Best Practices for Hybrid Systems for Capacity & Efficiency Enhancement of Combustion Turbines During Hot Weather

By Don Shepherd – Caldwell Energy Company

Sponsored by:

Turbine Inlet Cooling Association (TICA)

April 8, 2015; 1 PM (U.S. Central Time)

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Introductions

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Who is TICA?

- The Turbine Inlet Cooling Association (TICA) promotes the development and exchange of knowledge related to gas turbine inlet cooling
- The TICA website is one-stop source of TIC technical information, including Installation Database & Performance Calculator
- TICA is a non-profit organization.

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TICA Member Benefits

- Access to full/detailed version of TIC Installation Database
- Access to full/detailed version of the TIC Technology Performance Calculator
- GT Users get access to the TIC Forum
- Suppliers have access to advertisement space on the TICA Website and access to booths at various electric power trade shows

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List of Series of Turbine Inlet Cooling Best Practices Webinar Presentations

- ***June 11, 2014: Wetted-Media Evaporative Cooling***
- ***August 9, 2014: Fogging***
- ***October 8, 2014: Chiller Systems***
- ***January 22, 2015: Thermal Energy Storage***
- ***February 11, 2015: Wet Compression***
- ***April 8, 2015: Hybrid Systems***

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Agenda:

- Why Cool Combustion Turbines (CT)
- What are Hybrid Systems
- Best Practices for Using Hybrid Systems
- Maintaining your Hybrid System

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Unfortunate Fundamental Characteristics of All Combustion Turbine Power Plants

- During hot weather, just when power demand is at it's peak…….

1. CT Total Power output decreases up to 35% below rated capacity
   (Extent of the decrease depends on the CT design)

2. Efficiency decreases leading to increased fuel consumption (heat rate) and emissions per kWh……..up to 15% more fuel consumed
   (Extent of the decrease depends on the CT design)

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Why CT Power Output Capacity Decreases with Increase in Ambient Temperature?

- Power output of a turbine is proportional to the mass flow rate of hot gases from the combustor that enter the turbine
- Mass flow rate of combustor gases is proportional to the flow rate of the compressed air that enters the combustor
- Compressors provide compressed air and are volumetric machines, limited by the volumetric flow rate of inlet air they can pull or suck in
- As ambient temperature increases, the air density decreases. This results in a decrease of the mass air flow rate
- Reduced mass flow rate of inlet air reduces the mass flow rate of the combustor gases and hence reduced power out put of turbine

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Why CT Efficiency Decreases with Increase in Ambient Temperature?

- Compressor of a CT system consumes almost two-third of the turbine's gross output
- Compressor requirement increases with increase in air temperature
- Increased power required by the compressor reduces the net electric power available from the CT system

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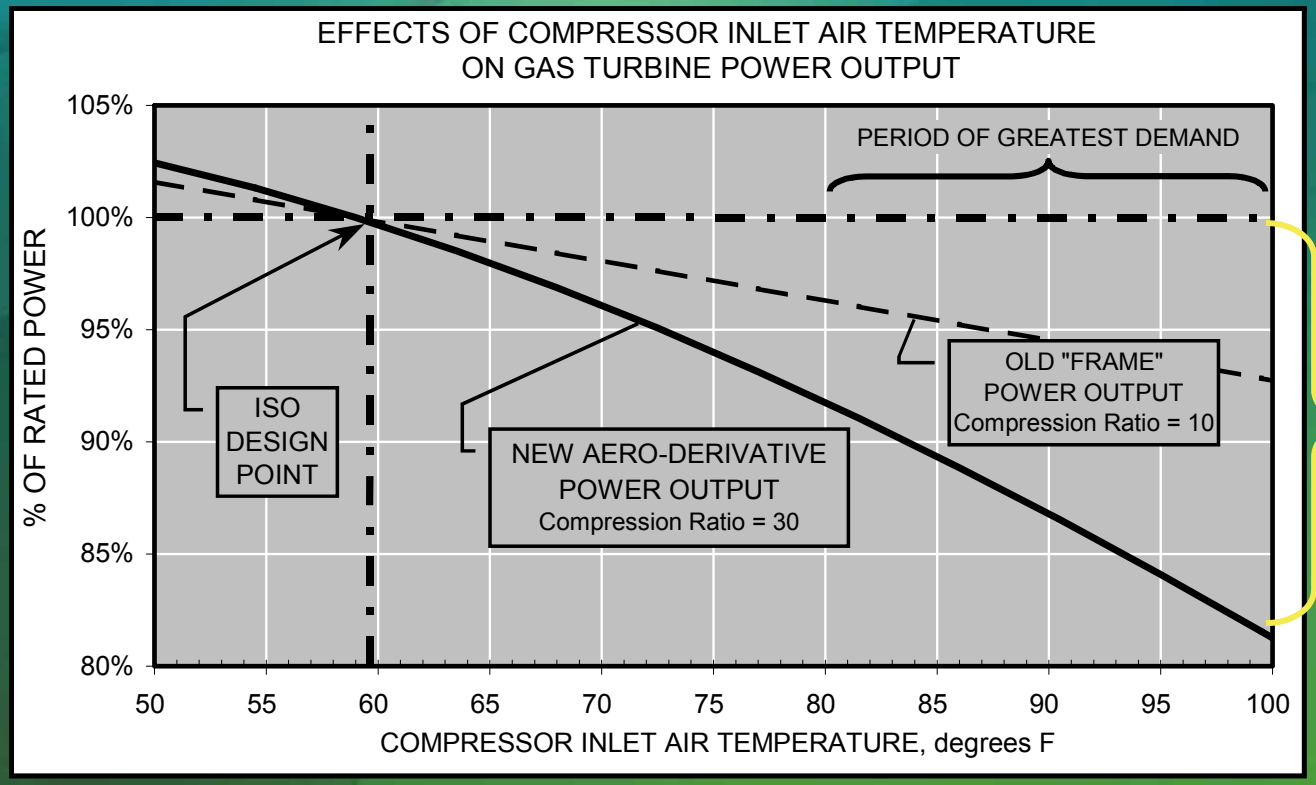
Effect of Hot Weather on CT Generation Capacity Depends on CT Design



Up to 19% capacity loss at peak demand for this CT

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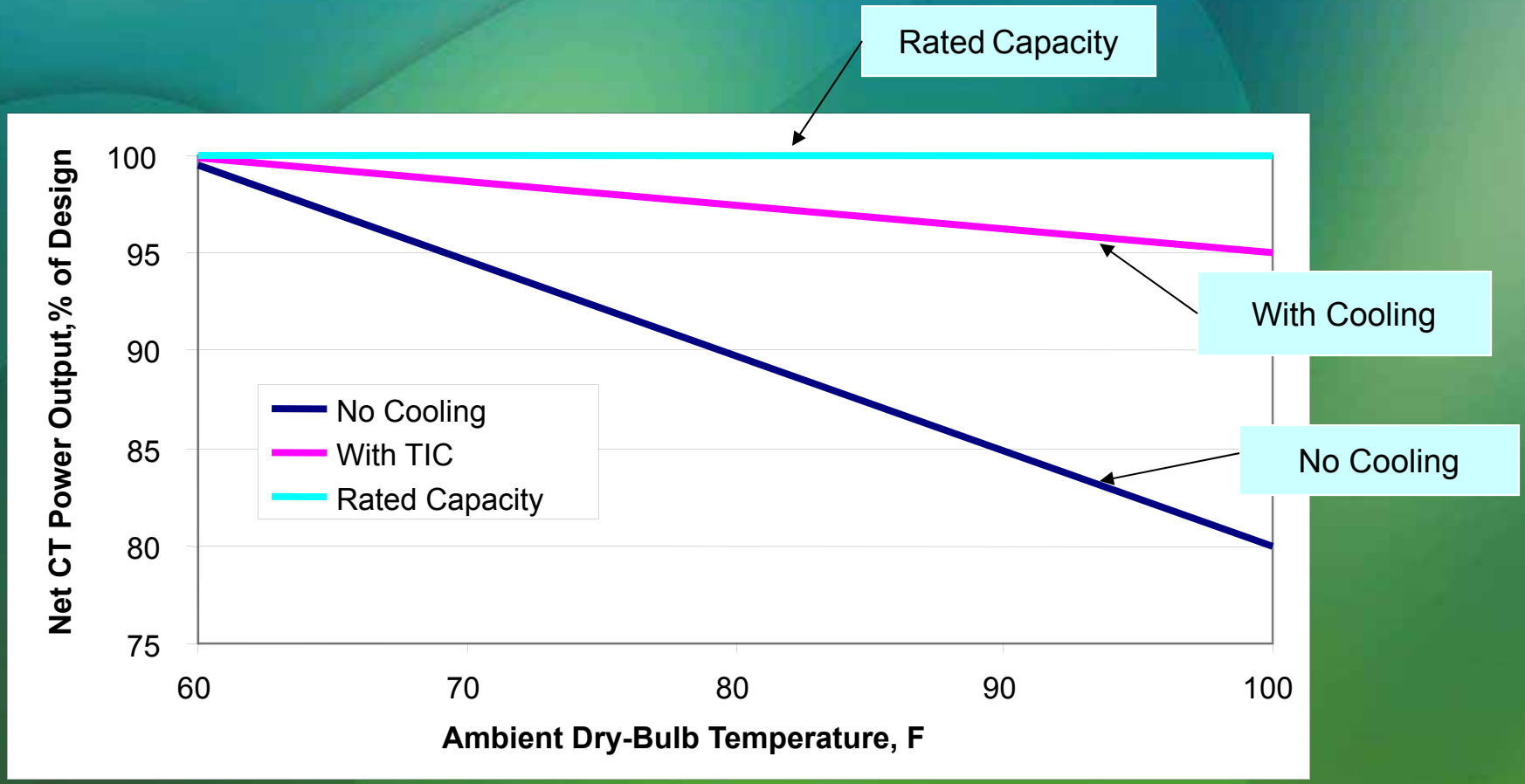
Turbine Inlet Cooling Overcomes the Effects of the CT Characteristic During Hot Weather



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Hybrid Inlet Cooling Systems

- Hybrid systems are systems that use more than one technology together to achieve the desired inlet condition
- Systems which draw elements from different technologies to:
  - Maximize Power Output
  - Minimize Heat Rate
  - Operational flexibility as economics change
  - Reduction of capital costs by using existing resources. …. Site Specific

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Inlet Cooling and Power Augmentation Technologies

- Evaporative (Media or Fogging)
- Chilling (Mechanical or Absorption)
- Thermal Energy Storage
- Wet Compression
- Hybrid

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Example Hybrid Inlet Cooling Systems

- Electric Chiller with TES
- Electric Chiller with Absorption Chiller
- Electric Chiller with IC Engine Chiller
- Any Technology with Wet Compression
- Chillers with Fogging

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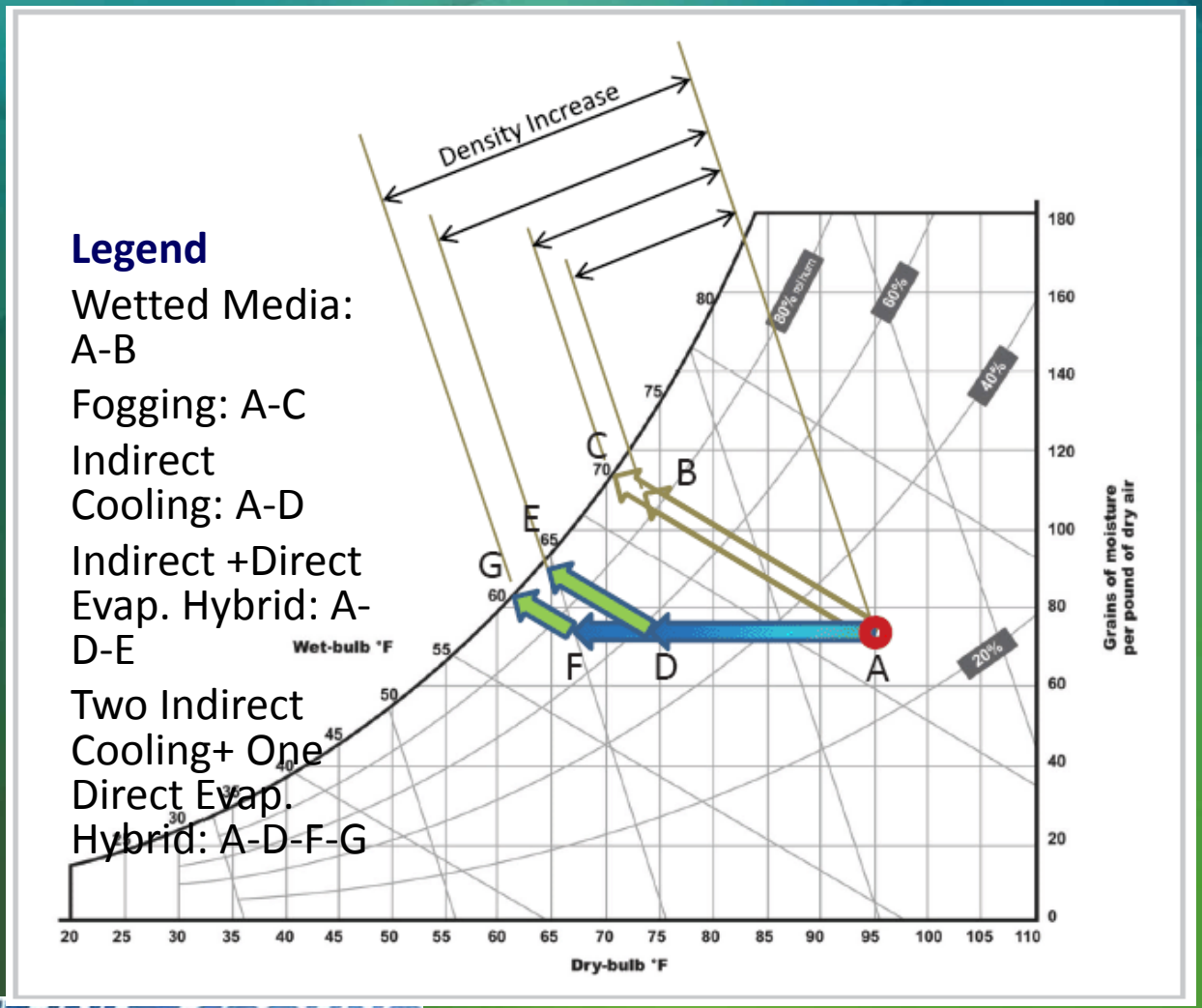
Pyschrometric Chart for Some TIC Examples



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Source: Schlom, L.A. , *Energy-Tech* June 2009

Energy Sources for Hybrid Inlet Chilling Systems

- Waste Heat
- Steam
- Fuel - Natural Gas, Fuel Oil, etc.
- Solar
- Other - LNG, Natural Gas, etc.

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Waste Heat as Energy Source

- Process Hot Water
- Exhaust Gas off back end of HRSG
- Heat Recovery from engine driven equipment (e.g. chillers !!!)

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Use Hybrid Concept to Support Auxiliary Systems …

- Generator Cooling
- Lube Oil Cooling
- Step-Up Transformer Cooling

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Examples of Hybrids

- Rolls Royce Trent 64 uses fogging and wet compression
- Rolls Royce Mehoopany uses chilling and wet compression
- Dominion Energy uses fogging and wet compression on 7EA's
- LM6000's uses chilling and wet compression

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Examples of Hybrids

Las Vegas Cogen

- LM6000's (4)
- TIC System
- Fogging followed by chillers to cool inlet air to 50°F
- Only fogging when ambient <70°F
- Chiller (absorption) alone when humidity is high

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Hybrid Systems Example

Calpine Clear Lake Cogeneration, Pasadena, TX (1999*)

Gas Turbines

- Three W501D (106 MW each)

Hybrid System

- Absorption chillers followed by mechanical chillers
- Absorption chillers (8,300 tons operating on hot water heated by HRSG exhaust) produce chilled water at 41^{0}F and mechanical chillers (1,200 tons) operating in series further reduce the chilled water temperature to 38^{0}F for storage in a 107,000 Ton-hrs TES tank

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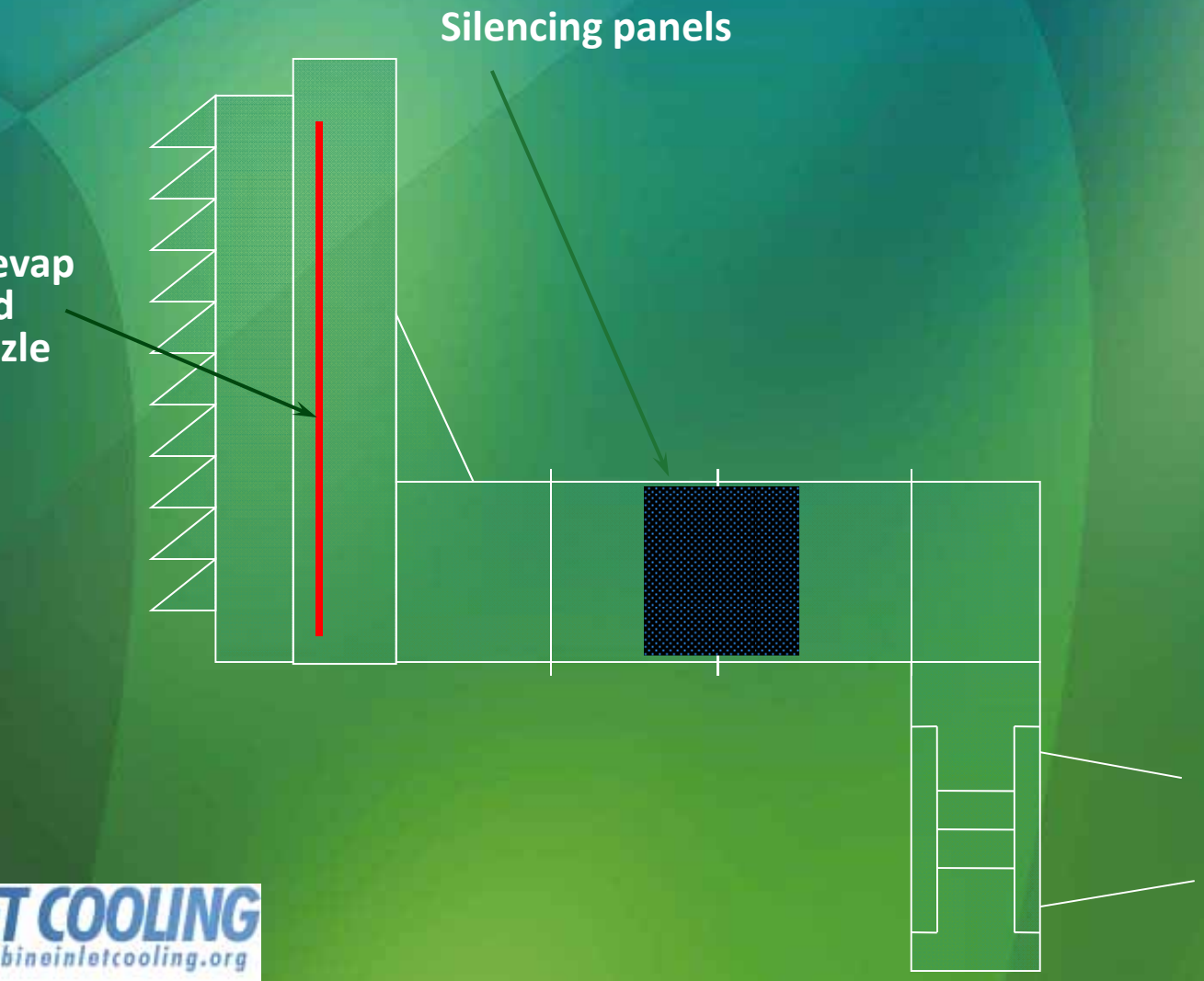
Cooling Location



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Maintaining your Hybrid System

- Daily Inspections
- Monthly Inspection
- Yearly Inspections

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System Inspection (Daily)

- Pump seals both water and oil/grease
- System leaks
- Operating pressures
- Instruments
- Noise
- Vibration

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System Inspection (Monthly)

- All Items for weekly
- Water quality
- Amp Draws on equipment
- Belts worn?
- Hoses

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Chilled Water Pumps

System Inspection (yearly)

- Duct work condition
  - Materials of construction
    - Coating systems
  - Drain System
  - Obstructions
- Water Source
- Control System Integration
- Nozzles
- Evaporative media condition

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System Inspection (yearly) conti.

- TES Tank Conditions
  - Materials of construction
    - Coating systems
- Instruments
- Chiller Tubes
- Winterization

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Coil Inspections (downstream)

System Components

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Thermal Energy Storage

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Thermal Energy Storage Tank With Ice Makers

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Chiller Building

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Recap

- Use equipment to its maximum efficiency
- Use existing equipment as much as possible
- Use waste heat source available
- Maintain the equipment
- Maintain the water quality
- Be creative

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Thank You!

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