Fuel Flexibility in Co-Generation Applications
Natural Gas: the Fuel of Choice?

What can be done if natural gas is not available?

- Temporary interruption
  - Liquid fuel as back-up

- Long-term interruption or non-availability of gas

- Consider alternative fuels
  - Refined Liquid Fuels
    - Diesel, Kerosene, IF and HFO
    - Crude oil and refinery residues
  - Volatile liquid fuels
    - NGLs, LPG, Naphtha, ethanol
  - Alternative gas fuels
    - Biogases, process off-gases

- All these alternatives are potential fuels for Gas Turbines
  - Project economics may be affected but may be preferable to complete loss of production
Examples of Fuels assessed by Siemens
The bulk of fuels typical of natural gases. 
Fuel types to lower LH corner are typical of increased dilution from CO2 or N2 species
Fuel Types / Ranges

Consider the influence of diluents such as Carbon Dioxide and/or Nitrogen

- As diluent amount increases the energy content of the fuel decreases, therefore more “weakened” fuel flow required

- Applying a rigorous development process, as will be described in the next slide the capability to burn such fuels was released

- This recognised the physical limitations on supply pressure and combustor pressure drop (more on this later)
Combustion Development Process

- Water flow tests: aerodynamic analysis
- Spray tests: injector analysis
- Sprays in situ: oil/aerodynamics interaction
- Atmospheric combustion test: Ignition tests, study combustion modes
- High pressure Combustion tests: proving design
- Models: CFD, FEA
  
  Models underpin the development process
  Models evolve through the development process

- Analytical methods underpin practical tests
- High pressure combustion testing applied to can type combustion hardware
- Design or geometry change rapidly accommodated
Fuel Types / Ranges – Combustion Rig Facilities

Combustion Facilities

High Pressure Combustion Rigs
- Allows combustion testing at full engine temperature and pressure
- Facility covers all current product range

Gas Fuel Mixing Facility
- Ability to mix fuels to meet full WI range
- Covers range 15 – 65+MJ/m3 WI
Fuel Types / Ranges
Impact of fuel heating value

- Low Calorific Value (LCV)
- Medium Calorific Value (MCV)
- Pipeline Natural Gas
- High Calorific Value (HCV)

Temperature Corrected Wobbe Index

Supply Pressure
Pressure drop across burner

Burner A  Burner B  Standard Burner

Standard range for supply pressure or pressure drop across burner
Alternative Gas Fuels

University of New Hampshire (UNH), USA

- Tri-generation plant provides power, heat and cooling to University campus
- Low emissions, 15ppm NOx, requirement
- Initial operation on natural gas with diesel fuel as back-up
- Availability of landfill gas from nearby source as low cost fuel
  - WI range to wide to consider common configuration
  - LFG processing required
- Gas fuel system able to operate on processed landfill gas as well as natural gas
  - WI control 32MJ/Nm³ acceptable
  - Variable composition: natural gas mixed with landfill gas to boost heating value
  - PLG of insufficient quality or quantity

https://132.177.103.142/RSViewWeb/default.htm
Alternative Gas Fuels

Intelligent Fuel Control for Low NO\textsubscript{x} emissions

- Developed for UNH
- Variable fuel composition sometimes caused emissions limit to be exceeded
- Intelligent control developed to adjust pilot fuel schedule to produce minimum NO\textsubscript{x}
- Demonstrated ability to meet NO\textsubscript{x} limits despite variations in fuel composition
- Released and available across product range

Histogram of NO\textsubscript{x} emissions over 2 months, 1 year apart, before and after installation of Intelligent Fuel Control
Fuel Types / Ranges

Ethanol Plant

- Operation on By-product Biogas:
- Composition: CH4 60mol%; CO2 37mol%
- TCWI circa 20-22MJ/m3 @ ~55°C
- Commissioned May 2013
- Estimated Hours ~10,000hrs (Dec ‘14)
- Start fuel: Biogas.
Ethane  C2H6
Typically a by-product of the process industry, but now an increasing “waste” from treatment of “shale Gas”
Ethane can be assessed as a gas turbine fuel in the same way as any gaseous fuel, giving due consideration:
  • Specified in suitable units (usually mol%, mol fraction, vol%)
  • All contaminants are specified

Assessment defines parameters of gaseous fuel:
  • Dew point (hence supply temperature)
  • Calorific value; Wobbe Index, sg
  • Minimum supply conditions
At minimum conditions for superheat above dew point (20degC) WI of Ethane lies above the upper approved range limit (49MJ/m3). Elevating supply temperature reduces the WI (Hence Temperature Corrected Wobbe Index, or as another GT OEM refers to Modified Wobbe Index). The next limit to apply is the fuel system limit (120DegC)
In this exercise methane has been used with ethane added until the fuel is all ethane (range is 100% methane to 100% ethane).

In blue is the WI of Ethane as ethane content is increased. This is at ISO conditions.

Upper limit of standard natural gas range is 49MJ/m³ (note this is not a “hard stop”)

Minimum supply temperature (fuel system operating limit) is +2.5degC

Above about 20degC gas temperature the fuel requires additional heating to ensure TCWI <49MJ/m³

Above 80% Ethane content supply temperature adjustments is close to upper systems limitation, 120degC

If no methane available then a small amount of air can be used for dilution: 10% air results in acceptable TCWI/supply temp
Volatile Liquid Fuels

By-products from processing or refining processes that may offer a lower cost alternative to premium refined fuels

- Natural Gas Liquids (NGL)
- Liquified Petroleum Gas (LPG)
- Naphtha
- Ethanol

- Require changes to the liquid fuel system of Gas Turbines

- Need to ensure fuel stays as a liquid
  - High pressure fuel systems (typically 200 bar)
  - Siemens developed a low pressure system (40 bar) for increased safety
- Low viscosity and lubricity requires special fuel pumps
- Ethanol has only 60% energy content of diesel
  - Greater volumes required so larger pipework, burner galleries etc.
Volatile Liquid Fuels

Naphtha-fuelled installation, Turkey

- Industrial customer suffering from frequent power outages and loss of production
- Natural gas pipeline not yet constructed
- Selected naphtha as fuel for initial years of operation until natural gas became available
- Chose Siemens to supply a gas turbine for a Cogeneration plant
- Improved production volumes and quality due to reliable supplies of electricity and process heat
Alternative Gas Fuels

Sometimes there are alternative gas fuels available to act as a substitute natural gas

- **By-products from industry**
  - Coke Oven Gas; Blast Furnace Gas; Refinery Gas
  - Also Syngas from gasification of biomass, coal or Municipal or Medical Wastes
  - Tend to be hydrogen-rich gases, often with carbon monoxide
  - Lower heat energy than natural gas
  - Require changes to the burners, fuel and safety systems
  - Increased volume flow; Hydrogen embrittlement; Flashback risk

- **Naturally-occurring methane-rich gases**
  - Landfill gas, digester (sewage) gas, biogas
  - Weak natural gases (methane + carbon dioxide)
  - Minor changes to fuel systems and burners
  - High volume flows
  - Low pollutant emissions as suitable for DLE combustors

Cogeneration plant in a Refinery
Alternative Gas Fuels

Coke Oven Gas Installation, China

- Coke Oven Gas (COG) is a waste gas from coke production for the steel industry
- Often just flared off as a waste product
  - Free fuel
- COG mainly composed of hydrogen and carbon monoxide
- Siemens SGT-200 high hydrogen fuel capability expanded to cover COG
- Gas cleaning prior to turbine to remove or reduce levels of contaminants
- Several units installed with lead units >30,000 operating hours
Summary / Conclusions

- Natural gas is the most common fuel for Power Generation and Cogeneration
- There are many alternative fuels that can be used
  - To cover a temporary loss of gas supply
  - As a lower cost source of fuel
  - Local ‘waste’ fuels can displace natural gas
  - Potentially ‘free’ or lower cost fuels
  - Avoid import of natural gas by using local resources to best ability
- Multi-fuel capability of Gas turbines allows
  - Secure supply of energy
  - Optimisation of economics
  - Low environmental impact