Combustion Turbine Inlet Cooling using Wet Compression

By Don Shepherd – Caldwell Energy Company

Sponsored by:

Turbine Inlet Cooling Association (TICA)

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Introductions

Annette Dwyer
- Munters Corporation
- Chairman, TICA

Don Shepherd
Caldwell Energy Company
TICA Board Member
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

Upcoming Webinar Schedule

- 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 Combustion Turbines (CT)
- How Wet Compression Works
- Components of Wet Compression systems
- Things to Consider before applying Wet Compression on CT’s
- Quick Comparison to Other Cooling Technologies
- Why Apply Wet Compression on Combustion Turbines
Unfortunate Fundamental Characteristics of All Combustion Turbine Power Plants

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 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

EFFECTS OF COMPRESSOR INLET AIR TEMPERATURE ON GAS TURBINE POWER OUTPUT

PERIOD OF GREATEST DEMAND

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

![Graph showing the effects of turbine inlet cooling on rated capacity during hot weather. The graph compares net CT power output with and without cooling under different ambient dry-bulb temperatures. The lines indicate the performance with and without cooling, showing a significant improvement with cooling, especially at higher temperatures.](image-url)
Why Use Wet Compression for Turbines

- Wet Compression (WC) provides a cost-effective and energy-efficient means to increase a CT's output during hot weather.
- Wet Compression is an environmentally beneficial means to enhance power generation capacity.
- Wet Compression is complementary to all other inlet cooling technologies.
- Wet Compression is highly reliable, available when needed, with very low maintenance requirements.
How it works: Four-fold effect

- Compressor Efficiency Dramatically Improved
  - Water inter-cools the CT compressor
- Mass flow enhancement
- Lower CDT allows more fuel to be fired (at constant firing temperature)
- Cools air to very near WBT @ bell-mouth
  - Adiabatic cooling of inlet air
  - Usually operated with an existing fogger, evap cooler, or chiller upstream

Overall net impact: 12-15 MW on a GE 7EA, simple cycle
WC Performance Effects

Base Case: 85% fogging @ 95 / 75°F

Air → Comp → Turb → Exhaust

Fuel

NOx 42 ppm

Most plants will not exceed 40 tons per year of “Criteria Pollutants” (NOx, SOx, CO, UHC), therefore not triggering NSR / PSSD

1.75% Wet Compression:

Air → Comp → Turb → Exhaust

Fuel +13%

NOx 38 ppm
Flow + 2.5%
Enthalpy + 10%

Power +18%
Wet Compression Nozzle Location

Typical Fogging nozzle location

Silencing panels

Remove elbow for access, and line wetted surfaces w/ SS lining
Array Manifold 7EA
Manifold Installation
Duct Work Treatment LM’s
Wet Compression Arrays LM2500
VFD Wet Compression Pump Skid
Advantages With Nessie High Pressure Water Pumps

50-100/90

Axial piston pump:
- Based upon well know principle from oil hydraulics.
- Swash plate type with fixed displacement.
- Various displacements in same frame.

- High efficiency
- Compact design
- 50 - 100 cc/rev
- 68 – 145 litre/min output flow
- 160 Bar Continuous pressure
- AISI 316 Stainless Steel Housing
Wet Compression Install Considerations

- Duct work condition
  - Materials of construction
  - Drain System
  - Obstructions
- Lube Oil System Capacity
- Generator Capacity
Wet Compression Install Considerations

- Rotor Grounding
- Guide vane
- Water Source
- Control System Integration
- 18 years of patented WC experience shows no failures
- This is not “spray and pray”
Inlet Icing

• Although power augmentation not required in cold ambient conditions, a WC system could operate down to ~41 F, without risk of bell-mouth icing.
  • Studies show maximum bell-mouth temperature drop is <9 degrees.

• Most operators use temperature-based permissive, such as 45, 50, 55, or 59 (F)
  • Caldwell provides this low-temp permissive at the time of controls commissioning.
Control System Integration

- HMI for normal system operation
  - Start-up, operation, shut down
- Emergency response
  - Hardwired CWCT Trip on CT Trip Signal
- Fuel step change to CT on CWCT Trip
- Emission control interface with injection systems or dry low NOx combustion
# How Wet Compression Compares

100 MW CT in Houston (98F/75F)

<table>
<thead>
<tr>
<th></th>
<th>Fog</th>
<th>Media</th>
<th>Mechanical Chilling</th>
<th>Wet Compression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deg of Cooling</td>
<td>22 F</td>
<td>20 F</td>
<td>50 F</td>
<td>NA</td>
</tr>
<tr>
<td>Water Evaporated</td>
<td>28 GPM</td>
<td>25 GPM</td>
<td>95GPM (at Cooling Tower)</td>
<td>100 GPM</td>
</tr>
<tr>
<td>Blow Down</td>
<td>5 GPM</td>
<td>10 GPM</td>
<td>42 GPM</td>
<td>15 GPM</td>
</tr>
<tr>
<td>Parasitic Power Loss</td>
<td>45 kW</td>
<td>10 kW</td>
<td>4250 kW</td>
<td>150 kW</td>
</tr>
<tr>
<td>Insertion loss</td>
<td>0.1”wg</td>
<td>0.4”wg</td>
<td>1.2”wg</td>
<td>0.25 WG</td>
</tr>
<tr>
<td>Increased MW</td>
<td>5.2</td>
<td>4.8</td>
<td>12</td>
<td>14</td>
</tr>
</tbody>
</table>
### Table 1: Performance Comparison of Various Combustion Turbines

<table>
<thead>
<tr>
<th>Combustion Turbine</th>
<th>Siemens W501FC</th>
<th>Siemens V84.2</th>
<th>GE LM2500PE</th>
<th>GE Frame 6B</th>
<th>SWPC W501D5A</th>
<th>Alstom GT-24</th>
<th>GE Frame 7EA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overspray, %</td>
<td>1.3</td>
<td>1.0</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1.2</td>
<td>1.5%</td>
</tr>
<tr>
<td>Compressor Discharge</td>
<td>90</td>
<td>50</td>
<td>Data not available</td>
<td>50</td>
<td>100</td>
<td>48</td>
<td>90</td>
</tr>
<tr>
<td>Temperature Reduction, °F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Flow Increase, %</td>
<td>N.D.</td>
<td>N.D.</td>
<td>4</td>
<td>8.2</td>
<td>13.2</td>
<td>5.5</td>
<td>11.5%</td>
</tr>
<tr>
<td>Change in Base Load Firing Temperature, °F</td>
<td>No Change</td>
<td>No Change</td>
<td>No Change</td>
<td>No Change</td>
<td>No Change</td>
<td>No Change</td>
<td>No Change</td>
</tr>
<tr>
<td>CT Power Increase, MW</td>
<td>17</td>
<td>5.2</td>
<td>1.6</td>
<td>3.3</td>
<td>15</td>
<td>15.5</td>
<td>14.9</td>
</tr>
<tr>
<td>Steam Turbine Power Increase, MW</td>
<td>Simple Cycle</td>
<td>Simple Cycle</td>
<td>-.5</td>
<td>0.3 (est.)</td>
<td>2 (est.)</td>
<td>1.8(est.)</td>
<td>Simple Cycle</td>
</tr>
<tr>
<td>CT Heat Rate Improvement, %</td>
<td>N.D.</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1.05%</td>
</tr>
<tr>
<td>NOx Info</td>
<td>-10%</td>
<td>N.D.</td>
<td>-14%</td>
<td>DLN</td>
<td>DLN</td>
<td>NoChange</td>
<td>-24%</td>
</tr>
</tbody>
</table>
Why Use Wet Compression

- One of the most cost effective solutions
  - Lowest first install cost
  - Low operating costs
  - Low maintenance cost
  - Complementary to other cooling methods
  - 10% to 20% Increase in output
  - Better Heat Rate on Simple Cycle unit

- Simple
  - To understand
  - To maintain

- 100’s of successful installations Worldwide
Low Maintenance

- Drain and protect from freezing – seasonally
- Clean filters once a year
- Change nozzles 4 to 5 yrs
- Replace or service pumps – 3 to 5 yrs
- Calibrate Instruments once a year
Thank You
And Don’t Forget to Join TICA