Absorption Refrigeration Cycle Inlet Conditioning

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The Problem

**Why chill?**
- Increased fuel efficiency (fewer emissions)
- Power production capability and turbine efficiency increase as inlet temperature decreases
- Electricity demand is highest on the hottest days, but as ambient temperature increases air becomes less dense, therefore less power can be produced
  - **Power is also the most valuable at these times so recovering power lost due to high ambient provides a significant Return on Investment**

**Why heat?**
- Anti-icing is required in icing conditions to prevent damage to turbine blades
- Aero-derivatives:
  - Anti-ice systems typically heat air 10 degrees F above ambient temperature, however power capability decreases as temperature decreases below the “sweet spot” so additional heating enables higher power output
  - **At part load, heating of the inlet air improves heat rate and emissions**
- Frames:
  - Anti-icing is typically accomplished by using bleed air from the compressor. This results in a two-fold power reduction:
    1. As inlet temperature increases, power production capability decreases
    2. Bleed heat robs valuable compressed air from the combustor (**ARCTIC eliminates this need**)

![Graph showing generator output vs. ambient temperature](image-url)
The Solution

Why ARCTIC?

Operational Flexibility:

• Fast Start Capability:
  • On Aero units ARCTIC can be fully chilling or fully heating within 10 minutes of turbine fire
• Dispatch order:
  • By optimizing the heat rate at the desired power level, plant can be dispatched sooner when preference is given to heat rate
• Peaking profile:
  • Summer – Chill to enable maximum power
  • Winter – Heat (beyond anti-icing) to enable maximum power
• Load following:
  • Varies inlet air temperature to optimize output and heat rate, regardless of ambient temperature
  • Can enable maximum turndown to maintain a lb/hr emissions limitation
  • Ability to improve heat rate/emissions at part load conditions
• Base load:
  • Constant, maximum power across broad ambient temp range
• Dry Low Emissions:
  • Reduced fuel mapping (constant inlet temperature)
  • Emissions reduction (“Green” Plants)
  • For same NET power production as unit with mechanical chiller, less lb of NOx and CO2 produced
  • For same emissions as unit with mechanical chiller, more NET power available
How Does ARCTIC Work?

1. Ammonia-water solution is vaporized in the HRVG
2. The rectifier separates vapor ammonia out the top and liquid water to the bottom
3. The condenser turns the vapor ammonia to liquid
4. The liquid ammonia gathers in the ammonia receiver
5. The high pressure liquid ammonia is expanded in the TCV
6. The ammonia is evaporated, chilling the water-glycol mixture
7. The water-glycol mixture passes through the TIAC coils, chilling the inlet air
8. The vapor ammonia is recombined with the water from the rectifier
9. The ammonia-water solution is pumped back into the HRVG
10. The cycle repeats

Abbreviations:
TIAC – Turbine Inlet Air Conditioning
TCV – Temperature Control Valve
HRVG – Heat Recovery Vapor Generator
Reuses waste product (exhaust energy)
For same NET power as mechanical chiller, less lb of NO\textsubscript{x} and CO\textsubscript{2}
Ammonia is naturally occurring, readily available, and inexpensive
Ammonia is environmentally friendly:
- Ozone Depletion Potential (ODP) = zero
  - R-134a = 0
  - R-123 = 0.02
- Global Warming Potential (GWP) = zero
  - R-134a = 1300
  - R-123 = 90
Better heat rate = more efficient use of fuel
Water recovery from inlet coil condensate
Morning Ambient Temperature: 34°F
Afternoon Ambient Temperature: 64°F
Although the ambient temperature increased 30°F, compressor inlet temperature only varied 6°F

Skid changes modes based on ambient temperature
Hands-off, automated transition
Only system available that performs both inlet conditioning functions
ARCTIC Skid – 2000 Ton Unit

- Skid mounted PLC/MCC
- Closed-loop
- Redundant pumps
- 40’ long x 14’ wide
- No large components or compressors (eliminating 4160V switchgear)
- Low maintenance/operation costs

Rectifier

LP Pumps

HP Pumps

PLC/MCC Panel
Simple Cycle Units
Simple Cycle – ARCTIC Output

Percent of Rated Output (%) vs. Ambient Temperature (°F)

- 7FA.04 Base
- LM6000 Base
- SGT6 5000F(4)
- 7FA.04 ARCTIC
- LM6000 ARCTIC
- SGT6 5000F(4) ARCTIC

80°F Maximum Wet Bulb Temperature
Sea Level

Mechanical Chilling
Evap Cooling
Simple Cycle – ARCTIC Heat Rate

Ambient Temperature (°F)

Percent of Rated Heat Rate (%)
## GE Frame Simple Cycle Summary

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>Evaporative Cooling</th>
<th>Mechanical Chiller</th>
<th>ARCTIC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output Gain</strong></td>
<td>158,107</td>
<td>8.7%</td>
<td>14.8%</td>
<td>21.1%</td>
</tr>
<tr>
<td><strong>Heat Rate Reduction</strong></td>
<td>10,310</td>
<td>-0.1%</td>
<td>3.2%</td>
<td>-2.2%</td>
</tr>
<tr>
<td><strong>Efficiency Improvement</strong></td>
<td>33.1%</td>
<td>0.0%</td>
<td>-1.0%</td>
<td>0.8%</td>
</tr>
</tbody>
</table>

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<th>ARCTIC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output Gain</strong></td>
<td>192,594</td>
<td>7.9%</td>
<td>10.6%</td>
<td>16.1%</td>
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<tr>
<td><strong>Heat Rate Reduction</strong></td>
<td>10,085</td>
<td>-1.2%</td>
<td>2.1%</td>
<td>-2.8%</td>
</tr>
<tr>
<td><strong>Efficiency Improvement</strong></td>
<td>33.8%</td>
<td>0.5%</td>
<td>-0.8%</td>
<td>1.1%</td>
</tr>
</tbody>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Output Gain</strong></td>
<td>75,360</td>
<td>8.3%</td>
<td>15.0%</td>
<td>22.6%</td>
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<tr>
<td><strong>Heat Rate Reduction</strong></td>
<td>11,812</td>
<td>-1.8%</td>
<td>1.8%</td>
<td>-4.5%</td>
</tr>
<tr>
<td><strong>Efficiency Improvement</strong></td>
<td>28.9%</td>
<td>0.6%</td>
<td>-0.6%</td>
<td>1.5%</td>
</tr>
</tbody>
</table>

* Heat rates based on fuel HHV

- Based on a 100°F day with 35% Relative Humidity
- Mechanical Chiller parasitic load is based on 1.6 kW/ton
- ARCTIC parasitic load is based on 0.11 kW/ton
## GE Aero Simple Cycle Summary

<table>
<thead>
<tr>
<th>Model</th>
<th>Output Gain</th>
<th>Heat Rate Reduction*</th>
<th>Efficiency Improvement</th>
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</thead>
<tbody>
<tr>
<td><strong>LM6 PCS</strong></td>
<td>37,606</td>
<td>20.3%</td>
<td>28.1%</td>
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<tr>
<td></td>
<td>9,868</td>
<td>-4.6%</td>
<td>-0.2%</td>
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<tr>
<td></td>
<td>34.6%</td>
<td>1.8%</td>
<td>0.1%</td>
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<tr>
<td><strong>LM6 PGS</strong></td>
<td>43,887</td>
<td>13.8%</td>
<td>24.7%</td>
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<tr>
<td></td>
<td>9,793</td>
<td>-2.7%</td>
<td>2.5%</td>
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<td></td>
<td>34.9%</td>
<td>1.1%</td>
<td>-0.9%</td>
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<tr>
<td><strong>LM6 PHS</strong></td>
<td>41,653</td>
<td>7.7%</td>
<td>17.3%</td>
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<td>9,713</td>
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<td>1.8%</td>
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<td></td>
<td>35.1%</td>
<td>0.7%</td>
<td>-0.7%</td>
</tr>
<tr>
<td><strong>LMS PA</strong></td>
<td>93,917</td>
<td>4.0%</td>
<td>8.4%</td>
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<tr>
<td></td>
<td>9,011</td>
<td>-1.1%</td>
<td>-0.7%</td>
</tr>
<tr>
<td></td>
<td>37.9%</td>
<td>0.5%</td>
<td>0.3%</td>
</tr>
<tr>
<td><strong>LMS PB</strong></td>
<td>83,912</td>
<td>4.4%</td>
<td>11.2%</td>
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<tr>
<td></td>
<td>8,997</td>
<td>-1.3%</td>
<td>0.4%</td>
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<tr>
<td></td>
<td>37.9%</td>
<td>0.6%</td>
<td>-0.2%</td>
</tr>
<tr>
<td><strong>LM25 +G4</strong></td>
<td>26,006</td>
<td>13.7%</td>
<td>22.1%</td>
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<td></td>
<td>10,373</td>
<td>-3.1%</td>
<td>0.6%</td>
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<tr>
<td></td>
<td>32.9%</td>
<td>1.1%</td>
<td>-0.2%</td>
</tr>
</tbody>
</table>

* Heat rates based on fuel HHV

### Worst, Better, Best
- **Worst**
- **Better**
- **Best**

### Heat Rates
- Heat rates are based on fuel HHV.
These values are based on power production at the generator terminals minus the parasitic loads of the inlet conditioning and some SCR tempering loads.

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