Safety advice.

Hydrogen.

Properties

Hydrogen is a chemical element with the molecular formula H₂.
Hydrogen is available as a gas and as a cryogenic liquid.

Physical properties
At atmospheric temperatures and pressures, hydrogen is a colourless and odourless gas which is lighter than air. Hydrogen molecules are very small and very mobile. Hydrogen has high heat conductivity. Liquid hydrogen forms below −253 °C.

Chemical properties
Hydrogen is an extremely flammable gas. It burns in air with a pale blue, almost invisible flame. In the pure state, hydrogen may cause stress corrosion cracking (hydrogen embrittlement).

Density of gases

<table>
<thead>
<tr>
<th>Density (kg/m³) at 15 °C, 1013 bar</th>
<th>Relative density, relating to air = 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>0.07</td>
</tr>
<tr>
<td>Helium</td>
<td>0.14</td>
</tr>
<tr>
<td>Methane</td>
<td>0.56</td>
</tr>
<tr>
<td>Ammonia</td>
<td>0.59</td>
</tr>
<tr>
<td>Acetylene</td>
<td>0.90</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.97</td>
</tr>
<tr>
<td>Air</td>
<td>1.00</td>
</tr>
<tr>
<td>Argon</td>
<td>1.11</td>
</tr>
<tr>
<td>Propane</td>
<td>1.39</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>1.50</td>
</tr>
</tbody>
</table>

Hydrogen is the lightest of all gases. Escaped hydrogen immediately rises upwards and accumulates under ceilings.
Hazards

Flammability
Hydrogen is an extremely flammable gas in air. The flammable range in air goes from 4 vol% to 77 vol%. Very little energy is required to ignite it, e.g. static electricity. Under certain conditions spontaneous ignition may occur. Hydrogen burns in air with a very hot and almost invisible flame, which emits very little radiant heat and therefore gives limited warning of hydrogen flames.

Gas under pressure
A hydrogen cylinder contains compressed gas under pressure (typically 200 or 300 bar). It may rupture (or burst) if heated.

Brittle fracture
Hydrogen molecules are very small and highly mobile. They can force their way into materials or through small gaps that would be impermeable for air and other gases. Certain metallic materials, when exposed to hydrogen gas under certain conditions, can be attacked by hydrogen embrittlement and/or stress corrosion cracking. Both processes reduce the ductility and tensile strength of the material.

Cold burns – skin and eyes
Liquid hydrogen is extremely cold (–253 °C) and will cause severe and immediate cold burns to unprotected skin or the eyes. Any direct contact with cryogenic liquid, uninsulated pipes or equipment will cause cold burns and tissue damage. The cold burn itself is similar to a burn from a hot source and will destroy tissue. Also, a jet of cryogenic gases may freeze the skin or eyes. See the safety advice on cryogenic liquefied gases for more details.

Asphyxiation
Hydrogen in high concentrations may cause asphyxiation.
Precautions

PPE
Wear eye protection when using gases. Wear flame resistant/retardant clothing. Wear working gloves and safety shoes while handling cylinders. Take precautionary measures against static discharges. Gas detectors should be used-installed when quantities of hydrogen may be released.

Leaks
The hydrogen system must be leak-proof from the source e.g. cylinder to the point of use.

Ignition sources
Avoid any potential ignition sources, including: matches or cigarette lighters, mobile phones, two-way radios, pagers, petrol driven engines, sparks from static electricity (even the static from wearing nylon or man-made fibres may ignite hydrogen), non-flameproof electrical equipment, friction, any item containing batteries, aluminium ladders or equipment impacting against rusted metallic materials. Flammable zones classification should be considered and only equipment suitable for potentially explosive atmospheres should be used with hydrogen.

Materials
Metal material must be selected considering the risks of hydrogen embrittlement and stress corrosion cracking.

Confined spaces
A risk assessment must be carried out before entering or working in a confined space and a permit to work must be obtained to ensure safe working conditions. When open flames are used, for example in welding or cutting, flames consume the oxygen in the air and oxygen deficiency may occur. Ensure proper ventilation is in place.

General recommendations
- Do not drag cylinders
- For capped cylinders, ensure the cap is fitted when they are being stored or transported
- Hydrogen cylinders should not be left in non-dedicated vehicles
- Perform valve leak test before transport and use
- External damage to cylinders and valves (e.g. by welding or striking electric arcs or impact by sharp objects) must be avoided
- Do not use cylinders as rollers or work supports
- Secure hydrogen cylinders during use, storage and transport on vehicles to prevent movement
- Any stamping or means of identification on the cylinder must not be altered
- Never heat cylinders, e.g. by direct flame, electrical devices or hot water, to raise the pressure or the flow rate
- Cylinders must be connected to low pressure equipment only when using proper pressure regulators
- Cylinder valves are unsuitable for pressure and flow regulation
- Close hydrogen cylinder valve when not in use
- Keep cylinder valve outlets and other equipment free from contaminants, particularly oil and water
- Do not repair or modify cylinders and valves. Any damage must be made known to the supplier
- Hydrogen should never be transferred from one container to another.
Emergency

Hydrogen is an extremely flammable gas. Eliminate ignition sources and do not extinguish a leaking gas fire unless the leak can be stopped. Exposure to a fire may cause cylinders to rupture/explode.

Spill or leak
1. If safe to do so, isolate container
2. Evacuate area, eliminate ignition sources and ensure adequate ventilation
3. Stop leak, if possible (e.g. close the cylinder valve wearing proper hand protection)
4. Prevent entry into waterways, sewers, basements or confined areas
5. Consider the risk of potentially explosive atmospheres
6. Do not direct water at spill or source of a liquid hydrogen leak (risk of ice building/blockages).

First aid
1. Inhalation: Remove victim to uncontaminated area and fresh air. Keep victim warm and rested. Call a doctor. Apply artificial respiration if breathing has stopped.
2. Skin or eye contact with cryogenic liquid: In case of frostbite or cold burn, spray with or place in lukewarm water for at least 15 minutes. Do not remove adhered clothing. Apply a sterile dressing. Obtain medical assistance. Immediately flush eyes thoroughly with lukewarm water for at least 15 minutes.

Fire
1. Suitable extinguishing media: water, dry powder or foam
2. Unsuitable extinguishing media: carbon dioxide
3. Do not extinguish a leaking gas fire unless leak can be stopped (e.g. closing the cylinder valve wearing proper hand protection)
4. Exposure to fire may cause containers to rupture or explode
5. Move container away or cool with water from a protected position
6. If the liquid hydrogen container is leaking do not spray water directly onto the container
7. Water the surrounding area to contain fire
8. Advise Fire Service of the location and quantities of hydrogen
9. Damaged / impacted containers should be handled only by specialists (return to supplier).

Refer to the relevant Safety Data Sheet for further information/contact your local Linde supplier for specific questions.