Hydrogen-ready solutions for compression stations

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Advancing the Hydrogen Revolution

Why Baker Hughes

2000+
Compressors working with H2 rich gases

70+
Gas Turbines burning H2 up to 100%

1915
First Reciprocating Compressor for H2

2009
First 100% H2 GT in commercial project
Hydrogen Transport: The EHB initiative

• Hydrogen is expected where electrification is not an option:
  • energy-intensive industry
  • heavy-duty transport sectors

Developing a dedicated hydrogen infrastructure is necessary to release the full potential of hydrogen as energy carrier.
H₂ Ready Pipeline Station
Gas Turbine
Managing Hydrogen in Gas Turbine: Blending H2 with Natural Gas

$\text{H}_2 = \downarrow \text{CO}_2 \text{ emissions}$

Different thermophysical properties

$\text{H}_2 = \downarrow \text{Energy density & Flame instability}$

$\text{H}_2 = \uparrow \text{Flame temperature} = \uparrow \text{NO}_x$

< 10% Safely tested at site for pipeline – no NOx increase

10% – 20% Minor modifications on package

>30% NOx significant increase and package modification

- H$_2$/NG Pipeline—Istrana, Italy
- Nova LT™12

Snam and Baker Hughes successfully completed First Trial for the use of H$_2$ as Fuel in a Gas Compression Station
Challenges of Hydrogen Utilization in Gas Turbines

Engine and package modifications are needed for hydrogen fuel

**Combustion**
- High flame speeds
- Wide flammability limits
- High flame temperatures
- Flashback
- Combustion dynamics

**Delivery & Package**
- Storage
- Sealing
- Material compatibility
- Equipment validation & ATEX/NEC certifications

**Operation**
- Start-up and shut-down procedures
- Fuel system/engine/package purge requirements
- Flame detection
- Gas detection
- Performance/durability (high % H₂)
Managing Hydrogen in Gas Turbine: 100% Hydrogen

- Unabated NOx emission 160 ppmvd @15%O₂
- Enhanced burners design: Parts’ life analysis in line with NG maintenance plan
- Specific solutions to reach 15 ppmvd @15%O₂ or less
H₂ Ready Pipeline Station Compression
Impact of hydrogen on centrifugal compressors

Material

- **Hydrogen Attack**
  Affect Carbon and low alloy steels, $T > 200^\circ C$
  *usually not applicable for pipeline CC*

- **Hydrogen Embrittlement (HE)**
  Affect high-strength steels and titanium alloys, $T < 150^\circ C$
  *applicable for pipeline CC*

  Hydrogen dissociates in atoms and penetrates the material $\rightarrow$ local plasticization and brittle failure

  **LIMITS ON MAXIMUM YIELD STRENGTH AND HARDNESS**

Thermodynamic performances

When Hydrogen content increases...

- Head increases
- Power increases
- Discharge temperature increases

  **MAIN CHALLENGE $\rightarrow$ COMPACT SOLUTION**
Summary – material impacts

considering ≈ 70 bar reference pressure (assuming also for auxiliaries)

**Modification in this range driven only by thermodynamic limits**

- **0%**
- **5%**
- **10%**
- **20%**
- **100%**

**Detailed checks on auxiliaries** are required

**Worst case:** to replace the seal system and antisurge loop

**Detailed checks on Flange to flange** is required

**Worst case:** to replace the rotor

**Detailed checks on DGS cartridge**

**Worst case:** to replace the cartridge

- Hardness < 34
- Max yield strength < 827MPa
Performances impact – General

**Impact on speed and power (at constant Nm3/h)**

When the \( \text{H}_2 \) content raises, both operating speed and absorbed power increase as indicated in the graph above.

**Impact on Nm3/h (at constant gas energy)**

At constant gas energy, higher is the \( \text{H}_2 \) content, larger will be the flow, demanding more speed and power.
Performances impact – General

Impact on Pressure Ratio

Pressure ratio decreased by 9 times with 100% H₂ compared to 100% CH₄.

Keeping same pressure duty, polytropic head requirement increases consequently.

How to increase head capability?

- Increasing the number of stages (up to the max allowed by one casing or adding casings)
- Using high head impellers
- Increasing rotating speed (increase impeller tip speed)

High Pressure Ratio
Compressor technology
**Case study – Pipeline Compression Station**

**Case study**
Flow constant: 2000 MMSCFD,
Inlet Pressure: 60 bar
Outlet Pressure: 110 bar

<table>
<thead>
<tr>
<th>Hydrogen Blend [% mol]</th>
<th>0%</th>
<th>10%</th>
<th>20%</th>
<th>30%</th>
<th>40%</th>
<th>50%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of impeller required</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Standard PCL impellers U2 = 250 m/s</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>28</td>
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<tr>
<td>High head impellers U2 = 300 m/s</td>
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<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>HPRC impellers U2=450 m/s</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>9</td>
</tr>
</tbody>
</table>

**HPRC solution is a great option when H2 content is predominant**
Conclusion
Conclusion – Roadmap to decarbonization

Initial H₂ availability

Today

First step to decarbonization

Goal: starting H₂ demand, test of infrastructure

Blend up to 10%:
- Possible with little modifications
- No need for compressor rebundle
- No major impact on safety

Blend up to 20%:
- Possible with minor modifications
- Engineering work to be foreseen
- Check of compressor performances (possible rebundle)

Tomorrow

Further CO₂ reduction leveraging H₂

Combustion system ready for H₂ blend up to 100%

Compression technology ready for 100% H₂ pipeline station

Full decarbonization

Goal: Decarbonization of the hard to abate sectors
- Low Nox Gas turbines
- Compression equipment fit for H₂
- Package components tested for H₂
- Safety handling

Decarbonization journey can start today
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