Combustion Turbine Inlet Cooling using Direct Evaporative Cooling

By Pat Zeller, Munters Corporation

Sponsored by:
Turbine Inlet Cooling Association (TICA)

August 22, 2012; 1 PM (U.S. Central Time)
Call-In Number: 1 877 406 7969
Access Code: 4147918 #
Introductions

Trevor Richter
  Chairman, TICA
  Stellar Energy Inc.

Pat Zeller
  Munters Corporation
The Turbine Inlet Cooling Association (TICA) promotes the development and exchange of knowledge related to gas turbine inlet cooling.

The TICA website is a 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

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Turbine Inlet Cooling Technologies

Webinar Schedule

- August 22, 2012: Wetted-Media Evaporative Cooling
- October 18, 2012: Fogging
- December 19, 2012: Chiller Systems
- February 13, 2013: Thermal Energy Storage
- April 17, 2013: Wet Compression
- June 19, 2013: Hybrid Systems

All Webinars start at 1 PM (U.S. Central Time)
Agenda:

- Why Cool Turbine Inlets
- How Direct Evaporative Cooling Works
- Anatomy of Direct Evaporative Coolers
- Things to Consider in Evaporative Cooling of CT’s
- Water Quality and Usage
- Quick Compare to Other Cooling Technologies
- Why Direct Evaporative Cooling for Combustion Turbines
During hot weather, just when power demand is at its 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)
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 the turbine.
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
Effect of Hot Weather on CT Generation Capacity Depends on CT Design

Up to 19% capacity loss at peak demand for this CT
Turbine Inlet Cooling Overcomes the Effects of the CT Flaws During Hot Weather

![Graph showing the effect of ambient dry-bulb temperature on net CT power output. The graph compares 'No Cooling', 'With TIC', and 'Rated Capacity'. The y-axis represents net CT power output (% of design), and the x-axis represents ambient dry-bulb temperature (°F). The graph illustrates that cooling significantly improves the net CT power output at higher temperatures.](image-url)
Why Use Direct Evaporative Cooling for Turbine Inlets

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
How Direct Evaporative Cooling Works

Dry Bulb Temperature, Deg. F

Humidity Ratio, lb Moisture/lb Dry Air

Saturation Line
or
100% Relative Humidity

Rain or Fog
Moisture Content in Air

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

100% RH

W = .022

50% RH

W = .011

20% RH

W = .0044

10% RH

W = .0022

Dry Bulb Temperature, Deg. F

Humidity Ratio, lb Moisture/lb Dry Air

0.000

0.002

0.004

0.005

0.010

0.015

0.020

0.025

0.030
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

100% 50% 20% 10%
Direct Evaporative Cooling of an Airstream

Cooling = 0.80 \times (110-70) = 78\%
Direct Evaporative Cooling of an Airstream

Cooling = 0.90 \times (110 - 70) = 74
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, %

30 40 50 60 70 80 90 100

30 40 50 60 70 80 90 100

Dry Bulb
Wet Bulb
Relative Humidity
Even in Humid Areas, Direct Evaporative Cooling Works

Shreveport, LA, July 18-31
Dry Bulb Temperatures Entering and leaving a 90% Pad

Date in July

Temperature, °F

Outside Air

Cooled Air

Wet Bulb
Looking at Tampa Florida

Tamp Florida, Month of July

- **TURBINE INLET COOLING ASSOCIATION**
  - [turbineinletcooling.org](http://turbineinletcooling.org)
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

![Graph showing outdoor and cooled air temperatures for Las Vegas in July](image-url)
Turbine Performance

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

Evaporative Media  Mist Eliminator Filters

Silencers OR

Pump
Construction & Examples
Installations
Installations
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

Media is the heart of Evaporative Cooling
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
Simple, but Require Engineering, Experience & Robust Design
Water Quality and 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.
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 \pm 0.25  
Ryznar Index = 6.0 \pm 0.5  
Puckorius Index = 6.5 \pm 0.5

<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 (\mu)mhos</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 Water Management
## 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><strong>Evaporation, GPM</strong></td>
<td>180</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td><strong>Bleed, GPM</strong></td>
<td>20</td>
<td>80</td>
<td>180</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>200</td>
<td>260</td>
<td>360</td>
</tr>
</tbody>
</table>
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>3181 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>76 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>0.05”wg</td>
<td>1.0”wg</td>
</tr>
</tbody>
</table>
Low Maintenance

- Flush and dump water distribution headers - quarterly
- Clean strainer - quarterly
- Drain and protect from freezing - seasonally
- Change media - 2 to 5 yrs
- Replace or service pumps - 1 to 5 yrs
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