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

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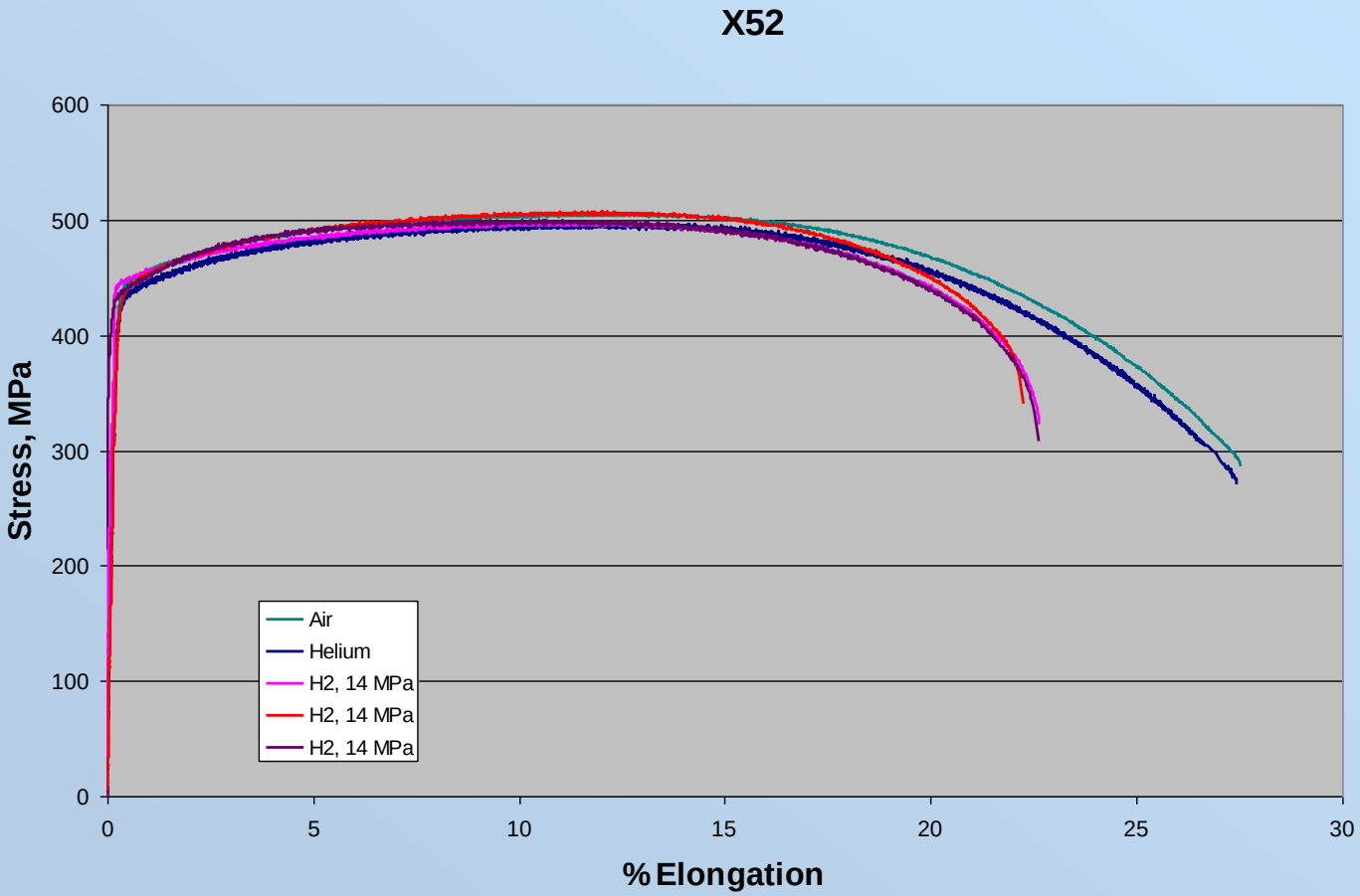
Outline / Introduction

- 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



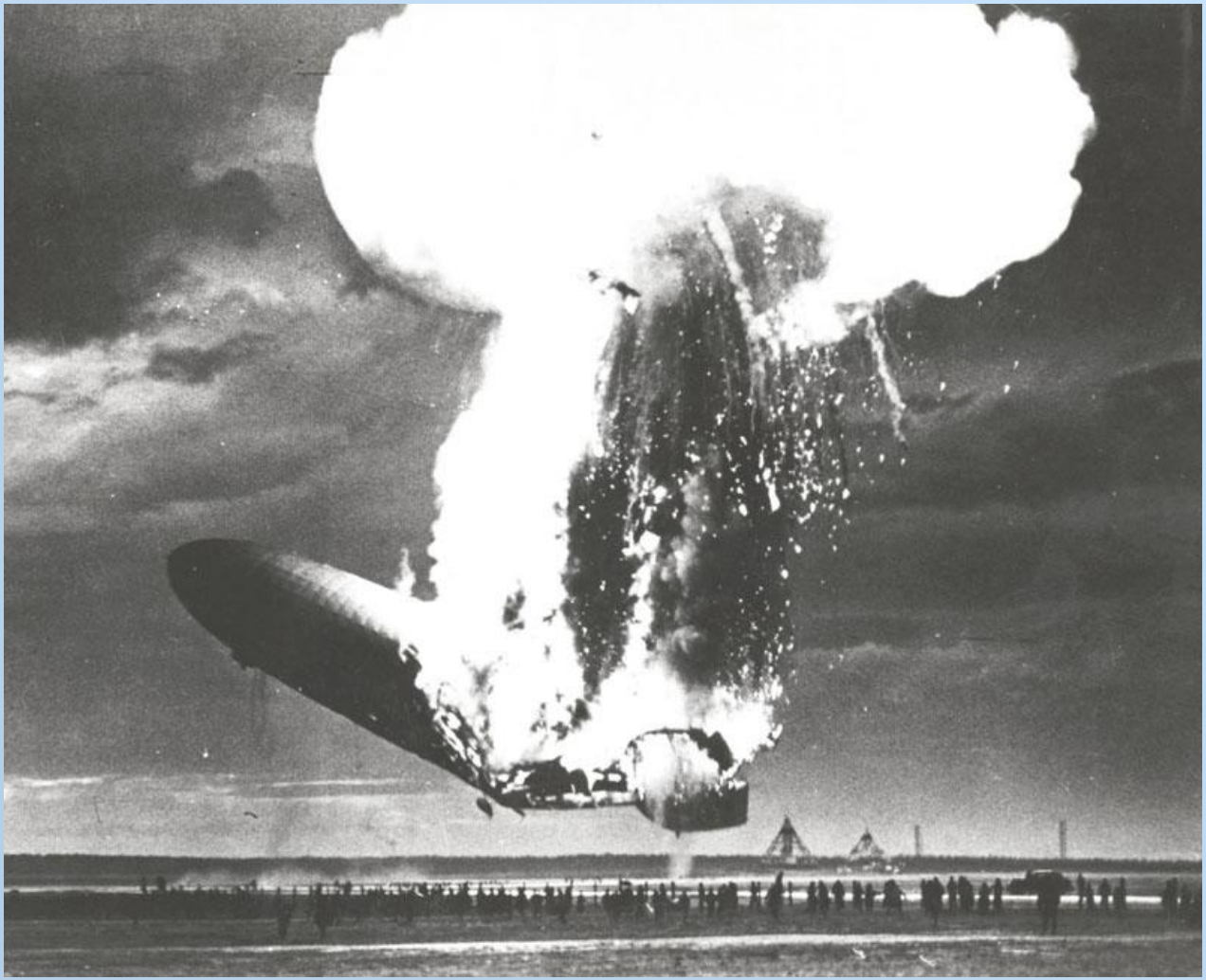
Tested in Helium

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

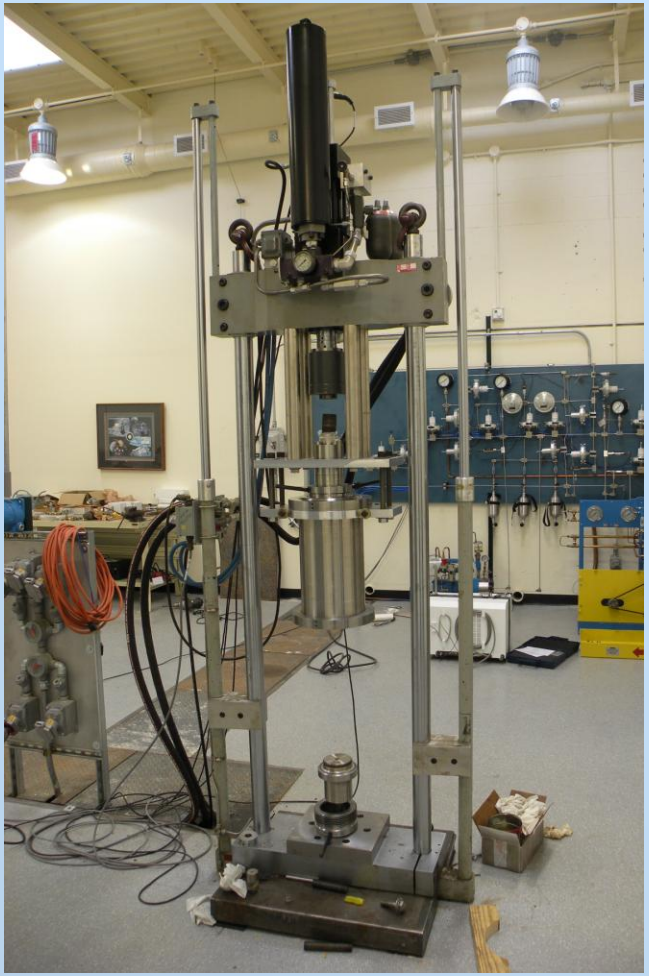
- Flammability limits of 4 % to 75 % in air
- Need fuel, oxidizer, and initiation
- Keep it away from sparks and flames
  - Hindenburg thought to initiate from a spark
  - Challenger initiated from a flame

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



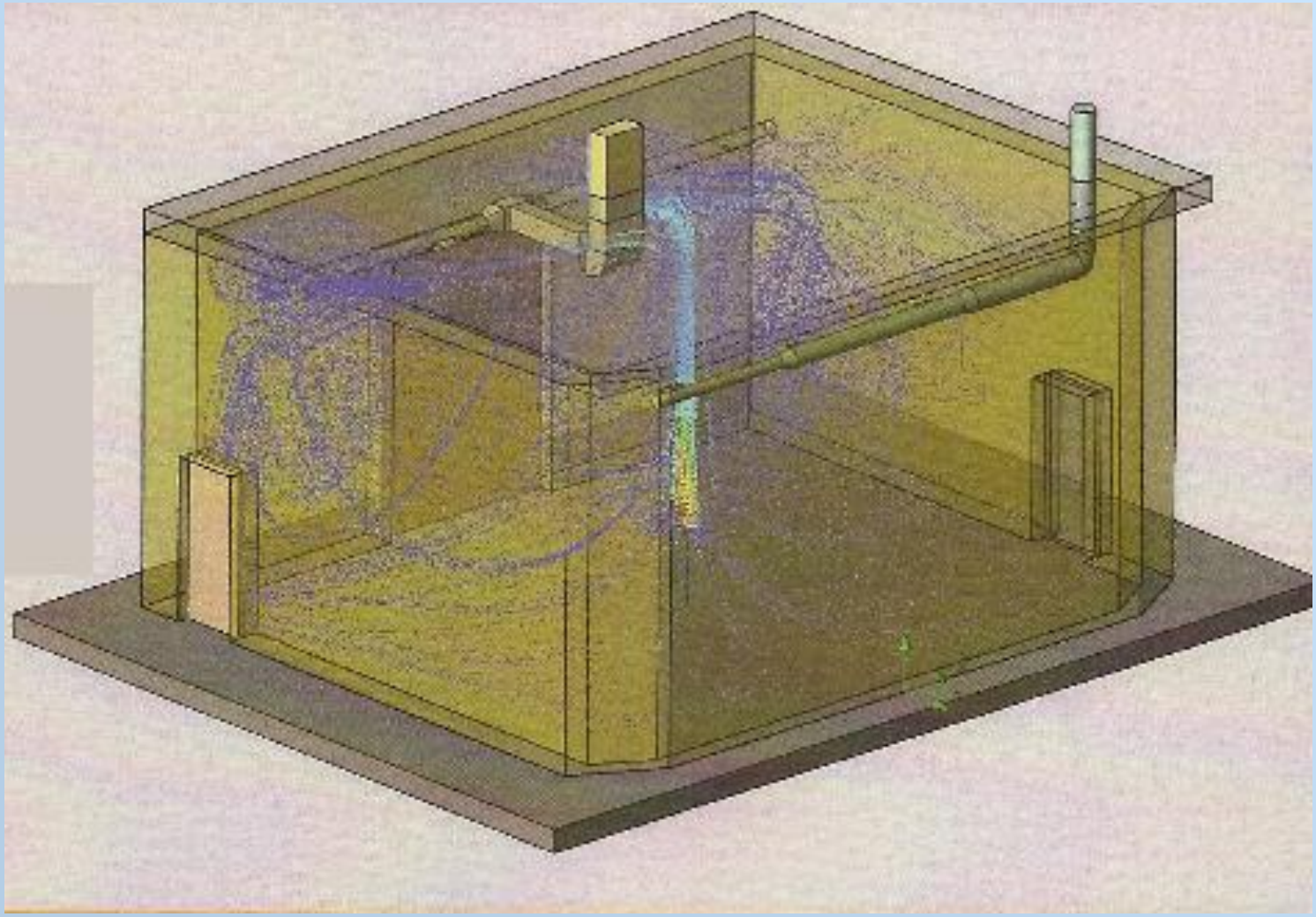
Where Does NIST Look for Codes?

- 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



Load Frame Placement

- Based on flow dynamics, load frames were placed in areas of maximum mixing

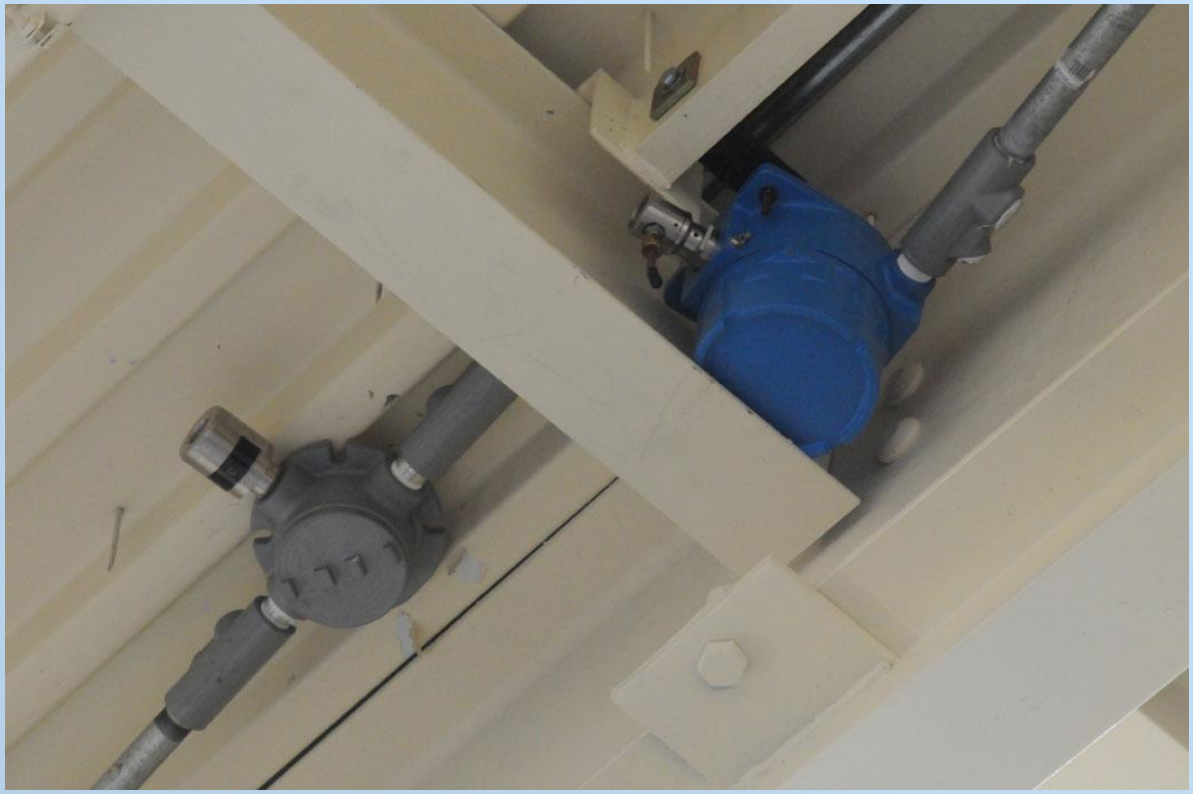
Laboratory Building

- New Construction
  - Class I, Division II, Group B: testing and research laboratory
  - 925 ft^2
  - 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

- NHA: http://www.hydrogenassociation.org/
- http://www.hydrogenandfuelcellsafety.info/resources.asp
- DOE: http://www.hydrogen.energy.gov/
- Our SOP used the DOE Safety Planning Guidance for Hydrogen Projects as a template

Acknowledgements

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