Hydrogen Laboratories Safety and Design Considerations

CHS Webinar Q&A

Key words: laboratory, materials, piping, tubing, outdoors, storage, separation distance, indoors, fire protection, design, ignition energy, ignite, fire, explosion, purge, nitrogen, helium, forming gas, environment, vent, fume hood, stack, tools, non-sparking, flammable, hazard analysis, consequences, risk, emergency response, joint, compression fitting, cylinder, storage

The information in this document provides answers to the questions that were raised during the Center for Hydrogen Safety September 4, 2023 webinar.

1. **What materials are suitable for piping hydrogen and hydrogen mixtures? Are there any guides or references available for selecting piping and fittings for hydrogen applications?**

   In laboratories, 316 stainless steel tubing is frequently the first choice for small flow and pressures less than 2800 psi (19 MPa). See https://h2tools.org/bestpractices/material-compatibility for hydrogen compatibility with various materials . Always work within manufacturer's pressure ratings adjusted for temperature. Read and follow manufacturer's instructions on making up tubing fittings, avoid threaded fittings, and properly purge with nitrogen, helium or other inert gas to remove air before introducing hydrogen.

2. **What are the best practices for working with hydrogen outdoors?**

   Outside storage is generally considered safer and is required for large amounts of gas. Stationary storage should be located outside at a safe distance from structures and ventilation intakes, and protected from vehicle impact.

   Hydrogen storage separation distance requirements are typically based on the quantity and pressure of the hydrogen or the piping diameter, depending on the type of storage. Consideration should be given to distances between multiple containers to prevent interaction during an unintended hydrogen release. More detailed guidance can be found in the applicable codes and standards such as NFPA 2, *Hydrogen Technologi*es.

3. **What are the best practices for storage and use of hydrogen cylinders inside the lab?**

   In general, indoor storage should be limited and the use of hydrogen indoors should be the least necessary. Look to store flammable gases outdoors in dedicated protected area when practicable. Check to see what adopted building and fire codes in your jurisdiction say. NFPA 2, *Hydrogen Technology Code*, Sections 6.4.1 and 16.3 prescribe requirements to limit hydrogen storage and use in laboratories. NFPA also prescribes requirements for ventilation, gas cabinets, electrical classification, and fume hood operations. Consider outdoor or dedicated storage facilities if you need more than one standard-sized cylinder of hydrogen to support your work.

4. **Are sprinkler systems, dry chemical systems, or clean agent system suitable for the protection of laboratories handling hydrogen?**

   Sprinkler systems and other fire suppression means are prescribed per building and fire codes to limit fire spread to other materials. In the case of a hydrogen leak and fire, it is best practice

to isolate the hydrogen source, and let any residual hydrogen gas burn out. Even if the initial fire is extinguished, additional leaking hydrogen may accumulate and ignite with the potential for an explosion.

5. **We currently run appliance testing with an 80/20 natural gas/hydrogen blend, and want to get our lab ready for 100% hydrogen appliance testing. Is there a contact or service that will help us design and implement this change?**

   There are several resources that can help review designs, such as the Hydrogen Safety Panel and other outside consultants that are members of the Center for Hydrogen Safety.

6. **With the extremely low minimum ignition energy (MIE) of Hydrogen, is it best to basically consider it as pyrophoric?**

   Because hydrogen leaks frequently ignite, and because about half the time the ignition source is not identified, when evaluating hazards with hydrogen leaks, many people just assume the leak will be ignited. Note that consideration needs to be made for what may happen with immediate ignition (jet fire) and what may happen with delayed ignition (explosion).

   It is still important to minimize the probability of ignition and to minimize the consequences if it does ignite. We do that by properly characterizing hydrogen with all its unique properties, including flammability and low MIE, and by providing the appropriate safeguards prescribed by codes and standards specific to hydrogen. These safeguards include minimum quantities, using proper materials of construction, leak prevention practices, proper ventilation, proper disposal to safe areas, and ignition source control such as the use of non-sparking, electrical grounding, and classified electrical equipment.

7. **What reference is available to help me understand purging requirements for hydrogen gas systems?**

   See https://h2tools.org/bestpractices/purging for a description of different purging approaches for hydrogen systems.

8. **Is there a hazard using a 4/96% hydrogen/nitrogen blend if it is released to the air?**

   If the concentration of hydrogen is less than the Lower Flammability Limit (LFL) of 4% in an inert gas, it is unlikely that a leak of this gas mix will form a flammable mixture as it dilutes into air. For example, industry uses ‘forming gas’, a mixture of 4 to 5% H2 in nitrogen, as an oxide reducing agent in materials processing furnaces and soldering operations. This mixture can also be used in conjunction with a hydrogen detector for leak testing gaseous hydrogen equipment.

9. **Any environmental concerns about hydrogen venting from experiments?**

   The key concern with any hydrogen release is the risk of creating a flammable mixture. There should be no environmental issues if you properly vent hydrogen to a safe area where it is diluted in air below the flammability limit before contacting an ignition source. Very small

quantities of hydrogen are frequently releasing into a fume hood. Releases have to be small enough so that the vent air is sufficient to dilute to below the lower flammability limit. The fume hood face velocity should be in excess of 100 ft/min (30 m/min).

Larger quantities of hydrogen should be released through a properly designed and constructed hydrogen vent stack. Standards and codes such as CGA G 5.5 and NFPA 2 provide guidance for vent stack design and installation.

10. Is there a big risk of fire when a person uses metallic tools inside a fume?

Using tools inside a fume hood that may have a flammable gas mixture should be prohibited. A properly operating hood of the right capacity should keep the mixture of hydrogen in air inside the hood below the Lower Flammability Limit (LFL) of hydrogen further reducing any risk.

If the use of tools is necessary, the source of hydrogen should be isolated before the work begins even if the concentration of hydrogen is expected to be below the LFL. It is best practice to leak test equipment before introducing hydrogen to minimize the probability of leaks. If spark resistant tools are suitable for a specific task for working with hydrogen systems, use of such tools will lower the probability of producing a spark.

11. When doing a hazard analysis, are there any guidelines regarding severity of consequences? What if the release was of 500 mL of hydrogen?

Frequency and severity off consequences are situational and subject to the safety review team's best judgement. One measure of severity is an estimate of the energy released if ignited. Assuming the worst-case mix to be stoichiometric, the energy content of a 500 mL of hydrogen in air is about 0.2 Wh (700 Joules), comparable to the energy release of a wooden, blue-tipped matchstick (~1kJ or 1 Btu). This may not be very significant in a safe location such as an operating fume hood. See Risk assessment and risk ranking at https://h2tools.org/bestpractices/ranking-risks for more information.

12. What actions are needed and what precautions should be taken in the event of a hydrogen fire?

After moving people to a safe location, if it safe to do so, isolate the source of hydrogen feeding the fire. Burns and explosions are hazards when exposed to a hydrogen fire. For more best laboratory preventative safety practices as well as first responder response to a hydrogen incident See both CHS training resources:

- https://www.aiche.org/ili/academy/courses/ela210/hydrogen-laboratory-safety
- https://www.aiche.org/ili/academy/courses/ela253/introduction-hydrogen-safety-first-responders

13. What are best practices for joining metallic tubing?

Flare-less compression style fittings are commonly used. Choose tubing materials and tube wall thicknesses suitable for hydrogen and pressures you are using. Make sure all tubing joints

are properly made, mechanically supported to minimize stress and vibration, are in a ventilated space, and are easily accessible for inspection and leak testing.

14. Do hydrogen gas cylinders need to be stored separately from other gas cylinders or can they be stored together?

Store flammable gas cylinders such as hydrogen, separated from oxidizing (e.g. oxygen), toxic, pyrophoric, corrosive, and reactive Class 2, 3, or 4 gases. Non-reactive gases, such as helium, may be co-located. See codes and standards such as NFPA 2 [7.2.1.1 Incompatible Materials] for further guidance.