Safety Considerations in Designing a Facility for Mechanical Property Measurements in High Pressure Gaseous Hydrogen Environments

NIST, Materials Reliability Division
Outline / Introduction

• New facility using high-pressure hydrogen (140 MPa or 20,000 psi)
• Fatigue measurements on linepipe steels (X52 to X100)
• Hazard Review/Codes
• Multi-Level safety design
  – Codes and Standards define safe design and operation
• Where did we look for resources?
The Facility
Mechanical Measurements
Mechanical Measurements

**X52**

- Tested in Helium
- Tested in Hydrogen

<table>
<thead>
<tr>
<th>Stress, MPa</th>
<th>% Elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>500</td>
</tr>
<tr>
<td>Helium</td>
<td>450</td>
</tr>
<tr>
<td>H2, 14 MPa</td>
<td>400</td>
</tr>
<tr>
<td>H2, 14 MPa</td>
<td>350</td>
</tr>
</tbody>
</table>

- Tested in Helium
- Tested in Hydrogen
Hazard Review

• Done by technical colleagues: great to have many eyes looking at the problem
• On-site safety office
• Hazard Review Committee had no hydrogen experience
Upon Announcement of Work on the Facility, This is What the Hazard Review Committee Had in Mind
Or This
Hydrogen Flammability

- Flammability limits of 4 % to 75 % in air
- Need fuel, oxidizer, and initiation
- Keep it away from sparks and flames
  - Hindenburg thought to initiate from a spark
  - Challenger initiated from a flame
Hazard Review

• Mitigation
  – Invited the police and fire departments
  – Hired hydrogen safety experts as part of the review

• Light, high diffusivity: disperses rapidly
Multiple Levels of Safety

• Safety begins with codes and standards
• Ventilation
• Small Volume of Gas
• Large Building
• Sensors
• Fail-Safe Design
• Minimize Spark Sources
Where Does NIST Look for Codes?

• Normally codes are defined by your local municipality
• Boulder, CO: start with International Codes
  – International Building Code
  – International Fire Code
• NFPA
• ASME
• NHA Website extensively used
Ventilation

- ASHRAE 62.1, 7 air changes per hour, 100 % outside air
Flow from a Hydrogen Source
• Based on flow dynamics, load frames were placed in areas of maximum mixing
Laboratory Building

• New Construction
  – Class I, Division II, Group B: testing and research laboratory
  – 925 ft²
  – IBC, NEC, IFC, IMC, IFGC, IPC, IECC, NFPA 45
  – (building, electrical, fire, mechanical, fuel gas, plumbing, energy conservation, lab chemicals)
Small Volume of Gas, Large Building

- Current maximum gas volume = 2.5 m$^3$ (89 ft$^3$)
- Future maximum gas volume = 6.4 m$^3$ (226 ft$^3$)
- Building volume = 350 m$^3$ (1240 ft$^3$)
- Current, 0.7 %; Future, 1.8 % at uniform distribution
Hydrogen Sensors

- Catalytic bead and palladium thin film
- ANSI/ISA RP12.13.02 Recommended practice for the installation, operation and maintenance of combustible gas detection instruments
Hydrogen Sensors

• Placed above each load frame and above each hydrogen compressor, which also corresponds to the plumbing wall

• First alarm at 1 % H2 (shut off gas supply), second alarm at 2 % H2 (lock down system and vent pressure vessel)
Fail-Safe Design Concepts

- System is automated and includes interlocks to the gas supply
- Normally-closed, air-operated valves (with backup manual valves on the gas supply, located behind the blast wall)
- Upon power loss, compressed air loss, or failure of either the incoming or exhaust ventilation, the system locks down
- Shut off gas supply, closes all valves, isolating sections of the system
Electrical Spark Sources

- Explosion Proof (EP)
  - Contain the explosion or contain equipment away from the fuel
- Intrinsically safe
  - Insufficient ignition energy
  - Generally applied to electronics
  - ANSI/ISA RP12, IEC 61779, UL 913
- Upper half of lab is all EP
Finding Codes

- [http://www.hydrogenandfuelcellsafety.info/resources.asp](http://www.hydrogenandfuelcellsafety.info/resources.asp)
- Our SOP used the DOE Safety Planning Guidance for Hydrogen Projects as a template
Acknowledgements

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