Gas Turbine Fuel Flexibility: An Enabler For Regional Power Generation

JEFFREY GOLDMEER

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Concerns facing the global energy industry today

- Energy security
- Fuel costs
- Ancillary industry opportunities
- Resource scarcity
- Economic uncertainty
- Fuel diversification
- Changing regulatory landscape
- Increasing renewables
- Grid stability

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But, resources and fuels are regional

North America
- Natural gas
- Shale gas
- Coal syngas
- Process gas
- Refinery off-gas
- LNG (export)

W. Europe
- Natural gas
- Blast furnace gas
- Coal syngas

E. Europe
- Natural gas
- LNG (import)
- Biofuels
- Coal syngas

China
- Blast furnace gas
- Refining pet coke
- Heavy fuels
- LNG (import)

Latin America
- Natural gas
- Ethanol
- Heavy liquids
- Sour gas

Middle East
- Natural gas
- Heavy liquids
- Syngas
- Lean fuels
- Sour gas
- LNG (export)

India
- Liquefied natural gas
- Blast furnace gas
- Refinery off-gas
- Naphtha

Asia
- Natural gas
- Coal syngas

This requires flexible platforms to meet customer needs
It’s all in the combustion ...

... with little or no change in the availability, reliability and economics associated with traditional natural gas operated units.
Focus for today’s presentation

• Gas fuels:
  - Natural gas fuel variation
  - Process and low heating value fuels
  - Sour gas

• Heavy liquid fuels

• Biofuels

• High H2 fuels
Fuels and challenges: gaseous fuels
Technical challenges with opportunity fuels ... Wobbe variation

<table>
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<th>Gaseous fuels including high LHV gaseous fuels</th>
<th>Typical composition</th>
<th>Typical specific fuels</th>
<th>Technical challenges</th>
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<td>CH₄ = 90% CₓHᵧ = 5% Inerts = 5%</td>
<td>Natural gas</td>
<td>Liquefied natural gas (LNG)</td>
<td>Wobbe index variation</td>
</tr>
<tr>
<td>CH₄ and higher hydrocarbons CₓHᵧ &gt; 10%</td>
<td>Liquid petroleum gas (butane, propane)</td>
<td>Refinery off-gas</td>
<td>Combustion dynamics</td>
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Dry Low NO$_x$ (DLN) combustion tuning

Tuning adjusts the fuel flow to each of the four fuel circuits via the GCV valves to simultaneously:

- Keep emissions low
- Prevent hardware damage from high dynamics
- Avoid trips due to loss of flame (lean blowout, LBO)

Primary reasons for tuning include:

- Ambient temperature changes
- Ambient humidity changes
- Fuel composition changes
- Hardware changes and degradation
- Fuel valve calibration
OpFlex* AutoTune DX

Model based control (MBC) turbine thermodynamic cycle model (ARES) plus closed-loop DLN control module

Model-Based Control

Adaptive Real-time Engine Simulation (ARES)

Physics-based boundary models

Detailed combustor models developed from extensive field characterization testing

Combustion dynamics feedback

AutoTune DX

Automated, real-time tuning of DLN fuel-splits ...

settings checked about 25 times/sec

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AutoTune response to shale gas transients
(site in Ohio, May 2013)

Monthly Gas heating value variability
(May 1-31, 2013)

Output remain stable

-~70 Btu/SCF (~7% MWI) change in ~30 min

-~90 Btu/SCF (~9% MWI) change in ~45 min

Real-time fuel split adjustments GT1 and GT2
## Technical challenges: low heating value fuels and sour gas

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<th>Typical composition</th>
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<tr>
<td><strong>Ultra/Low LHV gaseous</strong></td>
<td>H₂ &lt; 10%</td>
<td>Blast furnace gas (BFG)</td>
<td>Fuel flow</td>
</tr>
<tr>
<td></td>
<td>CH₄&lt;10%</td>
<td>Air blown IGCC-N₂ enriched</td>
<td>Low hydrogen content</td>
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<td></td>
<td>N₂+CO &gt;40%</td>
<td>Biomass gasification</td>
<td>Compression</td>
</tr>
<tr>
<td><strong>Medium LHV gaseous</strong></td>
<td>CH₄&lt; 60%</td>
<td>Weak natural gas</td>
<td>Fuel flow</td>
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<tr>
<td></td>
<td>N₂+CO₂ = 30-50%</td>
<td>Landfill gas</td>
<td>Combustion dynamics</td>
</tr>
<tr>
<td></td>
<td>H₂ = 10-50%</td>
<td>Coke oven gas</td>
<td>Emissions</td>
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<td></td>
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<td>Corex gas</td>
<td>Operability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sour gas</td>
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<td></td>
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<td>IGCC – O₂ enriched</td>
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Multi nozzle quiet combustor (MNQC) offers widest range of fuel capability

- Same combustor architecture
  - End cover/fuel nozzle assembly nearly identical, except for minor scaling
  - Combustor liner and cap configurations similar, scaled to different operating conditions

- Capable of running on traditional syngas, high $\text{H}_2$, liquids, BFG, COG, sour gas, as well as traditional natural gas
  - Emissions profile vs. DLN

- Full scale, full pressure syngas testing
  - Capability for unique, non-traditional fuel blends
  - Identical combustor hardware to engine
  - Full and part load characterization of performance, dynamics, and emissions

MNQC/syngas test stand
MNQC combustor applicability for syngas

**Key features**
- Air extraction available to support process island and plant operations
- Ability to operate on syngas as a high $H_2$ fuel
- Combustion system with extensive field validation
- Increased mass flow (relative to natural gas 7F products) with syngas and diluent for higher output
- Proven syngas hot gas path materials
- Natural gas and co-fire operation available

**Fuel heating value**
- **Low**
  - Air IGCC syngas
  - Blast furnace gas
- **Medium**
  - $O_2$ IGCC syngas
  - GTL off-gas
- **High**
  - High $H_2$ for CCS
  - High $H_2$ for EOR

**MNQC models**
- **6B** (50/60 Hz)
- **7E** (60 Hz)
- **9E** (50 Hz)
- **6F** (50/60 Hz)
- **7F** (60 Hz)
- **9F** (50 Hz)
Low BTU gas turbine installations

Experience:
- 4.7 GW installed (21 plants)
- 47 gas turbines with LBTU/syngas
- Over 2,100,000 operating hours
Case study ... H₂S in gas turbine fuel

Instead of utilizing expensive piping to transport H₂S containing natural gas or lean methane fuels to processing plant, why not just utilize it as fuel power generation via GE heavy-duty gas turbines?

Conventional well to power plant path for sour gas:

![Gas well](Image1) → ![Pipeline](Image2) → ![Acid gas removal](Image3) → ![Pipeline](Image4) → ![Power plant](Image5)

Well to power plant path with new sour gas capability:

![Gas well](Image1) → ![Pipeline](Image2) → ![Power plant](Image5)

Savings of ~$4–21MM USD in CapEx for sour gas pre-treatment (per gas turbine), plus possible reduced operating expenses

¹ Piping specifically lined for acid gas
H₂S concerns

**Gas turbine** –
- Wet corrosion and sulfidation corrosion of fuel nozzle
- Hot corrosion in hot gas path

**Accessories** –
Potential for wet corrosion and/or fouling in accessory systems, including valves and piping

**Heat Recovery Steam Generator (HRSG)** – Potential for acid-based corrosion, and if selective catalytic reduction (SCR) is present, impact to (a) NOₓ catalyst effectiveness, and (b) HRSG effectiveness due to downstream fouling

H₂S is a highly toxic gas and will generally require additional safety measures

Increase of SOₓ and particulate matter emissions

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Mitigation steps & other considerations

**Inlet filtration:**
Limit alkali metal intake

**Additional requirements/considerations:**
- Fleet leader inspections
- Fuel monitoring required to measure H₂S concentration
- Maintenance factor = 1 (to be reviewed during fleet leader program)

**HRSG:**
- If SCR present, increase volume of NOₓ catalyst
- If ammonia based SCR, ensure HRSG configuration allows for cleaning of downstream fins and tubes

**Exhaust:**
Post-combustion emissions treatment for SOₓ

**Accessories:**
- National Association of Corrosion Engineers (NACE) compliant materials
- Fuel purge systems
- Fuel heating
- Flare or treatment of vented fuel

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H₂S capability

Use of fuels with up to 1% H₂S (hydrogen sulfide) is now available on the following turbines & combustion systems:

- 6B: DLN1/1+, standard fuel nozzle
- 7E: DLN1/1+, standard fuel nozzle, multi-nozzle quiet combustor (MNQC)
- 9E: DLN1/1+, standard fuel nozzle, MNQC
- 6F: DLN2.6, MNQC
- 7F: DLN2.6, MNQC
- 9F: DLN2.6+, MNQC
Fuels and challenges: liquid fuels
Technical challenges with opportunity fuels ... contaminants, viscosity

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<td><strong>Liquid fuels</strong></td>
<td>CxHy, with x&gt;6</td>
<td>Diesel oil</td>
<td>Contaminants: sulfur, vanadium,</td>
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<td></td>
<td></td>
<td>Naphtha</td>
<td>salts</td>
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<td></td>
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<td>Crude oils</td>
<td>Viscosity</td>
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<td>Residual oils</td>
<td>Ash deposition</td>
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<td>Bio-liquids</td>
<td>Lubricity</td>
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Operational challenges with liquid fuels

**Accessories & controls**
- Wax in fuel
- Low lubricity
- Fuel volatility

**Combustion**
- Hot corrosion (corrosion (Na, K, V, Pb))
- Operability
- Emissions

**Hot gas path**
- Hot corrosion (Na, K, V, Pb)
- Deposits (Ca)
Light crude oil ... operational challenges

- Light crude oils have macro fluid properties similar to distillate oil, but they can also contain contaminants typically found in heavier crude oils.
  - For some light crudes, vanadium content is low enough to not require use of an inhibitor.

- Light crude is also more volatile than distillate due to lower initial boiling point temperature.

- The combustion related challenges were evaluated in GE’s state-of-the-art test facilities.
Operational improvements ...
Decreasing operating expense (OpEx), increasing availability

Technical solutions that enable shift to heavier and more sour liquids for primary and back-up fuels

Extending F-class operations on light crudes
- Start up/shut down
- Extended baseload operation
- Less reliance on distillate
- Higher efficiencies and output

Heavy fuel oil availability package
- 4 key attributes
  - Smart cool down
  - Automated water wash
  - Model based control
  - Open Stage 1 nozzle
- Decreases offline time to perform water wash (from 40 to <12 hours)
- Reduce degradation and maintain Tfire ... 25% reduction in output degradation rate

High ambient package
- More power, better efficiency while burning heavy liquid fuels
Summary

- Regional trends, operational constraints and fuel availability will continue to drive the power generation industry towards non-traditional fuels
- Gas turbines have demonstrated flexibility and economics to operate on a wide variety gaseous and liquid fuels
- GE has successfully tested/operated many of these fuels and decreased operational and capital expense impacts to the heavy duty gas turbine with a goal to achieve performance like it is operating on natural gas