

**BUREAU OF INDIAN STANDARDS**  
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*Draft Indian Standard*

**Code of Safety for Cryogenic liquid**

**Part 5 Liquid Hydrogen**

*(First Revision of IS 5931)*

*भारतीय मानक मसौदा*

**क्रायोजेनिक तरल के लिए सुरक्षा संहिता**

**भाग 5 तरल हाइड्रोजन**

*(पहला पुनरीक्षण)*

**(ICS 71.100.20)**

**Chemical Hazards Sectional Committee, CHD 07**

**Last Date of Comment: 21.07.2024**

**FOREWORD**

(Formal clause to be added later)

Handling liquid hydrogen safely is largely a matter of knowing their properties and using suitable procedures based on that knowledge. There are a number of general precautions and safe practices which shall have to be observed because of extremely low temperatures and high rates of conversion into gas of the liquid hydrogen mentioned in this standard. There are also certain specific precautions which shall have to be followed where a particular liquid may react with contaminants or may present a hazard to life.

The elimination of accidents is vital to public interest. Accidents produce social and economic loss and impair individual or group productivity. Realization of this loss has led the authorities to devote a good deal of attention to safety education. Apart from general precautions, some

typical precautions are required to be taken during manufacture, storage and handling of liquid hydrogen. The standard also prescribes safety measures for controlling hazards and essential information on symptoms of poisoning, first-aid, medical treatment, storage, handling, labelling and employee safety. This standard is intended to guide the users in the recognition of these hazards and in establishing safe handling procedures.

BIS has published a standard IS 5931: 1970 'Code of Safety for Handling of Cryogenic Liquids'. During the revision, considering the bulkiness of the standard, and recognizing the need for clarity, the committee decided to restructure it by splitting into various parts based on type of cryogenic liquids.

This (Part 5) prescribes a code of safety concerning hazards relating to liquid hydrogen. It describes the properties and essential information for the safe handling and use of liquid hydrogen, safety measures for controlling hazards and essential information on symptoms of poisoning, first-aid, medical treatment, storage, handling, labelling and employee safety.

The other parts of this standard are as following:

Part 1 Liquid Oxygen (*first revision*)

Part 2 Liquid Nitrogen (*first revision*)

Part 3 Liquid Argon (*first revision*)

Part 4 Liquid Helium (*first revision*)

Part 6 Liquid Krypton (*first revision*)

Part 7 Liquid Neon (*first revision*)

The various clauses of the standard have been aligned with the format being applied for all Indian Standards on code of safety of chemicals.

## **SCOPE**

**1.1** This code describes the properties of liquid hydrogen, the nature of hazards associated with it and the essential information on storage, handling, packing, labelling, and disposal of waste, cleaning and repair of containers, training of personnel, selection of personal protective equipment and first aid.

**1.2** This code does not deal with the specifications for design of buildings, chemical engineering plants, storage vessels and equipment for operations control and waste disposal.

## **2 REFERENCES**

The standards given below contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of standards given at below:

<i>IS No.</i>	<i>Title</i>
IS 1260 (Part 1): 1973	Pictorial marking for handling and labelling of goods: Part 1 Dangerous Goods
IS 2925: 1984	Specification for industrial safety helmets ( <i>second revision</i> )
IS 4155: 2023	Glossary of terms relating to chemical and radiation hazards and hazardous chemicals ( <i>first revision</i> )
IS 8520: 2023	Guide for selection of industrial safety equipment for eye, face and ear protection
IS 10245 (Part 1): 2023	Respiratory Protective Devices-Specification: Part 2 Self-Contained Open Circuit Breathing Apparatus ( <i>second revision</i> )
IS 15298 (Part 2) : 2016/ISO 20345: 2011	Personal protective equipment: Part 2 safety footwear ( <i>second revision</i> )
IS 15803 : 2008	Respiratory protective devices - Self contained closed circuit breathing apparatus chemical oxygen (KO <sub>2</sub> ) type, self generating, self rescuers - Specification

### **3 TERMINOLOGY**

For the purpose of this standard the definitions given in IS 4155 shall apply.

### **4 PROPERTIES LIQUID HYDROGEN**

#### **4.1 General Information**

Although the purpose of the code is to outline the basic techniques for the safe handling of liquid hydrogen, the liquid is invariably accompanied by a certain amount of gas. Since gaseous hydrogen is flammable over a wide range of concentrations in air, much of the material presented in this section has to do with handling the gas safely.

##### **4.1.1 Chemical Name - H<sub>2</sub>**

**4.1.2 Common Name & Synonyms -** Hydrogen (refrigerated), Cryogenic Liquid Hydrogen, Liquid Hydrogen

**4.1.3 Uses –** General Industrial.

#### **4.2 Identification**

4.2.1 *Formula* - H<sub>2</sub>

4.2.2 *CAS Number* - 1333-74-0

4.2.3 *UN Number* - 1966

4.2.4 *UN Class* - 2.1

### 4.3 Physical Properties

4.3.1 Liquid hydrogen has a relatively high coefficient of thermal expansion which should be taken into consideration in the design of equipment for handling liquid. The low temperature of liquid hydrogen can solidify any gas except helium.

4.3.2 *Molecular Mass* - 2 g/mol

4.3.3 *Physical State* - Liquefied gas

4.3.4 *Colour* - Colorless

4.3.5 *Odour* - Odorless.

4.3.6 *Boiling Point* - -423 °F (-253 °C)

4.3.7 *Melting Point* - 435 °F (-259.2 °C)

4.3.8 *Vapour Density (Air=1)* - 0.07 (air = 1) Lighter or similar to air.

4.3.9 *Specific Gravity*

a) Liquid (water = 1) – 0.070 81

4.3.10 *Viscosity at 30 °C* – No data available.

4.3.11 *Vapour Pressure at 76.6 °C* - No data available.

4.3.12 *Heat of Combustion* – No data available

4.3.13 *Refractive Index at 25 °C* – Not available

4.3.14 *Solubility in Water* – No data available

4.3.15 *Solubility in other solvents* – Not available

4.3.16 *Light Sensitivity* - Not available

### 4.4 Chemical Properties

4.4.1 *Reactivity* - No data available.

4.4.2 *Polymerisation* – Not available

4.4.3 *Allotrope formation* – Not available

4.4.4 *Corrosion properties* –. Not available

### 4.5 Fire and Explosion Hazard Properties

4.5.1 *Ignition Temperature* - No data available.

4.5.2 *Auto Ignition Temperature* - 560 °C

**4.5.3 Flash Point** - Not applicable.

**4.5.4 Upper Explosive Limit** - 77 percent (V)

**4.5.5 Lower Explosive Limit** – 4 percent (V)

**4.5.6 Fire Risk**

Liquid hydrogen is ignitable by static electricity, and burns with an invisible flame. Gas is lighter than air and can accumulate in the upper sections of enclosed spaces. Spill will rapidly vaporize and create an immediate flammable atmosphere. Move away from container and cool with water from a protected position. Keep containers and surroundings cool with water spray. Do not direct water spray at container vent. Do not extinguish a leaking gas flame unless absolutely necessary. Spontaneous/explosive re-ignition may occur. Extinguish any other fire. If possible, shut off the source of gas and allow the fire to burn itself out. Vapor cloud may obscure visibility.

## **5 HEALTH HAZARD & TOXICITY INFORMATION**

### **5.1 General Information**

Hydrogen gas is odorless and nontoxic but may produce suffocation by diluting the concentration of oxygen in air below levels necessary to support life.

### **5.2 Routes of entry**

#### **5.2.1 Skin**

In case of frostbite, obtain medical treatment immediately. Wash frost-bitten areas with plenty of water. Do not remove clothing. Cover wound with sterile dressing. Do not rub frozen parts as tissue damage may result. As soon as practical, place the affected area in a warm water bath-which has a temperature not to exceed 40 °C (105 °F).

#### **5.2.2 Eyes**

In the case of contact with eyes, rinse immediately with plenty of water and seek medical advice. Keep eye wide open while rinsing. Seek medical advice.

#### **5.2.3 Ingestion**

Ingestion is not considered a potential route of exposure.

#### **5.2.4 Inhalation**

Move to fresh air. In case of shortness of breath, give oxygen. If breathing has stopped or is labored, give assisted respirations. Supplemental oxygen may be indicated. If the heart has stopped, trained personnel should begin cardiopulmonary resuscitation immediately.

### **5.3 Toxicity information**

No data is available on the product itself.

### **5.4 Antidote**

### **5.5 Health Effects**

#### **5.5.1. Signs and Symptoms**

### **5.5.2 Acute Toxicity**

No data is available on the product itself.

### **5.5.3 Chronic Toxicity**

No data is available on the product itself.

## **6 PERSONAL PROTECTIVE EQUIPMENT**

### **6.1 Availability and Use**

### **6.2 Non-Respiratory Equipment**

#### **6.2.1 Eye and face Protection**

Safety glasses recommended when handling cylinders. Wear goggles and a face shield when trans-filling or breaking transfer connections (*see IS 8250*).

#### **6.2.2 Head Protection**

Safety helmet with face shield is recommended while handling the liquid hydrogen (*see IS 2925*).

#### **6.2.3 Foot and leg Protection**

Safety shoes are recommended when handling cylinders (*see IS 15298 (Part 2)*).

#### **6.2.4 Body, Skin and Hand Protection**

Wear work gloves when handling gas containers. Loose fitting thermal insulated or leather gloves. Chemical-resistant, impervious gloves complying with an approved standard should be worn at all times when handling chemical products if a risk assessment indicates this is necessary. Safety shoes are recommended when handling cylinders. Flame retardant protective clothing. Never allow any unprotected part of the body to touch uninsulated pipes or vessels which contain cryogenic fluids. The extremely cold metal will cause the flesh to stick fast and tear when one attempts to withdraw from it.

### **6.3 Respiratory Equipment**

Severe exposure to phenol may occur in tanks during equipment cleaning and repairs, during decontamination of areas following spills, or in case of failure of piping or equipment. Employees who may be subject to such exposures should be provided with proper respiratory protection as described below:

#### **6.3.1 Self-Contained Breathing Apparatus**

This apparatus permit the wearer to carry a supply of oxygen or air compressed in the cylinder (*see IS 10245 (Part 1)*) and the self-generating type which produces oxygen chemically (*see IS 15803*). These allow considerable mobility. The length of time, a self-contained breathing apparatus provides protection varies according to the amount of air, oxygen, or regenerating material carried. Compressed oxygen should not be used where there is danger of contact with flammable liquids, vapours, or sources of ignition, especially in confined spaces, such as tanks or pits.

## **7 STORAGE, HANDLING, LABELLING AND TRANSPORT**

### **7.1 General**

#### **7.2 Storage**

**7.2.1** It is desirable to convert liquid hydrogen to the stable para-form during liquefaction to avoid product loss during storage. It is usual to allow the evaporated gas to escape freely and in such a way that air is not permitted to diffuse back into the container. It is essential to keep the mouth of Dewars connected to a suitable vent line and to use a simple non-return bunsen valve. In laboratories a tight wad of cotton wool is usually pushed into the mouth of the neck-tube. It is also necessary to check daily whether the neck-tube is clear by carefully lowering a stout copper tube fitted with a collar. This relatively warm metal tube will usually vaporize solid air obstructions and the collar will prevent the tube from slipping too far into the Dewar and damaging the bottom. Alternatively, the obstruction may be dispersed by means of a jet of warm hydrogen introduced by means of a suitable tube.

**7.2.2** Super insulated vessels carry separate liquid and vent lines, which may be valved off. The vent is fitted with a relief valve and bursting disc and gives adequate protection, for almost any event.

**7.2.3** It is recommended that liquid hydrogen containers should be stored out of doors when not in service and smaller vessels should be protected from the weather. All vessels should be connected to a vent pipe which discharges hydrogen at a high point away from ignition sources. A flame trap or water seal, may be employed at the discharge point.

**7.2.4** Storage of liquid hydrogen containers shall be away from the liquefaction plant. The production and storage shall be planned according to the experimental programme; excessive storage is uneconomic and hazardous.

**7.2.5** The storage area shall be protected from any source of fire or ignition. There shall not be any combustible matter in the area.

#### **7.3 Handling**

**7.3.1** Safety precautions to be observed in areas where hydrogen is handled is briefly given in **7.3.1.1** to **7.3.1.5**.

**7.3.1.1** Efficient ventilation should be ensured to permit rapid diffusion of hydrogen gas.

**7.3.1.2** Open flame or smoking shall not be permitted in the area.

**7.3.1.3** Non-flameproof electrical equipment shall be placed in a safe area.

**7.3.1.4** All electrical equipment located in the area should be of the type, approved by the Chief Inspector of Explosives in India.

**7.3.1.5** Personnel entry in the area shall be restricted and the area barricaded to limit access. There shall be automatic monitors to signal dangerous proportions of hydrogen in the air.

**7.3.2** Safety precautions to be observed while working with the equipment that deals with hydrogen is briefly given in **7.3.2.1** to **7.3.2.6**.

**7.3.2.1** All vessels and pipes should be purged before introducing liquid hydrogen.

**7.3.2.2** Equipment should be tested for hydrogen leaks on ingress of air into it during its working.

**7.3.2.3** Filling and refilling operations of liquid hydrogen containers should be carefully done and it should be ensured that the containers are free from air by flushing them with liquid nitrogen or other liquid gas.

**7.3.2.4** Dewar weights should be manageable to be handled by a single man and the Dewars should be properly designed for venting, insulation and handling.

**7.3.2.5** Sealing liquid hydrogen containers with adhesive tapes should not be allowed. This is a source of static sparks and this causes explosions.

**7.3.2.6** Personnel working with liquid hydrogen should wear goggles and gloves. Liquid hydrogen in contact with skin gives serious burns; contact of bare hands with piping or containers is hazardous and should be avoided.

**7.3.3** The precautions given in **7.3.3.1** to **7.3.3.5** shall be taken to control static charges.

**7.3.3.1** All metal parts of equipment and piping, which contain hydrogen, should be grounded

**7.3.3.2** Anti-static belts for machinery in the place-of ordinary ones, which are not spark-free should be used.

**7.3.3.3** Nylons or other synthetic clothing should be avoided in areas where hydrogen is handled. Combing of hair also should be avoided.

**7.3.3.4** All personnel should be grounded before they handle Dewars. They should wear conducting shoes.

**7.3.3.5** Spark-proof (brass) tools should be used although they do not necessarily give adequate safety against ignition as the energy of activation is small.

## **7.4 Labelling**

**7.4.1** Each container (including tankers) should carry an identifying label or stencil as depicted in Fig. 2 in IS 1260 (Part 1). The storage containers shall be labelled or marked to identify as follows:

a) Contents of the container;

b) Name and address of the manufacturer or importer of the hazardous chemical; and

c) Physical, chemical and toxicological data as per the criteria given in the relevant schedule of the Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989. While referring to the statutes, the stipulations given in the subsequent amendments of those statutes shall be taken into account

## **7.5 Transport**

**7.5.1** The transport of Dewars has associated hazards during filling or transferring of liquid hydrogen from them into the equipment, due to leaks or by trapping of moisture. Overflows shall also be avoided by use of suitable devices. All the associated gadgets shall be flushed with liquid nitrogen and checked for absence of oxygen in the system.



**7.5.2** The transport of even 200 ml of liquid hydrogen from small units requires careful planning if the material passes through the crowded streets. The transport van shall be designed to have explosion proof sides, and suited for the purpose with due regard to fire and explosions risks, static charge and hydrogen gas leakage. The container Dewar shall be thoroughly insulated and checked for leakage before transport.

**7.5.3** The van shall not pass through the streets without escort preceding and following it at the safe distance showing up the danger signals (red flags). The transportation shall be done in accordance with the existing rules, if any, governing transport of liquid hydrogen. Liquid hydrogen shall be-not transported during the crowded hours of the day.

**7.5.4 Driver**

Only driver trained in handling should be employed for transportation of liquid hydrogen. Driver should carry TREM card, material Safety Data Sheet and other legal documents for safety needs when vehicle is on road.

## **8 SPILLAGE, LEAKAGE AND WASTE DISPOSAL**

### **8.1 General**

All personnel attending to spill/leak should use proper personal protective equipment and fire-fighting equipment while handling liquid hydrogen.

### **8.2 Spillage**

**8.2.1** Evacuate personnel to safe areas. Approach suspected leak areas with caution. Remove all sources of ignition. Ventilate the area. Never enter a confined space or other area where the flammable gas concentration is greater the 10 percent of its lower flammable limit.

**8.2.2** Prevent further leakage or spillage if safe to do so. Prevent from entering sewers, basements and work pits, or any place where its accumulation can be dangerous. Do not discharge into any place where its accumulation could be dangerous.

**8.2.3** If possible, stop flow of product. Increase ventilation to the release area and monitor concentrations. Do not direct water spray at container vent. Liquid spillages can cause embrittlement of structural materials. If leak is from cylinder or cylinder valve, call the emergency telephone number. If the leak is in the user's system, close the cylinder valve, safely vent the pressure, and purge with an inert gas before attempting repairs.

**8.2.4** When liquid hydrogen is spilled on a surface, it tends to cover it completely and, therefore, cools a large area. The evaporation rate of liquid hydrogen greatly reduces the period during which a spill constitutes a potential fire hazard. However, with a large spillage the surface freezes and the air above the surface liquefies. A large cloud of the very cold gas caused by evaporation of liquid on the surface stays over the surface till it picks up heat to rise up. If this gas gets ignited, it burn smoothly in air. The visible cloud does not confine to the flammable zone and ignition is possible outside the clouds. If 7.8 l of liquid hydrogen are spilled on 50 cm below an open flame, the mixture is ignited almost immediately, after about 0.5 second the flame reaches the height of nearly 8.5 m with a maximum width of 6 m.

**8.2.5** The duration of burning of liquid hydrogen after a small spill is usually very brief, lasting only a few seconds. In larger spills on hydrogen burning from open vessels, combustion may take several minutes until all the liquid is evaporated. The flame temperature is about 1 900

°K, but the radiation-intensity is low. Therefore, it is possible to get close to small quantities of smoothly burning liquid hydrogen because the flame has little luminosity and low radiant intensity. One is also able to approach flames more closely for fire-fighting or closing for supply valves.

### **8.3 Leakages**

#### **8.3.1 General Information**

Leaks of liquid hydrogen would rapidly vaporise the gaseous hydrogen would be initially very cold, especially if there was a significant leak. The gas, until it warms up, would be denser than air and behave as a dense gas and start accumulating at low level.

#### **8.3.2 Leak from the Truck**

The consequences of the accidental leakage of liquid hydrogen during transport from trucks are still poorly understood. It is important to be able to reliably predict how far the released hydrogen would spread, the thermal radiation levels if the hydrogen ignites to form a flame jet or the explosion pressures generated if there is a delayed ignition of the released hydrogen in order to assess the consequences of the leak, i.e. damage to equipment and injuries to people.

#### **8.3.3 Caution**

Remove all sources of ignition. Reduce gas with fog or fine water spray. Stop flow of product if safe to do so. Ventilate area or move container to a well-ventilated area.

**8.3.4** Manually carried or portable detection systems are not considered advisable from personnel safety considerations in large production programmes. It is necessary to install suitable sensors at various places for remote detection. For small laboratories portable detectors shall be used that are sensitive to 20 percent of lower explosive limit (about 1 percent hydrogen).

### **8.4 Waste Disposal**

**8.4.1** The venting of spent hydrogen is associated with hazard and shall be done very carefully.

**8.4.2** Return unused product in original cylinder to supplier. Contact supplier if guidance is required. Do not discharge into areas where there is a risk of forming an explosive mixture with air. Waste gas should be flared through a suitable burner with flash back arrestor. Return cylinder to supplier.

**8.4.3** In using 200 ml of liquid hydrogen, the vent gases (about 360 000 ml at room temperature pressure) shall be released gradually in a naturally ventilated atmosphere through a long vent tube over the roof. The explosion hazards are absent if the release is very gradual and no sources of ignition are present near release point.

**8.4.4** Disposal of vent gases by burning is a safe practice provided the amounts released are large and continuous, and this is an adequate safety in vent construction and water seal. The water vent tank is used to stop flashbacks which might occur if the hydrogen flow is below velocity and air diffuses down the pipe and mixes with the hydrogen gas.

**8.4.5** Alternative vent design is to omit the water seal tank and introduce the natural gas into the safety vent at a point near the vacuum tank so that the gas flows through the whole vent line and purges it.

**8.4.6** The actual vent design shall be made on the basis of available gas for disposal and location. The vent line design shall consider the dependence of lower limits of flammability on the size of vent piping.

## **9 FIRE PREVENTION AND FIRE FIGHTING**

### **9.1 General**

**9.1.1** Shutting off the source of the gas is the preferred method of control. Be aware of the risk of formation of static electricity with the use of CO<sub>2</sub> extinguishers and do not use them in places where a flammable atmosphere may be present. Ignitable by static electricity. Burns with an invisible flame. Gas is lighter than air and can accumulate in the upper sections of enclosed spaces. Spill will rapidly vaporize and create an immediate flammable atmosphere. Move away from container and cool with water from a protected position. Keep containers and surroundings cool with water spray. Do not direct water spray at container vent. Do not extinguish a leaking as flame unless absolutely necessary. Spontaneous/explosive re-ignition may occur. Extinguish any other fire. If possible, shut off the source of gas and allow the fire to burn itself out. Vapor cloud may obscure visibility.

**9.1.2** Wear self-contained breathing apparatus for firefighting if necessary.

**9.1.3** The presence of a hydrogen flame can be detected by approaching cautiously with an outstretched straw broom to make the flame visible.

### **9.2 Fire Prevention**

**9.2.1** To prevent fire incidents with hydrogen, the main principles to be applied are as follows:

- a) Segregation, by keeping hydrogen and air separate;
- b) Ventilation, sweeping away hydrogen which may have leaked out; and
- c) Ignition control, removing potential sources of ignition.

**9.2.2** In the working area, the allocation of space should be generous, preferably with a high sloping roof or ceiling, allowing free escape for the light buoyant hydrogen at the highest point. One may rely on the natural draught principle by using doors with levers at the bottom and an open roof ridge. During warm weather the open doors and windows increase ventilation, whereas in extreme winter judiciously spaced steam radiators provide upward convection to assist the buoyancy flow of contaminated air (detectors have shown that lateral diffusion of hydrogen is not so marked in a sudden spill of a few litres of liquid). Hydrogen rises in a compact area to clear the building within a few seconds.

**9.2.3** It is, therefore, advantageous to work in a large room, for instance, a spill of 5 l of liquid hydrogen in a room 6 m x 6 m x 6 m is unlikely to cause an explosion even in the absence of any ventilation. A good way of removing contaminated air is to work the liquid hydrogen equipment under a hood leading into a separate vent stack particularly for smaller operation. The vent should not be shared with non-hydrogen users and an extractor is not recommended. Where it is important to increase the draught, this may be induced by blowing fresh air into the stack. It is preferable to blow fresh air into the working area rather than extract it by way of an electric fan, since electrostatic discharges on blades may cause ignition. Ventilation rates of 20 to 30 air changes are recommended.

### **9.2.4 Control of Ignition**

All potential sources of ignition should be controlled and no naked lights or flames be allowed where hydrogen is handled. Attention should be given to electrical devices because they are most likely to cause sparks or hot spots as a result of failure or overloading.

### **9.3 Fire fighting**

Although specific fire-fighting procedures depend upon the quantity of liquid hydrogen involved, the following general procedures are applicable to all fires involving hydrogen:

- a) Remove everyone not actively engaged in fighting the fire. Liquid hydrogen exposed to the atmosphere will produce a cloud of moisture condensed from the air. The flammable-mixture zone may extend beyond this vapour cloud and, therefore, personnel should be evacuated to points well outside the area of visible moisture.
- b) If at all possible, shut off the flow of liquid or gaseous hydrogen.
- c) Use large quantities of water, preferably in the form of a spray, to cool adjacent exposures and to cool any burning material below the ignition point. Adequate sprinkler systems and fire hoses with stream-to-spray nozzles should be considered for areas where large quantities of liquid-hydrogen are handled.
- d) Depending upon the circumstances it is not usually advisable to extinguish a hydrogen flame in confined areas if it is not possible to shut off the hydrogen supply. The continued escape of unburned hydrogen may create an explosive mixture which may be ignited by other burning material or hot surfaces. Usually it is better to allow the hydrogen to burn in confined areas and keep adjacent objects cool with water rather than risk the possibility of an explosion.
- e) If electrical equipment is involved in the fire, be sure the electrical supply is disconnected before using water for fire-fighting or use carbon dioxide or dry chemical extinguishers.

## **10 TRAINING**

**10.1** All personnel directly involved in the commissioning, operation and maintenance of liquid hydrogen storage systems shall be fully informed regarding the hazards associated with liquid hydrogen and be properly trained, as applicable, to operate or maintain the equipment. Training shall be arranged to cover those aspects and potential hazards that the particular operator is likely to encounter.

**10.2** Training shall cover, but not necessarily be confined to, the following subjects:

- a) Potential hazards of liquid hydrogen;
- b) Site safety regulations;
- c) Emergency procedures;
- d) Use of firefighting equipment;
- e) Use of protective clothing/apparatus including breathing sets where applicable; and
- f) First aid treatment for cryogenic burns.

**10.3** In addition, individuals shall receive specific training in the activities for which they are employed.

**10.4** It is recommended that the training be carried out under a formalized system and that records be kept of the training given and where possible, some indication of the results obtained, in order to show where further training is required.

**10.5** The training programme should make provision for refresher courses on a periodic basis and for changes of site personnel.

**10.6** Safety in handling liquid hydrogen depends upon the effectiveness of employee education, training and supervision. The education and training of employees to work safely and to use the personal protective equipment and other safeguards provided for them is a responsibility of supervisor. Employee education and training should emphasize the need of safely handling liquid hydrogen according to the methods outlined in the manual, in order to avoid spilling or splashing, leaks, burns, inhalation of the vapor of burning material, or ingestion. Unauthorized and untrained employees should not be permitted in areas where liquid nitrogen is being handled.

**10.7** Before being placed on the job, all new employees should be instructed and trained to maintain a high degree of safety in handling procedures. Older employees should be re-instructed and trained periodically.

## **11 HEALTH MANAGEMENT, FIRST-AID AND MEDICAL TREATMENT**

### **11.1 First Aid**

#### **11.1.1 *General Principles***

Remove victim to uncontaminated area wearing self-contained breathing apparatus. Keep victim warm and rested. Call a doctor. Apply artificial respiration if breathing stopped.

#### **11.1.2 *Contact with Skin***

In case of frostbite, obtain medical treatment immediately. Wash frost-bitten areas with plenty of water. Do not remove clothing. Cover wound with sterile dressing. Do not rub frozen parts as tissue damage may result. As soon as practical, place the affected area in a warm water bath-which has a temperature not to exceed 40 °C (105 °F).

#### **11.1.3 *Contact with Eyes***

In the case of contact with eyes, rinse immediately with plenty of water and seek medical advice. Keep eye wide open while rinsing. Seek medical advice.

#### **11.1.4 *Ingestion***

Ingestion is not considered a potential route of exposure.

#### **11.1.5 *Inhalation***

Move to fresh air. In case of shortness of breath, give oxygen. If breathing has stopped, give assisted respirations. Supplemental oxygen may be indicated. If the heart has stopped, trained personnel should begin cardiopulmonary resuscitation immediately.