satisfactorily operate at the available temperatures
- Maintaining good airflow through the coils is critical to getting good results
  - Total cooling capability
  - Lowest return temperatures from the system

About the Speaker

Bobby Becker
EVAPCO

- Senior Global Products Manager at EVAPCO
- 14 years of experience at EVAPCO
- Bachelor degree in Mechanical Engineering from the University of Maryland, College Park

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The Significance of Thermal Performance Certification for Heat Rejection Equipment

Bobby Becker

Senior Global Products Manager

Significance of Thermal Performance Certification

Presentation Outline:

- Importance of CTI Certification
- CTI Test Codes & Standards
- Value of CTI Certification

The Importance of CTI Certification

Customers have many options and manufacturers to choose from:

Evaporative

Hybrid

Air-Cooled

Lacking certification, customers must rely on the manufacturer's <u>published</u> ratings

15-20% overstated thermal performance rating means….the unit will underperform when it matters the most

Underperforming units will consume more energy and water, and will miss temperature setpoints

The Importance of CTI Certification

Cooling Tower – Industrial Load Profile in Baltimore, MD

9,000 GPM of Water, 95°F Inlet / 85°F Outlet @ 78°F Ambient Wet-Bulb

	Current CTI Certified AT Cooling Tower		Pre-CTI Certification Cooling Tower (typical)
Percent Capacity	101.7%		87% (selected at 100%) **
Overall Unit Dimensions (LxWxH)	24'x36'x19'	**6% larger**	24'x36'x18'
Connected Fan Motor Power	240 HP	**50% greater**	160 HP
Annual Energy Usage	142,494 kWh	**15% less**	165,107 kWh

This unit **will not meet 95F/85F temps for almost 100 hours per year in Baltimore, Maryland

The Importance of CTI Certification

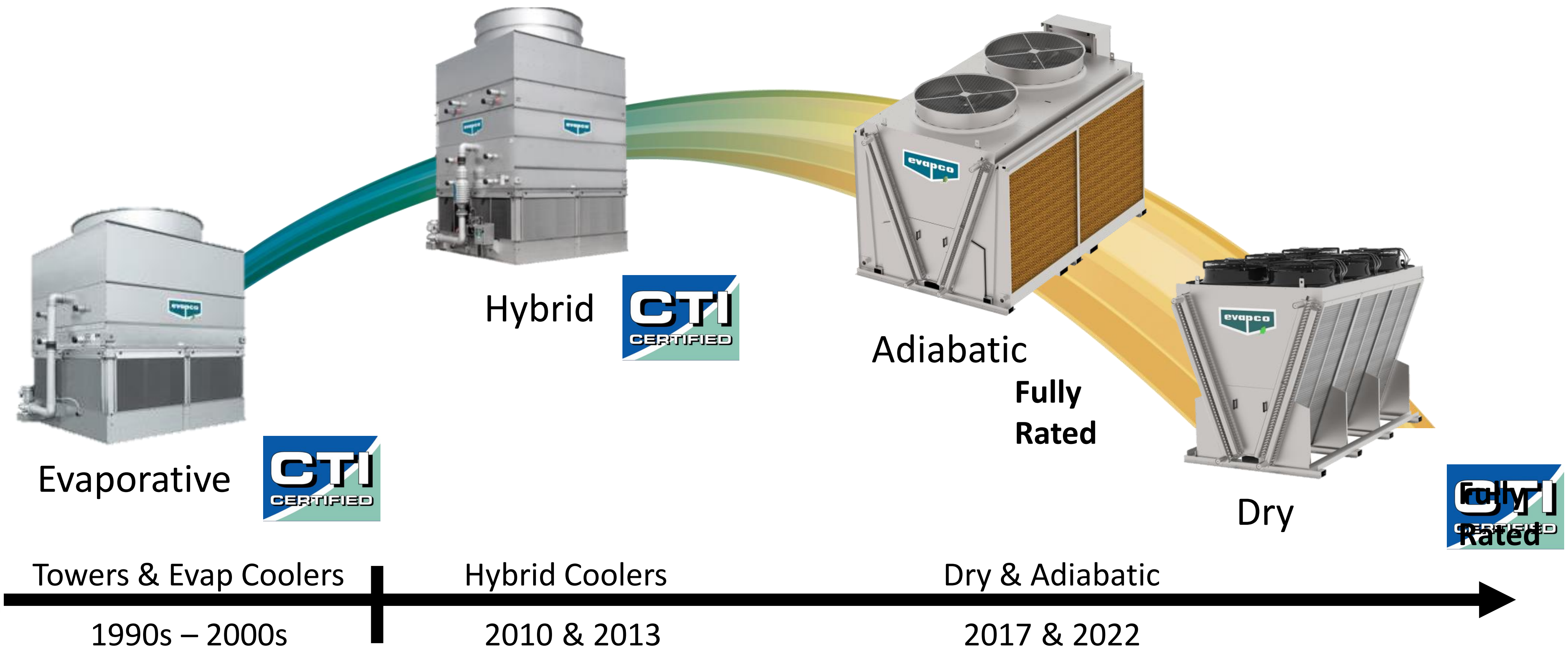
Dry Cooler – Industrial Load Profile in Baltimore, MD

2,000 GPM of Water, 120°F Inlet / 110°F Outlet @ 95°F Ambient Dry-Bulb

	Current CTI Certified EVAPCO Dry Cooler	Current Non-CTI Certified Dry Cooler
Percent Capacity	102.1%	78.7% (selected at 100%) **
Overall Unit Dimensions (LxWxH)	12’x40’x19’	12’x26’x19’
Heat Transfer Surface Area	126,041 sqft **14% greater**	110,954 sqft
Connected Fan Motor Power	150 HP **25% greater**	120 HP
Annual Energy Usage	60,957 kWh **44% less**	109,422 kWh

This unit **will not meet 120F/110F temps for almost 150 hours per year in Baltimore, Maryland

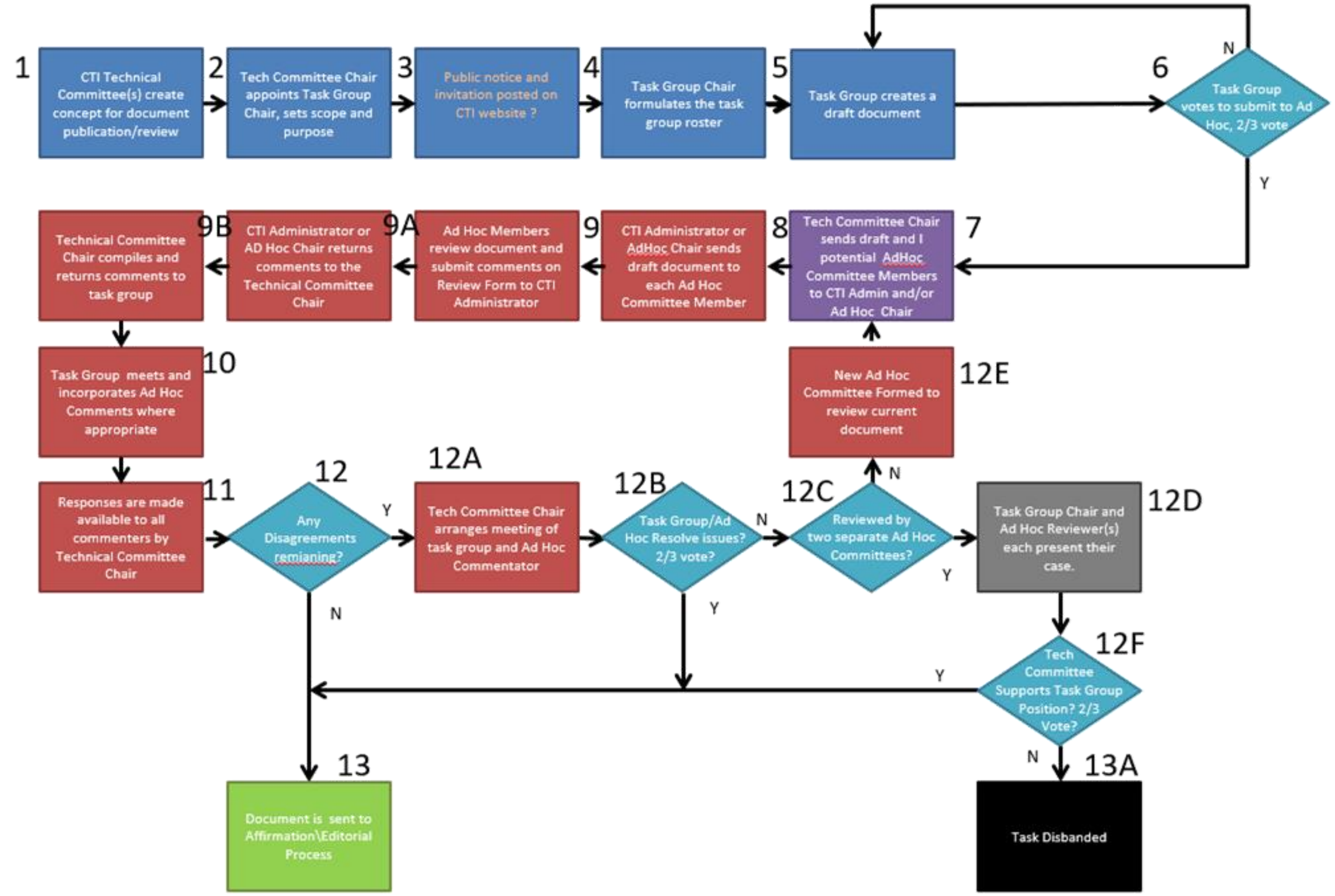
The Evolution of CTI Certification



CTI Test Codes & Standards

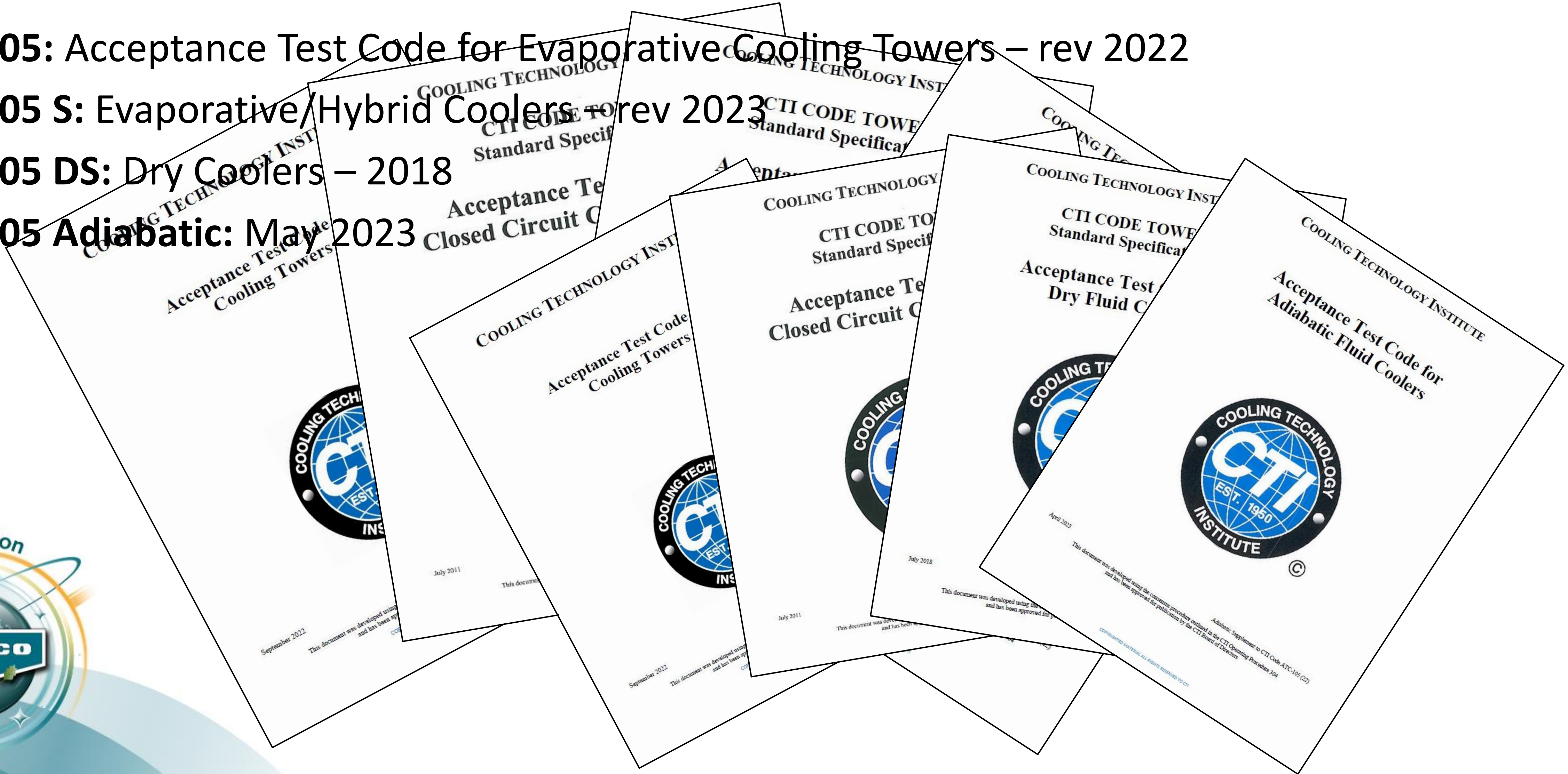
- Need for New/Revised Code or Standard is Motioned
- Task Group is Formed
- Draft Document/Revision
- Reviewed by 3rd Party Group
- Reviewed by CTI Board for Adoption

CTI PROCESS FOR OPERATIONAL DOCUMENT REVISION OR GENERATION



CTI Test Codes & Standards

- **ATC-105:** Acceptance Test Code for Evaporative Cooling Towers – rev 2022
- **ATC-105 S:** Evaporative/Hybrid Coolers – rev 2023
- **ATC-105 DS:** Dry Coolers – 2018
- **ATC-105 Adiabatic:** May 2023



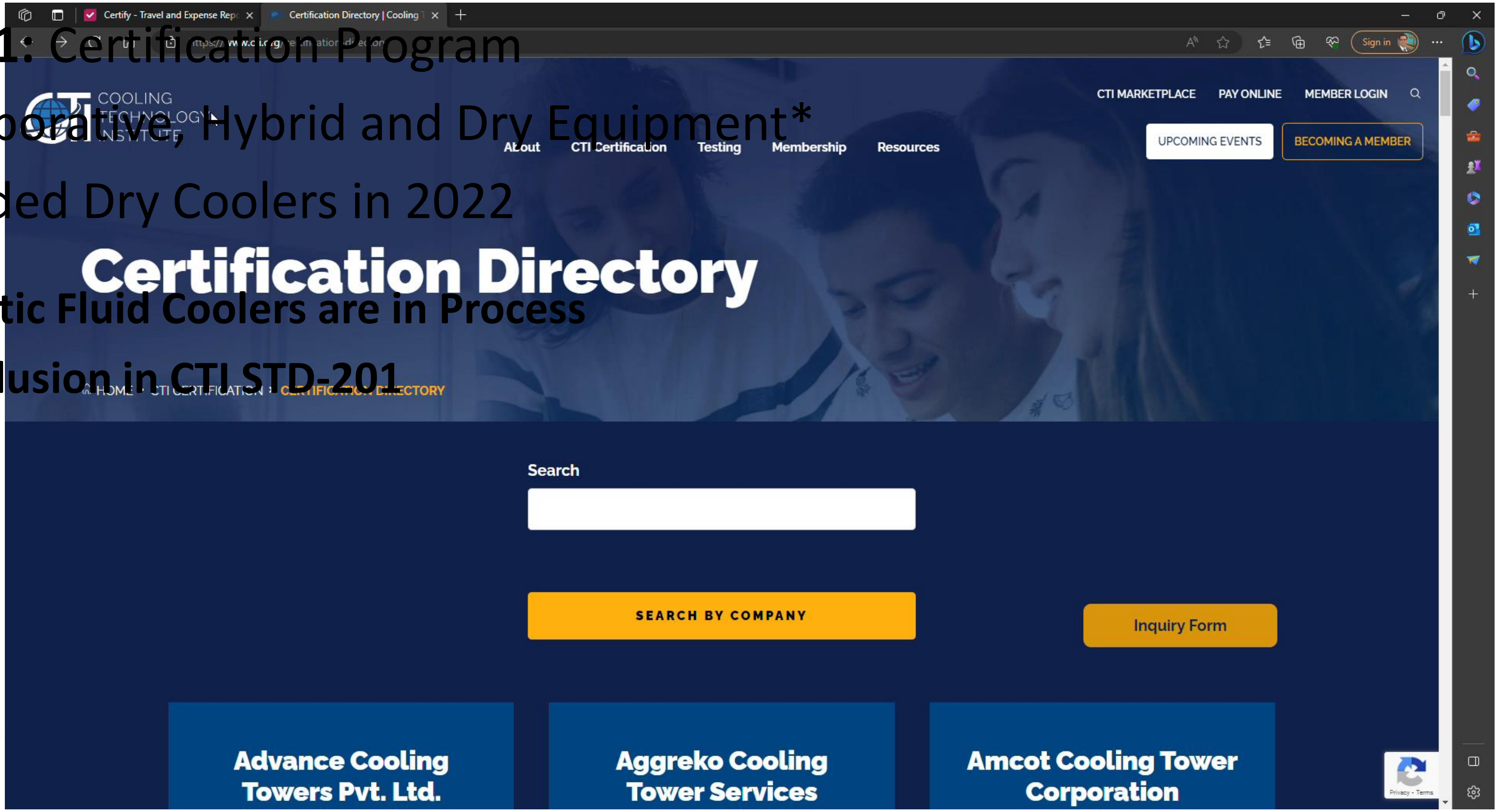
CTI Test Codes and Standards

- **CTI STD-201: Certification Program**

  for Evaporative, Hybrid and Dry Equipment*

  – Included Dry Coolers in 2022

  ***Adiabatic Fluid Coolers are in Process**
  for Inclusion in CTI STD-201



CTI Certified Products & Models are Listed on www.cti.org

CTI Test Codes and Standards

To Achieve CTI Certification, Manufacturers Must:

- Test Thermal Performance by a CTI Licensed Test Agency
  - Annual Reverification Required
  - Model(s) Selected by Thermal Certification Administrator
- Submit "Data of Record" to CTI
- Pay Testing & Certification Fees
- Publish Data to the Public
  - Manufacturer Website
  - Selection Programs
  - www.cti.org

Dry Cooler Test in EVAPCO R&D Lab

Full Spectrum Evolution evapco

Limits of CTI Thermal Certification

	SI Units	IP Units
Wet Bulb Temperature	10°C to 32.2°C	50°F to 90°F
Maximum Process Fluid Temperature	51.7°C	125°F
Minimum Range	2.2°C	4°F
Minimum Approach	2.8°C	5°F
Barometric Pressure	91.4 kPa to 105 kPa	27 in Hg to 31 in Hg

The STD-201 Limitations of Certification establish ranges of conditions under which the product lines may be accurately tested. The buyers of certified products are advised that if their specific design conditions fall outside of the STD-201 limitations of certification, then the capacity of any model selected (from any manufacturer) would not be certified by CTI.

Licensed CTI Test Agencies will not conduct a test outside of these conditions.

Limits of CTI Thermal Certification

Example: Cooling Tower

Design Conditions: 78°F Inlet / 69°F Outlet @ 66°F Ambient Wet-Bulb

Unit Comparison	78°F/69°F/66°F % Capacity	Nominal Conditions 95°F/85°F/78°F	Nominal Conditions % Capacity
Brand X	100%	1,007 Tons	100%
EVAPCO	86.4%	1,045 Tons	103.7%
Brand Y	89.7%	1,011 Tons	100.3%

Limits of CTI Thermal Certification

How to Handle this…. EDUCATION

- Discuss the Importance/Value of CTI Certification & Temperature Limits
- Schedule 2nd Set of Conditions within CTI Limits
  - Another Data Point will Expose Overstated Capacity Outside of Limits

SUMMER CAPACITY				WINTER CAPACITY			
PEAK FLOW RATE (GPM)	EWT (°F)	LWT (°F)	ENTERING AIR WET BULB (°F)	FLOW RATE (GPM)	EWT (°F)	LWT (°F)	ENTERING AIR WET BULB (°F)
1800	95	85	78	1440	50	40	29.4

The Value

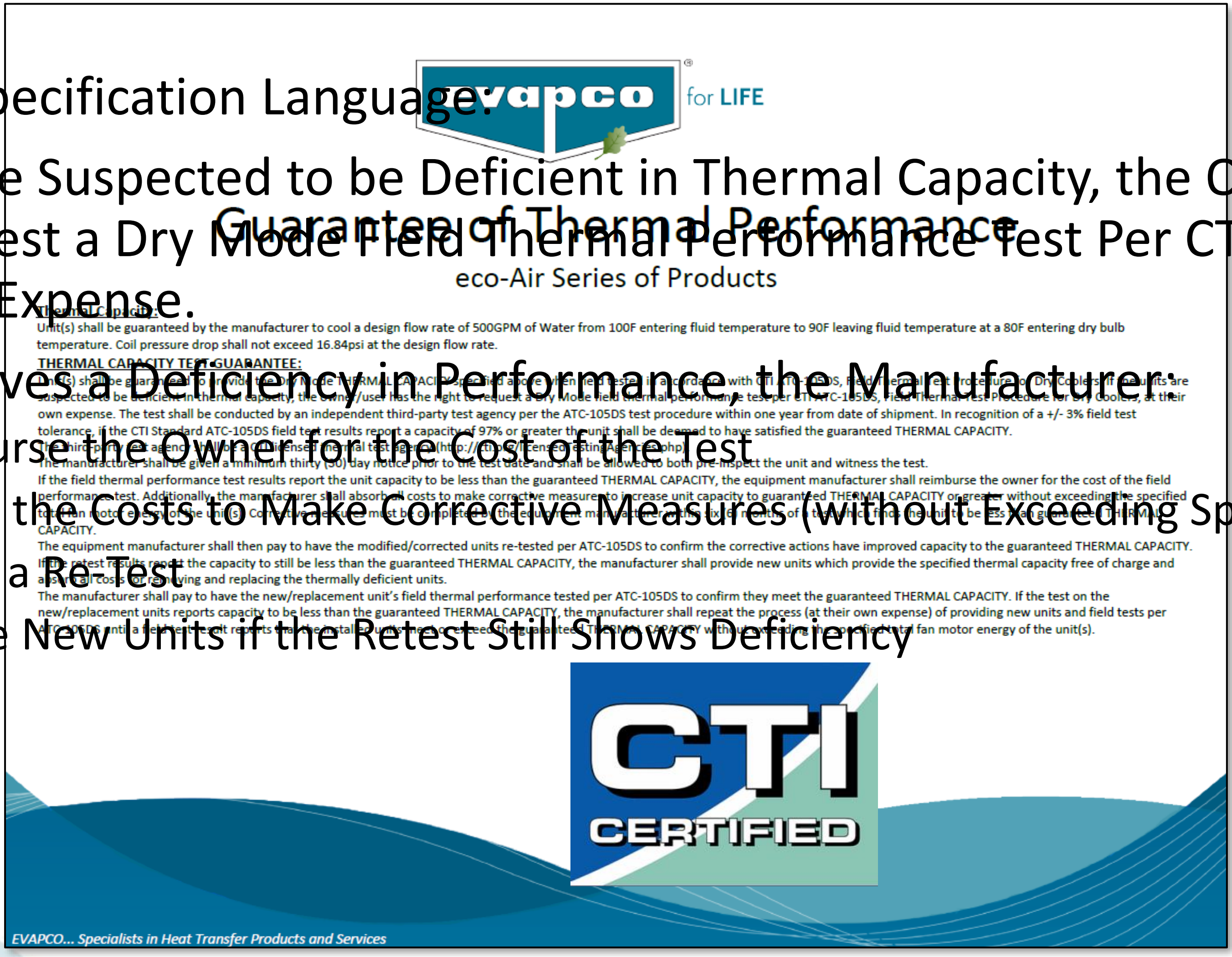
- Ensure a Level Playing Field
  - Specify CTI Certified Equipment
  - Purchase CTI Certified Equipment
- Engineers & Owners can Rest Assured that Their Equipment will Perform as Rated

Find EVAPCO & Other Manufacturer’s CTI Certified Products on www.cti.org

The Value of CTI Certification

eco-Air Series Specification Language:

- If the Units are Suspected to be Deficient in Thermal Capacity, the Owner has the Right to Request a Dry Mode Field Thermal Performance Test Per CTI ATC-105DS, at Their Own Expense.
- If the Test Proves a Deficiency in Performance, the Manufacturer:
  - Shall Reimburse the Owner for the Cost of the Test
  - Shall Absorb the Costs to Make Corrective Measures (without Exceeding Specified HP)
  - Shall Pay for a Re-Test
  - Shall Provide New Units if the Retest Still Shows Deficiency



Wilson E. Bradley Research & Development Center
Taneytown, MD

Contact Information:

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Please submit your answer in the upcoming poll

What is one key benefit of Evaporative and Dry Cooling compared to cooling tower systems?

A
- Higher water usage

B
- Significant water savings

C
- Lower efficiency

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Thermal Performance of Evaporative and Dry Cooling Systems

Q&A

Please submit any questions through the Question Window on your GoToWebinar interface, directing them to Chiller & Cooling Best Practices Magazine. Our panelists will do their best to address your questions and will follow up with you on anything that goes unanswered during this session.

Thank you for attending!

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Tom Jenkins, PE
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