COMBUSTION TURBINES
CHP TECHNOLOGIES
COLUMBIA GAS OF OHIO HOSTS:
COMBINED HEAT & POWER FOR
INDUSTRIAL, INSTITUTIONAL, AND COMMERCIAL
FACILITIES
JUNE 27, 2017

OCIEE The Ohio Center for Industrial Energy Efficiency

Presented by: Jon Green, Lathrop-Trotter

A CULTURE OF CUSTOMER CARE
SOLAR’S HISTORY

- 1927 founded - Solar Aircraft Company
- 1930s - Stainless Steel Exhaust Manifolds
- 1940s - Jet Engine Afterburners and Small Gas Turbines
- 1950s - Aerospace Industry and Shipboard Power Generation
- 1960s to today - Industrial Gas Turbines
“Simultaneous Production of Two Useful Forms of Energy from Same Source”
CHP ADVANTAGES

• Reliable Power Requirement
• Use of Thermal Energy
• Ratio of Thermal Energy to Electrical Energy (1.5:1)
• High Operating Hours
### BEFORE CHP

**36k lbm/hr Steam Example**

<table>
<thead>
<tr>
<th>ENERGY</th>
<th>ENERGY USAGE</th>
<th>ENERGY USAGE, MW</th>
<th>ENERGY INPUT, MW</th>
<th>SYSTEM EFFICIENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal</td>
<td>36 000 lbs/hr</td>
<td>10.7</td>
<td>13.1</td>
<td>82%</td>
</tr>
<tr>
<td>Electrical</td>
<td>5 460 kW</td>
<td>5.5</td>
<td>15.6</td>
<td>35%</td>
</tr>
<tr>
<td>Total</td>
<td>--</td>
<td>16.2</td>
<td>28.7</td>
<td>56%</td>
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TYPICAL INDUSTRIAL APPLICATION WITH CHP

- Steam Boilers
- Steam
- Direct Heat Utilization
- Gas Turbine
- Electricity Generator
- Electricity (Utility)
- Equipment

Fuel (Gas/Liquid)
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### CHP DIFFERENCE

#### Without CHP

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**43% Improvement in Efficiency**
More than 4,600 units in CHP Application

Solar Fleet fits most industrial thermal needs

Caterpillar: Non-Confidential
GAS TURBINE ADVANTAGES FOR POWER GENERATION

- High System Efficiency
- High Availability / Reliability
- Low Emissions / Beneficial Use of Natural Gas
- Project Economics / Reduced Energy Cost
- Low Life-Cycle Cost
- Quick Delivery and “On-Line” Capabilities
CHP SYSTEM WITH DIRECT HEAT TO DRYER
CHP SYSTEM WITH UNFIRED HEAT RECOVERY

12
CHP SYSTEM WITH SUPPLEMENTAL FIRING

- AIR INLET FILTER
- GENERATOR
- GAS TURBINE
- BYPASS EXHAUST SILENCER
- DIVERTER VALVE
- EXHAUST SILENCER
- SUPPLEMENTAL BURNER
- HEAT RECOVERY STEAM GENERATOR (HRSG)
- STEAM
HEAT / POWER RATIOS FOR CHP

Heat to Power: 6.5:1

Supplementary Firing

Combined Heat and Power System

Heat to Power: 1.5:1

2,800 °F

unfired

Solar Turbines
A Caterpillar Company
GAS TURBINES

Model | Centaur 40 | Centaur 50 | Mercury 50 | Taurus 60 | Taurus 65 | Taurus 70 | Mars 100 | Titan 130 | Titan 250
----- | ---------- | ---------- | ---------- | --------- | --------- | --------- | -------- | --------- | ---------
Power (MW) | 3.5 | 4.6 | 4.6 | 5.7 | 6.3 | 8.0 | 11.4 | 15.0 | 21.7

Note: Steam output ranges from an unfired basis to a max fired at 2000°F.
SOLAR GAS TURBINE FAMILIES

**Saturn 20**
1590 hp/1210 kWE
(Over 5040 Units)

**Centaur 40 & 50**
4700-6130 hp
3515-4600 kWE
(Over 3700 Units)

**Taurus 60**
7700 hp/5670 kWe
(Over 1990 Units)

**Taurus 70**
10,915 hp / 7965 kWe
(Over 860 Units)

**Mars 90 & 100**
13,220 – 15,900 hp
9450 – 11,350 kWe
(Over 1390 Units)

**Titan 130**
20,500 hp / 15,000 kWe
(Over 860 Units)

**Titan 250**
30,000 hp / 21,745 kWe
(Over 50 Units and Growing)
## Generator Set Performance - English Units

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>POWER MWe</th>
<th>HEAT RATE Btu/kW-hr</th>
<th>SITE SPECIFIC POWER - Thousand lbs/hr</th>
<th>STEAM PRODUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>EXHAUST TEMP ºF</td>
<td>EXHAUST FLOW lb/hr</td>
</tr>
<tr>
<td>Saturn 20</td>
<td>1.2</td>
<td>14 025</td>
<td>952</td>
<td>51.5</td>
</tr>
<tr>
<td>Centaur 40</td>
<td>3.5</td>
<td>12 240</td>
<td>835</td>
<td>149.6</td>
</tr>
<tr>
<td>Centaur 50</td>
<td>4.6</td>
<td>11 630</td>
<td>956</td>
<td>150.3</td>
</tr>
<tr>
<td>Mercury 50</td>
<td>4.6</td>
<td>8 863</td>
<td>710</td>
<td>140.4</td>
</tr>
<tr>
<td>Taurus 60</td>
<td>5.7</td>
<td>10 860</td>
<td>960</td>
<td>171.3</td>
</tr>
<tr>
<td>Taurus 65</td>
<td>6.3</td>
<td>10 373</td>
<td>1032</td>
<td>163.4</td>
</tr>
<tr>
<td>Taurus 70</td>
<td>7.5</td>
<td>10 100</td>
<td>914</td>
<td>212.3</td>
</tr>
<tr>
<td>Mars 90</td>
<td>9.5</td>
<td>10 710</td>
<td>875</td>
<td>316.2</td>
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<tr>
<td>Mars 100</td>
<td>10.7</td>
<td>10 520</td>
<td>915</td>
<td>329.1</td>
</tr>
<tr>
<td>Titan 130</td>
<td>15.0</td>
<td>9 695</td>
<td>932</td>
<td>392.2</td>
</tr>
<tr>
<td>Titan 250</td>
<td>21.7</td>
<td>8775</td>
<td>865</td>
<td>541.5</td>
</tr>
</tbody>
</table>

ISO Performance: 59°F (15°C); Sea Level; No Inlet and Exhaust Losses.
Specific Site Performance: 102 mm (4 inches) Inlet, 254 mm (10 inches) Exhaust Losses; Saturated Steam @ 10.3 Bar (150 psig)
### NEW EQUIPMENT SOLONOX EMISSIONS RATINGS – NATURAL GAS

<table>
<thead>
<tr>
<th>Mercury 50</th>
<th>Titan 250</th>
<th>Titan 130</th>
<th>Mars 100</th>
<th>Titan 250</th>
<th>Titan 130</th>
<th>Mars 100</th>
<th>Mars 90</th>
<th>Titan 250</th>
<th>Titan 130</th>
<th>Mars 100</th>
<th>Mars 90</th>
<th>Titan 250</th>
<th>Titan 130</th>
<th>Mars 100</th>
<th>Mars 90</th>
<th>Titan 250</th>
<th>Titan 130</th>
<th>Mars 100</th>
<th>Mars 90</th>
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</thead>
<tbody>
<tr>
<td>ppm</td>
<td>mg/Nm³</td>
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<tr>
<td>NOx</td>
<td>5</td>
<td>11</td>
<td>15</td>
<td>30</td>
<td>25</td>
<td>50</td>
<td>38</td>
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<td>CO</td>
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<td>13</td>
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<td>30</td>
<td>50</td>
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<tr>
<td>UHC</td>
<td>10</td>
<td>8</td>
<td>25</td>
<td>18</td>
<td>25</td>
<td>18</td>
<td>25</td>
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<tr>
<td>Load Range</td>
<td>50-100%</td>
<td>50-100%</td>
<td>50-100%</td>
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</tr>
<tr>
<td>Ambient Temperature</td>
<td>0 to 120°F (–20 to 49°C)</td>
<td>0 to 120°F (–20 to 49°C)</td>
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PipeLine Quality Natural Gas, Titan 250 to 40% Load Standard. New Production HED Mars 100, Taurus 70 & Taurus 60 to 40% Load with SER
New Production @ 42 ppm from -20 to 0°F (-29 to -20°C), VOC can be estimated as 5-10% of UHC

Note: Conventional Combustion NOx emissions range: 120-350 ppm
TYPES OF COMBUSTION FLAMES

• Diffusion Flame (*Conventional*)
  - Air, Fuel Injected into Combustor Separately
  - Burning at Interface (Flame Front), *Stoichiometric* Fuel-to-Air Ratio

• Lean, Premixed Flame (*SoLoNOx*)
  - Air, Fuel *Premixed* in Fuel Injector
  - Burning at Lower Temperature, *Fuel-Lean Conditions*
• Industrial Gas Turbine
• Annular Combustor for Durability and Low Emissions
• 30,000 Hours Between Overhaul (MBTO)
• No Parts Change Between Overhaul
• Tilt-Pad Bearings Utilize Mineral (Non-Synthetic) Oil
SOLAR’S COMBUSTION SYSTEM COMPONENTS

COMBUSTOR LINERS

Conventional  SoLoNOx

FUEL INJECTORS

SoLoNOx  Conventional

Solar Turbines
A Caterpillar Company

Caterpillar: Non-Confidential
COMBUSTION SYSTEM EMISSIONS CHARACTERISTICS

New Operating Range

EMISSIONS

LEAN

FLAME TEMPERATURE
(ALSO: FUEL/AIR RATIO)

STOICHIOMETRIC

CO

NOx
This drawing to be considered typical. Project specific drawings will be issued during the project execution phase.
TITAN 130 GENERATOR SET
TITAN 130 LUBE OIL SYSTEM

- PG Oil Pumps
- Main, Engine Driven
- AC Pre/Post
- DC Post Backup
- PG Oil Filters
- Simplex/Duplex with Transfer Valve
GAS ONLY FUEL MODULE

MAIN FUEL CONTROL VALVE

PILOT FUEL CONTROL VALVE
FIRE SUPPRESSION CABINET

- May be CO2 or Water Mist suppressant
- Activated by Fire System Controller
- Immediate Release Bottles
- Extended Release Bottles
- Manual Trip Mechanism
• Sound Attenuation for 85 dBA
• Fire Detection, Fire Suppression, Gas Monitoring
• Local or Remote Operation
SERVICE AGREEMENT OPERATIONAL GOALS
Maximize Reliability
Control Operating Costs
Mitigate Risks

A CULTURE OF CUSTOMER CARE

Solar Turbines
A Caterpillar Company
Caterpillar: Non-Confidential
EQUIPMENT HEALTH MANAGEMENT
THANK YOU

Solar Turbines
A Caterpillar Company

Caterpillar: Non-Confidential
Jon Green
Mechanical Equipment Consultant
Lathrop-Trotter Co.
Mobile: 513-478-7288 Email: jon.green@lathroptrotter.com

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