ADVANCEMENTS IN H CLASS GAS TURBINES FOR COMBINED CYCLE POWER PLANTS FOR HIGH EFFICIENCY, ENHANCED OPERATIONAL CAPABILITY AND BROAD FUEL

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Gas turbine industry leader

Strongest catalog

<table>
<thead>
<tr>
<th>Model</th>
<th>H-class</th>
<th>F-class</th>
<th>E-class</th>
</tr>
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<tbody>
<tr>
<td>9HA</td>
<td>.02</td>
<td>.01</td>
<td>.05</td>
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<td>132</td>
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<tr>
<td>7HA</td>
<td>.02</td>
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<td>275</td>
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<td>7F</td>
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<tr>
<td>7E</td>
<td>.03</td>
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</table>

Geared

<table>
<thead>
<tr>
<th>Model</th>
<th>Reliability</th>
<th>Availability</th>
<th>Start Reliability</th>
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<tr>
<td>6F</td>
<td>98.3</td>
<td>92.6</td>
<td>98.1</td>
</tr>
<tr>
<td>6B</td>
<td>98.3</td>
<td>92.6</td>
<td>98.1</td>
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</table>

Technology & plant capability drives the industry

Technology drives efficiency... market transition to H-

>62% efficiency today for HA technology on Gas Turbine World basis

H-class fastest growing segment

Market shifting to high efficiency generation for better economics

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HA gas turbine platform evolution

Three generations of gas turbine technology

9H
2003
4-stage VGV
4-stage turbine

9F.05
2005
DLN 2.6+

7F.05
2012
14-stage compressor
Field-replaceable blades
3-stage VGV
Advanced HGP

7/9HA
2014

A decade of technology advances and lessons learned

Note: Year denotes first operation
HA high efficiency gas turbines
The most cost effective conversion of fuel to power

Compressor
- Field replaceable blades
- 7F.05 validated

Hot gas path
- Air cooled
- Proven super alloys

DLN2.6+ Combustor
- Proven performance
- Broad fuel flexibility

Product performance

<table>
<thead>
<tr>
<th></th>
<th>GT MW</th>
<th>1x1 CC MW</th>
<th>CC Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>7HA.01</td>
<td>293</td>
<td>435</td>
<td>&gt; 61.5%</td>
</tr>
<tr>
<td>7HA.02</td>
<td>346</td>
<td>509</td>
<td></td>
</tr>
<tr>
<td>9HA.01</td>
<td>429</td>
<td>645</td>
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<tr>
<td>9HA.02</td>
<td>519</td>
<td>774</td>
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</table>

Flexibility

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Fuel</td>
<td>Ethane, ASL</td>
</tr>
<tr>
<td>Turndown</td>
<td>25% GT base load</td>
</tr>
<tr>
<td>Ramp rate</td>
<td>15% GT MW/min</td>
</tr>
</tbody>
</table>

HA Gas turbines ... for reliable, cost effective power generation
7 & 9HA power plants around the world

**9HA.01 EDF Bouchain**
1x1 Single Shaft
GT installed...July ’15
Commissioning Feb-May ’16
COD ... June ‘16

**7HA.02 Exelon Wolf Hollow**
2x1 Combined Cycle
1st GT installed ... May ‘16
Commissioning ... in progress
COD ... Q2 ‘17

**7HA.01 Chubu Nishi Nagoya**
3x1 Combined Cycle (2 blocks)
1st GT Installed ... May ‘16
Commissioning ... in progress
COD ... Q2 ‘17

Gas turbine Full-load validation supports fast site schedules
9HA plant record performance achievement

World’s most efficient
Combined Cycle Power Plant
62.22%
HA validation
Advanced technology validation milestones

- Off-grid, full load
- 50Hz & 60Hz
- Gas & liquid fuels
- Gas turbine commissioning & digital twin assessment
- Installation & maintenance routine

$500M investment to validate technology reliably
TS7 Off-Grid Testing Benefits

- **No grid restrictions** ... no frequency or load limitations
  - Testing at all load ranges on-frequency (50 and 60hz capable)
  - Testing at load ranges off-frequency for variation and grid events
  - Testing at transient conditions
- Deliver thorough product mapping **beyond field operation** ... insurer and customer acceptance
- TS7 has **permanent data collection system**
  - Capable of 7000 data streams
  - High quality data due to permanent data and scanner rooms.

**FSFL provides data far beyond field operation**
Unprecedented facility and operations

Test sequence

- Start-ups, shut-downs, re-starts
- Speed sweeps at varying load conditions
- Low load mapping (0 - 30%)
- Emission compliant load range (30–100%)
- Extreme conditions ... over-fire, over-speed, under-speed at load
Most comprehensive validation in GE’s history

- 160 accelerometers
- 120 clearance probes
- 330 light probes
- 750 strain gages
- 3,300 thermocouples
- 1,890 pressures probes
- 300 thermal Crystals
GE’s HA gas turbine exceeds expectations
9HA.01 & 7HA.01 validated, 7HA.02 testing on-going

**Test Stand**
- 1 Unit
- 200 Hours

**Field Operation**
- 500 Units
- 1 Year

- Off-grid full speed, full load test capability
- Able to operate beyond “real world” limits
- Comprehensive validation before FF in field
- Enabling rapid acceptance by customers, insurers & lenders

**Proven Results**
- Baseload performance achieved
- +110% output / high flow demonstrated
- +75°F overfire demonstrated
- Emissions & operability verified
- <25% turndown achieved
- <10 min fast start demonstrated
- 80 MW/min ramp rate demonstrated
- Gas variation – doubled (to ± 15% MWI)
- Cold fuel to base demonstrated

**Comprehensive understanding of design processes, technology & capability**
Pre-engineered and packaged accessories
Enhanced construction, maintenance & reliability

Up to 25% faster installation than 7F.03

- Customer connections ↓ 40%
- Field welds ↓ 40%
- Electrical terminations ↓ 80%
- Field installed valves ↓ 98%

### Key features

- Elimination of hydraulics
- Quick roof lift off – no equipment
- Simplified combustion piping
- Water purge eliminates oil coking
- Increased access space
- Reduced outage time … up to 20%

<table>
<thead>
<tr>
<th>Field installed valves</th>
<th>7F.03</th>
<th>7HA</th>
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</thead>
<tbody>
<tr>
<td>Cooling &amp; sealing air</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>Gas fuel</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Atomizing air</td>
<td>1</td>
<td>0</td>
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<tr>
<td>Inlet bleed heat</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Lift oil</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Water wash &amp; false start DRN</td>
<td>17</td>
<td>0</td>
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<tr>
<td>Gas fuel purge</td>
<td>6</td>
<td>0</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>45</strong></td>
<td><strong>1</strong></td>
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</tbody>
</table>

7HA construction … 10,000 man-hours less than 7F
Winning with the HA Gas Turbine

Technology Selections
- 7HA: 60
- 9HA: 43

Orders
- 7HA: 28
- 9HA: 19

Gas Turbine GW
- 7HA: 19
- 9HA: 21

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Future Evolutions
Enabling >65% combined cycle efficiency

Technology pipeline for the next decade:

**UNSTEADY PHYSICS**
Supercomputers unlock improved aero layouts

**ADDITIVE MANUFACTURING**
Complex layouts enabled by advanced manufacture

**CERAMIC MATRIX COMPOSITE**
Durability 500F hotter than metals, uncooled

**COMBUSTION**
Low emissions at 3000F

Leveraging GE’s aero engine heritage and F-fleet experience
HA gas turbine power plants ... reliable, cost-effective power generation

✓ Strong technology heritage

✓ FSFL validation

✓ Wide gas & liquid fuels capabilities

✓ Simplified & packaged systems

✓ 103 units selected ... 47 ordered

Technology pipeline for sustained product & industry leadership