Ignition Reliability in SGT-750 for Gas Blends at Arctic Conditions

Magnus Persson
Combustion Expert / Distributed Generation / Sweden
Table of content

- Objectives of the Project
- SGT-750 Combustion System
- Test Scope
  - Atmospheric Combustion Rig
  - High Pressure Combustion Rig
  - Engine Validation Test
- Rig Operation on Cold Air
- Results
- Summary
Objectives of the Project

Growing needs of ability to operate medium size gas turbines on the broad range of gaseous fuels at extremely low ambient (arctic) conditions was a main driver for this project.

The overall goals were realized by three-step test approach

- Simulation of ignition and startup reliability on natural gas blends with CO₂/N₂ inert content and the process air temperature at minus 60°C ⇒ **Full-scale, single-burner system in Atm Comb Rig**
- Screening of system performance and operation on natural gas blends at pressurized conditions. Pressure and temperature of the process air were adjusted to the operation line at true arctic conditions ⇒ **Full-scale, single-burner system in HP Combustion Rig**
- Effect of the inert gas content on operation ability and combustion performance during start and loading ⇒ **Standard SGT-750 engine in test bed**

All test were performed with original standard engine hardware.
SGT-750 Combustion system

**SGT-750**
- Twin-shaft, rated at 41 MW with 41.6% simple cycle efficiency
- Pressure ratio of 24
- Compressor discharge temperature 490ºC

**SGT-750 Combustion System**
- Eight can annular type combustors
- Dry Low Emission burners
- Compressor air fed to the burner through serially cooled can and to impingement cooled double-skin transition duct
- Three premixed fuel stages – pilot Main1 and Main 2
- Rich Pilot Lean (RPL) burner in the center
- Radial swirl generator to maintain fuel mixing and flame stability by central recirculation zone
Test Setup
Atmospheric Combustion Test Facility

For the test purposes the test rig facility was completed by adding
• Fuel mixing station
• Air supply unit (cold air)

Objective:
Screening of start settings at true arctic conditions and diluted natural gas for reliable ignition

Test hardware:
Original single-burner combustor with original auxiliaries (exciter, flame sensing)
Test Setup
High Pressure Test Rig

- Air pressure and preheat temperature set to arctic conditions across the engine operating line
- Test with natural gas with up to 40 vol% CO₂ and 53 vol% of N₂

Objective: Stress test of combustion performance at authentic arctic compressor discharge data and natural gas diluted with inert gases

Test hardware: Single burner complete combustion system
Test Setup
Engine in Test Bed

- No modification of the fuel nozzles needed
- No gas chromatograph for Wobbe index required
- Max content of inert gases tested: \( \text{N}_2 > 45 \), \( \text{CO}_2 > 35 \) vol% 

**Objective:** Validation of engine operation with \( \text{N}_2/\text{CO}_2 \) diluted natural gas at near ISO conditions

**Test unit:** Standard SGT-750 with governing software adapted to automatic sensing of fuel Wobbe

**Test bed:** A temporary fuel mixing station and storage for N2/CO2 for test purposes was assembled
Atmospheric Ignition Test on Cold Air Air Supply Station

The air supply station was specially assembled for the ignition test purposes

Main components:
- Liquid air storage (~20 tons)
- Liquid air evaporator with steam driven heat exchanger
- Diesel fired boiler, providing steam to the evaporator
- Air flow and temperature control unit

Test constraints & requirements:
- Air flow rate: 400 ÷ 600 g/s ± 20 g/s
- Air temperature: -60 ÷ -15 ºC ± 5 ºC
- Oxygen content in process air: 20 ÷ 22 vol% 

Risks:
- Oxygen/nitrogen separation in storage – oxygen content outside permissible range
- Temperature in exhaust below design limit
Atmospheric Ignition Test on Cold Air Test Rig

Three main components were deployed:

- Fuel gas mixing station
  - Mass flow meters on each gas component
- Pressure vessel
  - Thick thermal insulation needed to keep the process air temperature at required level
  - New orifice plate at insulated pipe
- Exhaust passage
  - Stream of fresh ambient air to be mixed with cold process air – design requirement

The oxygen content in the process air was monitored by a sampling probe in the exhaust
Results
Ignition Window of Main Flame for N₂ gas blends – ISO vs. Arctic Conditions

Reliable ignition was validated as a function of equivalence ratio at burner outlet.
Flame light was indicated by the optical flame detector installed in the burner.
Results
Ignition Window of Main Flame for CO₂ gas blends – ISO vs. Arctic Conditions

Reliable ignition was validated as a function of equivalence ratio at burner outlet.

Flame light was indicated by the optical flame detector installed in the burner.
Results

Summary of Ignition Test at Arctic Conditions

- Reliable ignition of the central RPL-burner was obtained at:

<table>
<thead>
<tr>
<th>Ambient temperature range</th>
<th>CO₂ content range</th>
<th>Φ range for CO₂ blends</th>
<th>N₂ content range</th>
<th>Φ range for N₂ blends</th>
</tr>
</thead>
<tbody>
<tr>
<td>[°C]</td>
<td>[vol%]</td>
<td>[-]</td>
<td>[vol%]</td>
<td>[-]</td>
</tr>
<tr>
<td>-60 - +25</td>
<td>0 – 48</td>
<td>1.0 – 1.1</td>
<td>0 – 55</td>
<td>0.9 – 1.0</td>
</tr>
</tbody>
</table>

- Reliable ignition of the main flame was obtained at:

<table>
<thead>
<tr>
<th>Ambient temperature range</th>
<th>NG</th>
<th>CO₂ blends</th>
<th>N₂ blends</th>
</tr>
</thead>
<tbody>
<tr>
<td>[°C]</td>
<td></td>
<td>-60 - +25</td>
<td></td>
</tr>
<tr>
<td>Maximum content</td>
<td>[vol%]</td>
<td>100</td>
<td>31</td>
</tr>
</tbody>
</table>
Results
Summary of HP Combustion Test on N₂/CO₂ Blends in Single Burner Rig

Part load operating points with high concentrations of N₂ and CO₂ in the fuel were tested
- Stress test of operability and stability
- Pressure and preheat temperature adjusted to arctic conditions (-60°C)

<table>
<thead>
<tr>
<th></th>
<th>5% load</th>
<th>25% load</th>
<th>5% load</th>
<th>25% load</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ (vol%)</td>
<td>37</td>
<td>40</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N₂ (vol%)</td>
<td>0</td>
<td>0</td>
<td>42</td>
<td>53</td>
</tr>
<tr>
<td>NOₓ (ppm at 15% O₂)</td>
<td>8.4</td>
<td>5.3</td>
<td>10.9</td>
<td>3.7</td>
</tr>
</tbody>
</table>
Results

Summary of Engine Test on N₂/CO₂ Blends

Final verification of SGT-750 fuel flexibility.
The test was performed at near ISO ambient conditions

NOₓ in stack vs Engine Load on Inert Gas Blends

CO in stack vs Engine Load on Inert Gas Blends
Summary

• The fuel flexibility test campaigns extensively performed in 2016 have proven the SGT-750 and its combustion system to be very tolerant to variation of fuel quality at various ambient conditions.

• Three-step approach starting with ignition testing in atmospheric rig through testing in high pressure rig and finally engine test was satisfactory from testing methodology point of view.

• The tests at the combustion rigs both atmospheric and high pressure were carried out with the original setup of the SGT-750 single burner combustor and the flame monitoring devices.

• It was proven that the ignition capability and reliability at artic conditions is satisfactory for natural gas blends containing up to 55 vol% of N₂ and 30 vol% of CO₂.

• Stress test in the high pressure combustion rig of a single burner combustor has proven operability and combustion stability on the inert gas blends.

• Engine operation of the SGT-750, including ignition, start and transient load changes was successfully performed using gaseous fuels containing up to 50 vol% of nitrogen and 40 vol% of carbon dioxide.

• Start settings and the algorithm for governing software can be directly applied in the engine’s control system.
Thank you for your attention

Dr. Magnus Persson
Combustion Expert
Gas Turbine Research & Development
612 83 Finspang
Sweden

Phone: +46 122 87703
Mobile: +46 702 36 63 28
E-mail: magnus.persson@siemens.com

siemens.com/power-gas
Disclaimer

This document contains statements related to our future business and financial performance and future events or developments involving Siemens that may constitute forward-looking statements. These statements may be identified by words such as "expect," "look forward to," "anticipate" "intend," "plan," "believe," "seek," "estimate," "will," "project" or words of similar meaning. We may also make forward-looking statements in other reports, in presentations, in material delivered to shareholders and in press releases. In addition, our representatives may from time to time make oral forward-looking statements. Such statements are based on the current expectations and certain assumptions of Siemens’ management, of which many are beyond Siemens’ control. These are subject to a number of risks, uncertainties and factors, including, but not limited to those described in disclosures, in particular in the chapter Risks in Siemens’ Annual Report. Should one or more of these risks or uncertainties materialize, or should underlying expectations not occur or assumptions prove incorrect, actual results, performance or achievements of Siemens may (negatively or positively) vary materially from those described explicitly or implicitly in the relevant forward-looking statement. Siemens neither intends, nor assumes any obligation, to update or revise these forward-looking statements in light of developments which differ from those anticipated.

Trademarks mentioned in this document are the property of Siemens AG, its affiliates or their respective owners.

TRENT® and RB211® are registered trade marks of and used under license from Rolls-Royce plc.
Trent, RB211, 501 and Avon are trade marks of and used under license of Rolls-Royce plc.