Gas Fuel Flexibility in Dry Low Emissions Combustion Systems

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Introduction

Why is Fuel Flexibility important?

- Local availability / supply constraints
  - Fixed versus interruptible tariffs
  - Non-availability of pipeline quality natural gas
- Cost
  - Opportunity fuels, e.g. process off-gas
  - 50MW class GT: US$0.50 mmbtu cost saving
    → US$2 million/year saving
- Environmental footprint
  - Reduce or eliminate flaring
  - Lower carbon content fuels
Wide variety of gaseous fuels
Assessing Fuel Suitability

What do I need to consider?

- Fuel volume required
  - Supply volumes available
  - Need for blending

- Fuel Composition
  - Wobbe Index
  - Fuel treatment / blending
  - Auto-ignition
  - Flame speed
  - Emissions

- Supply Temperature & Pressure
  - Dew Point
  - Temperature Corrected Wobbe Index
Assessing Fuel Suitability

Wobbe Index / Temperature Corrected Wobbe Index

- Allows direct comparison of different fuels to be made based on heat content
- Determines:
  - Fuel volume required
  - Fuel system and fuel injector design
  - Requirement for blending / treatment
    - Ensure combustion system design parameters are met
  - Fuel switching capabilities using single fuel system

\[
WI = \frac{LCV}{\sqrt{sg}}
\]

\[
Cv = \text{Net Calorific Value} \quad sg = \text{specific gravity}
\]

\[
WI_T = WI_{15} \times \sqrt[15]{\frac{T_{15}}{T_T}}
\]

\[
\Rightarrow WI_T = WI_{15} \times \sqrt[15]{\frac{288}{T_T}}
\]

Temp in Kelvin
Assessing Fuel Suitability

Wobbe Index Impact on Burner Architecture

The diagram illustrates the relationship between supply pressure, pressure drop across the burner, and temperature corrected Wobbe index for different burners and fuel types. The burners are categorized as Burner A, Burner B, Standard Burner, and Burner D. The diagram shows the standard range for supply pressure or pressure drop across the burner for different Wobbe index values, which are categorized into Low Calorific Value (LCV), Medium Calorific Value (MCV), Pipeline Natural Gas, and High Calorific Value (HCV).
Dew Point

- Water
- Hydrocarbons
- Superheating
- Unmetered Combustion:
  - Potential Damages
Assessing Fuel Suitability

Flashback

- If the flame speed does not match the flow speed of the reactants, the flame front will move.
- If the flame speed is too high, you can get flashback (flame moving upstream towards the fuel injection).
- If the flame speed is too low, you can get blow-off (flame pushed downstream).

Stable flame

\[ U_{\text{flow}} = U_{\text{flame}} \]

Flame Failure

Engine Stop
Example of Standard Combustion System
Lean Pre-Mix

- Pilot Tip
- Thermocouple
- Igniter
- Liquid Core
- Main Burner
- Pre Chamber
- Double Skin Impingement Cooled Combustor

- Pilot Gas Injection
- Main Gas Injection
- Igniter
- Radial Swirler
- Air Flow
- Fuel Input
- Air
Performance Impact

Impact of increasing inert gas content on shaft power output and heat rate of Siemens SGT-700 gas turbine compared to natural gas.
Testing and Operational Experience

- Combustor Rig Testing
- Single Burner Testing
- Full engine tests
- Customer-witnessed combined test
- Developments on DLE burners for variable fuel compositions
  - Intelligent DLE
  - Dual Gas & Tri-Fuel
  - Onshore and Offshore Operational Experience
Operational Experience: SGT-300-1S, Trigeneration Plant, USA

SGT-300 Typical 24 hour operation – large power swings, auto fuel change overs, low NOx
AND NO INTERVENTION REQUIRED

- Weak gas (42% CO₂)
- Liquid
- Weak gas
- Liquid
- Natural gas
- Weak gas

Liquid fuel
Low NOx
Variable Gas fuel
Operational Experience: SGT-700 China

Propane Dehydrogenation Plant (PDH)

- Single gas fuel system
- DLE Combustor
- Propane used for start-up
- Operation on de-ethanizer off-gas plus other waste gas streams
  - Huge variations in gas composition
  - Fuel gas included C₄ + C₅ and higher
  - Ethylenes, acetylene, dienes and hydrogen
  - Stable operation for more than 8000 hours with < 35ppm NOₓ
- 2 additional SGT-700 units on site operate on natural gas with propane as back-up fuel

Example fuel samples over 8 month period
Hydrogen

Methane / Hydrogen blends can be used in DLE combustors

- Standard DLE burner: up to 20% H₂ (vol)
- SGT-600, SGT-700: up to 40% H₂ (vol)
- SGT-800: up to 30% H₂ (vol)

2. http://www.youtube.com/watch?v=zG_yZmwPhIU

Single burner high pressure rig testing with increasing H₂ content in Natural Gas
Conclusions

Dry Low Emissions Combustors can operate on a wide variety of gaseous fuels

- Proven operational experience on ‘rich’ and ‘lean’ gases
- Variability of fuel gas can be compensated for without external tuning / shutdown
- Some $\text{H}_2$ content permissible
- Auto-changeover between fuels
- Emissions will differ from ‘pipeline quality’ natural gas
- Able to demonstrate both economic and environmental benefits
Thank you for your attention!

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