Usage of H2

1 Introduction

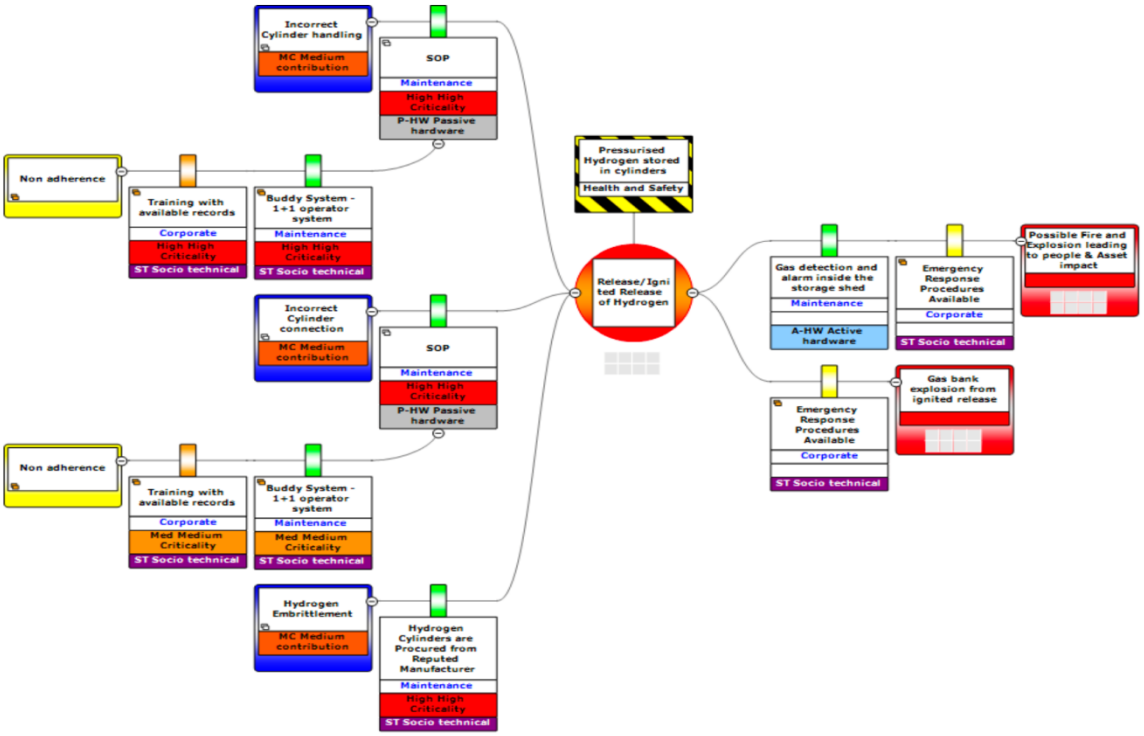
H2 is commonly used in many labs in IISc. High-pressure H2 is a hazardous gas that can easily explode or catch fire. Users are requested to give it more respect. Any H2 cylinder on campus must conform to the following standards.

2 Do you really need 200 bar H2?

1. Department should explore replacement of 100% H2 with of "5%H2" cylinders with balance N2 or Ar. Below 5 %, H2 is intrinsically safe even at high pressures. So,there is need any extra safety precautions beyond those prescribed for compressed N2. This is the cheapest and easiest solution.
2. In case some labs require 100% pure H2, Safety Committee recommends use of low-pressure H2 cylinders, with pressure capped at 4 bar. At no time can the amount of H2 stored in lab exceed 1% of the laboratory volume (at standard pressure). E.g., for in 40 m3 room, you cannot have more than 400 litres of H2. This ensures that even in case of catastrophic release, the total amount of H2 in lab remains below ignition levels.
5. Tabletop H2 generators are an easy solution for small quantities of H2. They are intrinsically safe and don't require any special precautions (same as #2). Prices start at 2 lakhs. Here are some links for H2 generators of various pricing and capacity:
    a. https://www.fuelcellstore.com/pem-hydrogen-generator-ql-300
    b. https://www.sigmaaldrich.com/catalog/substance/parkerh2pemhydrogengenerator1234598765
    c. https://www.sigmaaldrich.com/catalog/substance/domnickhunternitroxuhphydrogengenerator1234598765
    d. https://www.peakscientific.com/products/hydrogen/precision-hydrogen-100/
1. For the pressurized Parr reactions (in the room with autoclaves), consider generators that produce higher pressures, e.g. https://thalesnano.com/phoenix-h-genie-platform/

3 Safeguards

High-pressure H2 (> 4 bar) must be used with safeguards. It is mandatory to have at least one barrier to prevent a top event, for every escalation factor. It is mandatory to have one barrier to mitigate the effect of a top event, for every hazard. Safeguards must also be present to prevent degradation of a critical barrier.A safety bow-tie is a useful way to visualize the safety features. The analysis is usually the result of a formal HAZID/HAZOP study. OLSEH can help.



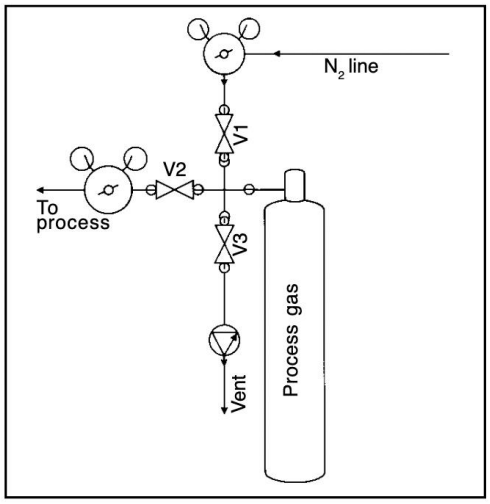
3.1 Mandatory barriers for > 4 bar H2

Following basic safety systems are needed for all H2 cylinders (including low-pressure cylinder recommended above)

1. Basic cylinder safety: Usual requirement for any compressed gas cylinder must be followed, e.g., restraints, labels, etc.
    a. As a corollary, cylinder should be transported safely in carts. No rolling.
    b. Get cylinders from reputed vendors.
2. Regulators. To step down the pressure for distribution. Output pressure should not be > 8 bar. Usage of H2 at higher pressure requires advanced safety features.
3. Flash arrestors: If the H2 is being used in an open-circuit (at some point H2 vents to air without scrubbing), then inlet lines must have flash arrestors. If flash arrestors are not possible, e.g., due to purity requirements, the lines must be closed loop with scrubber at the end.
4. Outlet valves and fittings: All distribution lines should have a high-pressure H2-rated rated diaphragm or ball-valve made of metal. Do not use low-cost unproved valves from a hardware store.All fitting, tubes, valves, must be made of metal. No insulating materials like plastic/rubber that can cause static.
5. Earthing. H2 is very susceptible to static. All H2 cylinders and lines must be connect to earthing cable. If the lines use insulating gaskets, like rubber, then individual sections of line must also be earthed.
6. Access-control. H2 cylinder change is a critical manoeuvre. Mistakes can be deadly. Only authorized and trained personnel are allowed to change H2 cylinders. The labs must have some access control (lock, room, etc.) to prevent unauthorized change of cylinders.
7. Log register. The log must list the following
    i. Date of installation with cylinder number; initial quantity of H2 in std. litres; cylinder pressure.
    ii. For every usage, there should be an entry with date; starting cylinder pressure; volume used in std. litres; final cylinder pressure; user name

iii. Date of removal of H2; final pressure.

2. Manifolds with a purge-cross (e.g., page 13 of this). These crosses must be used to evacuate residual air during cylinder changeover and filling of balloons. Here is an example SOP.
    a. Passive flow restrictors that limit flow to 1 litre/min. These can be simple orifices with correct diameter.
    b. Handheld H2 detectors to check for leaks during delivery and installation of new H2 cylinders. One/two can be shared across a department.



3.2 Additional Mandatory for > 8bar H2

In cases where 100% H2 at > 8bar is required, additional safety features are needed (over and above those given above). Details will vary, but we need to follow the attached checklist. Dept is welcome to submit a plan to OLSEH for consideration.The design of all gas distribution system of high-pressure H2 must be certified by two faculty members (with suitable expertise), other than the PI. OR approved by OLSEH

0. Sensors: All hazardous gases (NFPA >2 in any category) require interlocked sensors. These must be continually active sensors, mounted near the cylinder and usage point. The output of the sensor should be connected to a hooter and building fire alarm system. In case the sensor senses a leak, the departments must evacuate.
1. Gas-cabinets or gas-banks. High-pressure H2 cylinders should be ideally stored outside in a well-ventilated area. The H2 can be distributed from the gas-bank to the labs in SS-pipes. The gas-bank should be contracted such that H2 cannot accumulate at the top. The electrical fitting near H2 tank, must be explosive rated. Alternatively, the cylinder should be in a fire-rated, specially designed exhausted gas-cabinets. The gas cabinets may be completely automatic or semiautomatic thatshut off the gas flow from cylinder in case of alarms or gas leaks.
2. Cylinder manifold: All high-pressure H2 cylinders must be connected to a 5-valve or 7-valve purge manifold, rated for H2. Professionally constructed manifolds are commercially available.
3. Certification for cylinder. H2 causes embrittlement of metal. Any H2 cylinder must be certified by a reputed manufacturer for storage of H2. This often means regular isostatic testing. In cases where the certificates are not available, cylinder must be decarded every 5 years of use.
4. Non-arcing tools: Use non-arcing tools for cylinder change or line repair.
5. Gas distribution system: Gas distribution manifold must be constructed using fittings rated for H2. We strongly prefer welded, face-seal fittings (VCR® or equivalent). High-quality Swagelok® or other compression fittings with metal ferrules are also ok, if installed

professionally. No plastic tubing.All fitting carrying H2 must be He-leak checked after installation or repair.

6. Active fire-fighting equipment: To contain a fire, H2 cylinders must have active fire-fighting systems, e.g., sprinklers. A sprinkler in the vicinity of a H2 cylinder is mandatory.
7. Documentation:
    a. A clearly written SOP for common events like cylinder changes, and transportation. OLSEH must approve the SOP. A template is available on request.
    b. A list of users who have trained to change cylinders with dates or their training.
8. Depending on the capacity, autoclaves or other high-pressure equipment themselves might require safety paraphernalia like reinforced walls