Best Practice, Direct Evaporative Cooling Technology for Combustion Turbine

By Pat Zeller, Munters Corporation

Sponsored by:

Turbine Inlet Cooling Association (TICA)

June 11, 2014; 1 PM (U.S. Central Time)

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Access Code 2603587 #
Welcome & Introduction

• Webinar Series co-sponsored by Turbine Inlet Cooling Association

• Industry (end users, developers, engineers, etc.) looking to optimize and improve power generation and efficiency of the turbine inlets.
Introductions

Pat Zeller, GTEC National Sales
Munters Corporation

Annette Dwyer, Chair, TICA
Munters Corporation Technical Product Manager
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.
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 information space on the TICA Website and access to booths at various electric power trade shows

Become a Member Today!!!
Turbine Inlet Cooling Technologies

Webinar Schedule

June 11, 2014
  • Best Practices for Wetted-Media Evaporative Cooling

August 13, 2014
  • Best Practices for Fogging Evaporative Cooling

October 8, 2014
  • Best Practices for Chiller Systems

December 12, 2014
  • Best Practices for Thermal Energy Storage

February 11, 2015
  • Best Practices for Wet Compression

April 8, 2015
  • Best Practices for Hybrid Systems
Webinar Procedures

To avoid background noise, please mute your line

Please submit questions during the presentations by typing them into the “chat” window area of the screen

After the featured presentation is complete, we will answer your submitted questions

You may receive an online survey immediately following the webinar. We would appreciate your participation to:

• Provide feedback on webinar series
• Suggest other topics and speakers
Presentation Agenda

- Why turbine inlet cooling
- Direct Evaporative Cooling for Combustion Turbines
- How Direct Evaporative Cooling Works
- Where Direct Evaporative Cooling Works
- Examples
- Design Considerations
- Water Management
- Technology Comparison
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 output of turbine.
Smaller Capacity Systems More Sensitive to Ambient Temperature

Capacity Loss of over 21% from ~10,750 kW to ~8,500 kW

Efficiency loss of over 8% from HR of ~11,100 to ~12,000 Btu/kWh

Source: Solar Turbines
Turbine Inlet Cooling Overcomes the Effects of the CT Flaws During Hot Weather
Direct Evaporative Turbine Inlet Cooling (TIC) provides a cost-effective, energy-efficient, and environmentally beneficial means to enhance power generation capacity and efficiency of combustion/gas turbines during hot weather.
How Direct Evaporative Cooling Works
How Direct Evaporative Cooling Works, Dry Bulb
How Direct Evaporative Cooling, Dry Bulb
How Direct Evaporative Cooling Works, Wet Bulb
How Direct Evaporative Cooling Works, Wet Bulb
How Direct Evaporative Cooling Works

Rain or Fog

Saturation Line or 100% Relative Humidity
Moisture Content in Air

FOUR EQUAL SIZE CONTAINERS AT 80F WILL HAVE DIFFERENT MOISTURE CONTENTS AT DIFFERENT RELATIVE HUMIDITIES

100% RH 50% RH
W=.022 W=.011

20% RH 10% RH
W=.0044 W=.0022

Dry Bulb Temperature, Deg. F

Humidity Ratio, lb Moisture/lb Dry Air

0.000 0.005 0.010 0.015 0.020 0.025 0.030

10 20 30 40 50 60 70 80 90 100 110 120
As We Cool Air Close to the Wet Bulb Line

Dry Bulb Temperature, Deg. F

Humidity Ratio, lb Moisture/lb Dry Air

Wet Bulb Depression = 110 - 70
Direct Evaporative Cooling of an Airstream

Humidity Ratio, lb Moisture/lb Dry Air

Dry Bulb Temperature, Deg. F

Cooling = 0.8 \times \frac{110 - 70}{70} = 7.8\%
Direct Evaporative Cooling of an Airstream
Cooling Efficiency is the Same Regardless of the Starting Point

A 90% Effective Evaporative Cooler Will Cool 90% of the Wet Bulb Depression Regardless of the Starting Point
As the Day Temp Heats Up

Shreveport, LA, July 18-31, 1993
Dry-Bulb, Wet-Bulb & Relative Humidity

Date in July

Temperature, F
Relative Humidity, %
Even in Humid Areas, Direct Evaporative Cooling Works

Shreveport, LA, July 18-31

Dry Bulb Temperatures Entering and leaving a 90% Pad

Temperature, F

Date in July

Outside Air
Cooled Air
Wet Bulb
Looking at Tampa Florida

Tampa Florida, Month of July
Turbine Performance

Performance of 100 MW CT in Tampa, Month of July with 90% Effective Evaporative Cooler
Looking at Las Vegas Nevada

Las Vegas Month of July

- Outdoor Temperature
- Cooled Air Temperature

TURBINE INLET COOLING
ASSOCIATION
Turbine Performance

Performance of 100 MW CT in Las Vegas, Month of July with 90% Effective Evaporative Cooler
Direct Evaporative Cooler Anatomy
Construction & Examples
Location of the Evaporative Cooler

Filters | Evaporative Media | Mist Eliminator

Silencer

Pump Skid
Examples
Examples
Media Upstream of Filters

Media should have edge coat treatment

Filters should be tolerant to higher RH
Examples
Simple, but Require Engineering, Experience & Robust Design

Design & Construction Considerations

• Face velocity
• Materials of construction
• Material gauge
• Media type
• Water source
• Valve function and locations
• Drains and overflows
• Air bypass
• Sump water management
Simple, but Require Engineering, Experience & Robust Design

Design
Design around 500 ft/min (most efficient), dwell time
If exceed 650’/min, explore moisture elimination
In some applications, may determine air tunnel size

Specification
Full stainless construction is the best
Fully welded basins, no bolted panels
Appropriate steel gauges
Media TURBOdek or CELdek with edge coating
Proper water flow
Simple, But Require Engineering, Experience & Robust Design

Media is the heart of Evaporative Cooling
Drift Elimination

- 99.9% down to 50 microns
Drift Elimination

• Highest Efficiency, 99.9% to 25 microns
• Wide Velocity Range
• Low Pressure Drop
• Need Less room in Air Travel Direction
Simple, But Require Engineering, Experience & Robust Design
Simple, but Require Engineering, Experience & Robust Design

Areas "starved" for water will be the first to clog or soften.
Simple, but Require Engineering, Experience & Robust Design
Air follows the path of least resistance, think teenagers
Simple but Requires Engineering, Experience & Robust Design
Water Quality & Management

Continuous bleed / and or flush and dump used for scale control

• Scale inhibitors not recommended
• Bleed is major method of control
• Biocides not recommended, no oxidizing biocides allowed
• Corrosion inhibitors not recommended
• ALL SS and plastic construction
• Straight RO water is not recommended but a blend is okay
Water Quality and Management

• Chemicals dry out on the media each time the water is turned off, causing the chemicals to lose their effectiveness.

• Some chemicals are corrosive and will harm pads and turbine components.

• Some chemicals contribute to microbial growth.

• Many chemicals cause environmental problems.

• Those who use chemicals often feel they can neglect other maintenance requirements.
## Water Quality & Management

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reverse Osmosis</td>
<td>High Cost&lt;br&gt;High Maintenance cost&lt;br&gt;Minimal Bleed off</td>
</tr>
<tr>
<td>Demineralization</td>
<td>High Cost&lt;br&gt;Requires handling chemicals&lt;br&gt;Minimal Bleed off</td>
</tr>
<tr>
<td>Zeolite Softening</td>
<td>Changes Calcium Carbonate to Sodium Carbonate&lt;br&gt;Does not remove Silica&lt;br&gt;Requires bleed-off</td>
</tr>
<tr>
<td>Acid Addition</td>
<td>Typically use concentrated sulphuric acid&lt;br&gt;Makes Calcium and Magnesium less soluble&lt;br&gt;Requires continuous injection of acid&lt;br&gt;Dangerous to handle/ can add too much acid&lt;br&gt;Requires bleed-off</td>
</tr>
<tr>
<td>Crystal Modifiers</td>
<td>Requires continuous injection of chemical&lt;br&gt;Leaves a soft sludge residue that can blow downstream</td>
</tr>
<tr>
<td>Sequesterants</td>
<td>Require addition of sodium hexametaphosphate&lt;br&gt;Encourages algae growth</td>
</tr>
</tbody>
</table>
Water Quality & Management

**LIMITS FOR MAKE-UP WATER ANALYSIS**

The following water quality is established for evaporative cooler water make-up. This water can then be cycled up 2 to 6 cycles to obtain the following stability indices.

- Langelier Index = 0.5 + 0.25
- Ryznar Index = 6.0 + 0.5
- Puckorius Index = 6.5 + 0.5

**CONSTITUENT**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Allowable*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Hardness (as CaCO3)</td>
<td>50 - 150 PPM</td>
</tr>
<tr>
<td>Total Alkalinity (as CaCO3)</td>
<td>50 - 150 PPM</td>
</tr>
<tr>
<td>Chlorides (as Cl)</td>
<td>&lt;50 PPM</td>
</tr>
<tr>
<td>Silica (as SiO2)</td>
<td>&lt;25 PPM</td>
</tr>
<tr>
<td>Iron (as Fe)</td>
<td>&lt;0.2 PPM</td>
</tr>
<tr>
<td>Oil and Grease</td>
<td>&lt;2.0 PPM</td>
</tr>
<tr>
<td>Conductivity</td>
<td>&lt;750 μmhos</td>
</tr>
<tr>
<td>Suspended Solids</td>
<td>&lt;5 PPM</td>
</tr>
<tr>
<td>pH</td>
<td>6.0 to 8.5</td>
</tr>
</tbody>
</table>

* Need to be evaluated as a system, not in isolation
Water Quality & Management
Remote Sump Watermanagement
Remote Sump Water Management
Water Quality & Management

• We want your system to operate as designed and for your Media Engine to last as long as possible!!!

• PLEASE use Munters experience and chemists to analyze your site’s water more often than not………we make it easy!

Water is the life of our system and we recommend a full water analysis. Project can submit a written water report via the local water municipality or through a water sample. Please submit:

Report to Dan Schumacher
dan.schumacher@munters.com

Water Sample to Southern Analytical Laboratories, Inc
Attn: Travis Wright (for Munters Corp)
110 Bayview Boulevard,
Oldsmar, FL 34677
tel: 813-855-1844
Low Maintenance

Spray system
• Check water distribution, qtr
• Remove top media & clean spray holes, annual

Conductivity Controller & Bleed
• Clean probes from scale, annual
• Test bleed valve (adjusting conductivity setting), annual

Sump Water Level
• Look for proper water level and/or signs of over filing, annual

Pump Permissive
• Verify pump permissive and overflow switch operate properly, annual
## Water Usage

80 MW Turbine with 500,000 cfm, Arid Climate

<table>
<thead>
<tr>
<th></th>
<th>Softened Water</th>
<th>Moderate Water</th>
<th>Hard Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporation, GPM</td>
<td>180</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>Bleed, GPM</td>
<td>20</td>
<td>80</td>
<td>180</td>
</tr>
<tr>
<td>TOTAL</td>
<td>200</td>
<td>260</td>
<td>360</td>
</tr>
</tbody>
</table>
How Direct Evaporative Cooling Compares

Utilities Example for 100 MW CT in Tampa, FL

<table>
<thead>
<tr>
<th></th>
<th>Media</th>
<th>Fog</th>
<th>Mechanical Chilling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deg of Cooling</td>
<td>12.6 F</td>
<td>13.3 F</td>
<td>44 F</td>
</tr>
<tr>
<td>Water Evaporated</td>
<td>13 GPM</td>
<td>13.6 GPM</td>
<td>136 GPM (at Cooling Tower)</td>
</tr>
<tr>
<td>Blow Down</td>
<td>4 GPM</td>
<td>6.5 GPM (at RO plant)</td>
<td>4.5 GPM at Cooling Tower</td>
</tr>
<tr>
<td>Parasitic Power Loss</td>
<td>10 kW</td>
<td>27 kW</td>
<td>3131 kW</td>
</tr>
<tr>
<td>Insertion loss</td>
<td>0.3”wg</td>
<td>0.05”wg</td>
<td>1.0”wg</td>
</tr>
</tbody>
</table>
How Direct Evaporative Cooling Compares

Utilities Example for 100 MW CT in Las Vegas

<table>
<thead>
<tr>
<th></th>
<th>Media</th>
<th>Fog</th>
<th>Mechanical Chilling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deg of Cooling</td>
<td>37 F</td>
<td>39 F</td>
<td>57 F</td>
</tr>
<tr>
<td>Water Evaporated</td>
<td>35 GPM</td>
<td>37 GPM</td>
<td>78 GPM (at Cooling Tower)</td>
</tr>
<tr>
<td>Blow Down</td>
<td>12 GPM</td>
<td>18 GPM (at RO plant)</td>
<td>4 GPM</td>
</tr>
<tr>
<td>Parasitic Power Loss</td>
<td>10 kW</td>
<td>75 kW</td>
<td>2250 kW</td>
</tr>
<tr>
<td>Insertion loss</td>
<td>0.3”wg</td>
<td>0.06”wg</td>
<td>1.0”wg</td>
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</table>
Low Maintenance

Design
Design around 500 ft/min (most efficient), dwell time
If exceed 650’/min, explore moisture elimination
In some applications, may determine air tunnel size

Specification
Full stainless construction is the best
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Appropriate steel gauges
Media TURBOdek or CELdek with edge coating
Proper water flow
Why Use Direct Evaporative Cooling for Turbine Inlets

One of the most cost effective solutions

- Lowest first install cost
- Low operating costs
- Low maintenance cost

Simple

- To understand
- To design
- To install
- To maintain

1000’s of successful installations Worldwide
Thank You
And Don’t Forget to Join TICA