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BUREAU OF INDIAN STANDARDS
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Draft Indian Standard

Code of Safety for Handling Cryogenic liquid

(*First Revision of IS 5931*)

भारतीय मानक मसौदा

क्रायोजेनिक तरल के लिए सुरक्षा संहिता

(*पहला* पुनरीक्षण)

(ICS 71.100.20)

Chemical Hazards Sectional Committee, CHD 07	**Last Date of Comment: 06.05.2024**

Foreword
(Formal Clause to be added later)

Handling cryogenic liquids safely is largely a matter of knowing their properties and using suitable procedures based on that knowledge. There arena 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 all the liquids 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 caustic soda. 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.

This standard was originally published in 1970. With a view to update the standard based on the experience of last five decades and on the currently available data the Committee felt a need to revise the standard. In this revision following changes have been incorporated:

a) General properties have been incorporated and modifications have been made to update safety measures for controlling hazards and essential information on symptoms of poisoning, first-aid, medical treatment, storage, handling, labelling and employee safety based on the currently available data and last five decades experience;

b) For the purpose of easy reference, the code has been divided into five sections, namely:

i) Liquid oxygen;
ii) Liquid nitrogen;
iii) Liquid argon;
iv) Liquid helium; and
v) Liquid hydrogen.

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 standard prescribes a code of safety concerning hazards relating to cryogenic liquids. It describes the properties and essential information for the safe handling and use of caustic soda.

1.2 This code does not, however, deal with specifications for design of buildings, chemical engineering plants, method and ingredients used in the manufacture, equipment for waste disposal and operation control.

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:

IS No.	*Title*
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 (*second revision*)
IS 4155: 2023	Glossary of terms relating to chemical and radiation hazards and hazardous chemicals (*first revision*)
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 (*second revision*)

IS 15803:2008	Respiratory protective devices - Self contained closed circuit breathing apparatus chemical oxygen (KO2) type, self generating, self rescuers - Specification

3 TERMINOLOGY

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

SECTION 1 LIQUIFIED OXYGEN

4 PROPERTIES

4.1 General Information

4.1.1 Liquid oxygen is pale blue and extremely cold. Although non-flammable, oxygen is a strong oxidizer. Liquid oxygen is a cryogenic liquid. Cryogenic liquids are liquefied gases that have a normal boiling point below –130°F (–90°C). Liquid oxygen has a boiling point of –297°F (–183°C).

4.1.2 Oxygen is the second largest component of the atmosphere, comprising 20.8 percent by volume. Oxygen is necessary to support life. Oxygen will react with nearly all organic materials and metals, usually forming an oxide. Materials that burn in air will burn more vigorously in oxygen. The temperature difference between the liquid oxygen and the oxygen in surrounding environment is substantial, it requires special equipment for handling and storage.

4.1.3 *Chemical Name* - O_2

4.1.2 *Common Name & Synonyms* - Oxygen (refrigerated), Oxygen USP, LOX, Cryogenic Liquid Oxygen

4.1.3 *Uses*

Oxygen is most commonly used in its gaseous state. For its life sustaining properties Oxygen is used in health & medical applications. Oxygen is widely applied in metal industries for its strong oxidizing properties. Steel and iron manufacturers extensively use oxygen to affect chemical refining and heating associated with carbon removal and other oxidation reactions to get benefit of fuel and energy savings plus to lower total emission volumes. In the chemical and petroleum industries, oxygen is used as a feed component to react with hydrocarbon building blocks to produce chemicals such as alcohols and aldehydes. The pulp and paper industry uses oxygen as a bleaching and oxidizing agent. Similarly, oxygen enhances the combustion process in industries that manufacture glass, aluminum, copper, gold, lead, and cement, or that are involved in waste incineration or remediation. Liquid oxygen is used as an oxidant for liquid fuels in the propellant systems of missiles and rockets.

4.2 Identification

4.2.1 *Formula* - O_2

4.2.2 *CAS Number* - 7782-44-7

4.2.3 *UN Number* - 1073

4.2.4 *UN Class* - 2.2

4.3 Physical Properties

4.3.1 *General*

Liquid Oxygen is tasteless, odorless, non-flammable, oxidizing and extremely cold.

4.3.2 *Molecular Mass* — 32 gm/mol

4.3.3 *Physical State* — Liquefied gas. Blue

4.3.4 Colour — Blue

4.3.5 *Odour* — No odor warning properties.

4.3.6 *Boiling Point* — (-) 297 °F (-183 °C)

4.3.7 *Melting Point* — (-) 362 °F (-219 °C)

4.3.8 *Vapour Density* (Air=1) — 1.105 (air = 1) Heavier than air.

4.3.9 *Specific Gravity*

a) Liquid (water = 1) at 20 ºC, 1 atm — 1.14

4.3.10 *Viscosity* at 30 °C — Not applicable.

4.3.11 *Vapour Pressure* at 76.6 °C — Not data available.

4.3.12 *Heat of Combustion* — No data available.

4.3.13 *Refractive Index* at 25 °C — No data available.

4.3.14 *Solubility in Water* at 25 ºC, 1 atm — 3.1 percent by volume.

4.3.15 *Solubility in other solvents* – No data available.

4.3.16 *Light Sensitivity* - No data available.

4.4 Chemical Properties

4.4.1 *Reactivity*

Violently oxidizes organic material. May react violently with combustible materials. May react violently with reducing agents.

4.4.2 *Polymerization* – Oxygen can both initiate and inhibit polymerization process.

4.4.3 *Allotrope Formation* – O_3

4.4.4 *Corrosion Properties* –.Can speed up corrosion due to rapid rate of oxidation.

4.4.5 *Incompatible Materials*

Cryogenic liquids can cause embrittlement of some metals and alter the physical properties of other materials. Keep equipment free from oil and grease. Consider the

potential toxicity hazard due to the presence of chlorinated or fluorinated polymers in high pressure (>30 bar) oxygen lines and equipment in case of combustion.

4.5 Fire and Explosion Hazard Properties

4.5.1 *Ignition Temperature* — No data available.

4.5.2 *Auto Ignition Temperature* — No data available.

4.5.3 *Flash Point* — Not applicable.

4.5.4 *Upper Explosive Limit* — Not applicable.

4.5.5 *Lower Explosive Limit* — Not applicable.

4.5.6 *Fire Risk* — Oxygen can react explosively with oil and grease.

5 HEALTH HAZARD & TOXICITY INFORMATION

5.1 General Information

Normally, air contains 21 percent oxygen, and oxygen is essentially non-toxic. No health effects have been observed in people exposed to concentrations up to 50 percent at 1 atm for 24 h or longer. The inhalation at 1 atm of 80 percent oxygen for more than 12 h can cause irritation of the respiratory tract, progressive decrease in vital capacity, coughing, nasal stuffiness, sore throat, and chest pain, followed by tracheobronchitis and later by pulmonary congestion and/or edema. Inhalation of pure oxygen at atmospheric pressure or less can cause pulmonary irritation and edema after 24 h. Respiratory symptoms can occur in 2 h to 6 h at pressures above 1 atm. One of the earliest responses of the lung is accumulation of water in its interstitial spaces and within the pulmonary cells. This can cause reduced lung function, which is the earliest measurable sign of toxicity. Other symptoms include fever and sinus and eye irritation. When pure oxygen is inhaled at pressures greater than 2 atm or 3 atm, a characteristic neurological syndrome can be observed. Signs and symptoms include nausea, dizziness, vomiting, tiredness, light-headedness, mood changes, euphoria, confusion, incoordination, muscular twitching, burning/tingling sensations (particularly of the fingers and toes), and loss of consciousness. Characteristic epileptic-like convulsions, which may be preceded by visual disturbances such as loss of peripheral vision, also occur. Continued exposure can cause severe convulsions that can lead to death.

5.2 Routes of entry

5.2.1 *Skin*

Oxygen itself is not harmful when in its gaseous form and is essential for human respiration. However, when oxygen is cooled and liquefied, it becomes extremely cold, with a boiling point of -183°C (-297°F). This extreme cold temperature can cause severe frostbite and tissue damage upon contact with skin.

5.2.2 *Eyes*

Exposure of the eyes to liquid oxygen can cause immediate and severe injury such as frostbite due to the extreme cold temperatures of the liquid. The severity of the frostbite depends on the duration of exposure and the amount of liquid oxygen that comes into contact with the eyes.

5.2.3 *Ingestion*
Ingestion is not considered a potential route of exposure.

5.2.4 *Inhalation*
Breathing 75 percent or more oxygen at atmospheric pressure for more than a few hours may cause nasal stuffiness, cough, sore throat, chest pain and breathing difficulty. Breathing pure oxygen under pressure may cause lung damage and can also affect central nervous system.

5.3 Toxicity information
One of the earliest responses of the lung is accumulation of water in its interstitial spaces and within the pulmonary cells. This can cause reduced lung function, which is the earliest measurable sign of toxicity. Other symptoms include fever and sinus and eye irritation.

a) Time Weighted Average (TWA) — No Data Available
b) Short Term Exposure Limit (STEL) — No Data Available
c) Immediately Dangerous to Life and Health (IDLH) – No Data Available
d) Lethal Dose (LD_{50}) — No Data Available
e) Inhalation (Rat) Lethal Concentration (LC) — No Data Available

5.4 Antidote

Oxygen toxicity is managed by reducing the exposure to increased oxygen levels.

5.5 Health Effects

5.5.1 *Signs and Symptoms*
The inhalation at 1 atmosphere of 80 percent oxygen for more than 12 h can cause irritation of the respiratory tract, progressive decrease in vital capacity, coughing, nasal stuffiness, sore throat, and chest pain, followed by tracheobronchitis and later by pulmonary congestion and/or edema.

6 PERSONAL PROTECTIVE EQUIPMENT

6.1 Availability and Use

6.1.1 While personal protective equipment is not an adequate substitute for good, safe working conditions, adequate ventilation, and intelligent conduct on the part of employees working with caustic soda, it is, in many instances, the only practical means of protecting the worker, particularly in emergency situations. One should keep

firmly in mind that personal protective equipment protects only the worker wearing it, and other unprotected workers in the area maybe exposed to danger.

6.1.2 The correct usage of personal protective equipment requires the education of the workers in proper employment of the equipment available to him. Under conditions which are sufficiently hazardous to require personal protective equipment, its use should be supervised and the type of protective equipment selected should be capable of control over any potential hazards.

6.2 Non-Respiratory Equipments

6.2.1 *Eye and face Protection*
Eyes are most sensitive to the extreme cold of liquid oxygen and its vapors. The recommended personal protective equipment when handling or using liquid oxygen is a full face shield over safety goggles (*see* IS 8940).

6.2.2 *Head Protection*
Safety helmet with face shield is recommended while handling the liquid oxygen.

6.2.3 *Foot and leg Protection*
Safety shoes are recommended when handling liquid oxygen containers, cylinders.

6.2.4 *Body, Skin and Hand Protection*
6.2.4.1 Personnel who have been exposed to high concentrations of oxygen should stay in a well-ventilated or open area for 30 min before going into a confined space or near an ignition source. 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.

6.2.4.2 To use loose fitting thermal insulated cryogenic or leather gloves which must be clean and free of oil and grease. Always wear full sleeve cotton shirt & pant.

6.3 Respiratory Equipment
Not required for properly ventilated areas. In emergency situations, self-contained breathing apparatus (SCBA) must be used. Clothing that is fire resistant in air may be readily ignitable in oxygen-enriched atmospheres. Only trained and certified emergency responders should respond to emergency situations.

7 STORAGE, HANDLING, LABELLING AND TRANSPORT

7.1 General
Storage, handling, and transportation of liquid oxygen require careful consideration due to its cryogenic nature and high reactivity. Liquid oxygen (LOX) is stored and transported at extremely low temperatures (-183°C or -297°F) and is highly volatile, posing significant hazards if mishandled.

7.2 Storage
Liquid oxygen is stored, shipped, and handled in several types of containers, depending upon the quantity required by the user. The types of containers in use include the Dewar, cryogenic liquid cylinder, and cryogenic storage tank. Storage

quantities vary from a few liters to many thousands of gallons. Since store and use liquid containers with adequate ventilation. Do not store containers in a confined area or in area unprotected from the extremes of weather. Oxygen must be separated from flammables and combustibles by at least 6.09 m. Post “No Smoking” and “No Open Flames” signs.

7.2.1 *Storage in Containers*
Cryogenic containers are equipped with pressure relief devices designed to control the internal pressure. Under normal conditions these containers will periodically vent product. Do not plug, remove or tamper with any pressure relief device.

7.2.2 *Storage in Dewars*
A loose-fitting dust cap over the outlet of the neck tubes prevents atmospheric moisture from pugging the neck and allows gas produced from vaporized liquid to escape. This type of container is a non-pressurized container. The unit of measure for the capacity of a Dewar is typically the liter. 5 l to 20 l Dewars are available. Product may be removed from small Dewars by pouring, while larger sizes will require a transfer tube. Cryogenic liquid cylinders that are pressurized vessels are sometimes incorrectly referred to as Dewars.

7.2.3 *Storage in Cryogenic Liquid Cylinders*
Cryogenic liquid cylinders are insulated, vacuum jacketed pressure vessels. They come equipped with safety relief valves and rupture discs to protect the cylinders from pressure build up. These containers operate at pressures up to 350 psig and have capacities between 80 l and 450 l of liquid. Liquid oxygen may be withdrawn as a gas by passing liquid through an internal vaporizer or as a liquid under its own vapour pressure.

7.2.4 *Storage in Cryogenic storage tanks and Connected Transfer Lines*
Tanks may be spherical or cylindrical in shape. They are mounted in fixed locations as stationary vessels or on railroad car or truck chassis for easy transportation. Sizes range from 500 to 420,000 gallons, and all tanks are powder- and vacuum-insulated in the annular space. Tanks are equipped with various circuits to control product fill, pressure build up, pressure relief, product withdrawal, and tank vacuum.

7.2.4.1 *Transfer lines connected to storage*
A liquid transfer line is used to safely remove liquid product from Dewars or cryogenic liquid cylinders. A typical transfer line for Dewars is connected to a bayonet that provides a means of using product vapor pressure buildup or an external pressure source to remove the liquid. For cryogenic liquid cylinders, the transfer line is connected to the cylinder’s liquid withdraw a valve. Liquid product is typically removed through insulated withdrawal lines to minimize the loss of liquid product to gas. Insulated flexible or rigid lines are used to withdraw product from storage tanks. Connections on the lines and tanks vary by manufacturer.

7.2.5 The location should comply with Static and Mobile Pressure Vessel Rules (SMPV 2016, and annual external inspection should be carried out in accordance with SMPV Rules 2016.

7.2.6 Avoid installing liquid storage vessel in indoor environment and near drain or pits.

7.2.7 Oxygen storage should be separated from vacuum and medial air compressor plant to avoid possible oil contamination.

7.2.8 It is important to provide adequate ventilation in areas where liquid oxygen in use, due large expansion ratio of liquid to gas. A minimum of six changes per hour is suggested. The oxygen enriched atmosphere is one containing more than 23.5 percent of oxygen. Remember, oxygen has no warning properties.

7.2.9 Do not store containers in a confined area or in areas unprotected from the extreme weather.

7.2.10 Cryogenic containers are equipped with pressure relief devices designed to control the internal pressure. Under normal conditions these containers will periodically vent product. Do not plug, remove or tamper with any pressure relief device.

7.2.11 Liquid containers should not be left open to the atmosphere for extended periods. Keep all valves closed and outlet caps in place when not in use. If restriction results from freezing moisture or foreign material present in openings and vents, contact the vendor for instructions. Restrictions and blockages may result in dangerous over pressurization. Do not attempt to remove the restriction without proper instructions. If possible, move the cylinder to remote location.

7.3 Handling

7.3.1 Cryogenic containers must be stored, handled and transported in the upright position. When moving, never tip, slide or roll containers on their side. Use a suitable hand truck for moving smaller containers. Move larger containers by pushing, not pulling. Avoid mechanical and thermal shock. Never allow any unprotected part of the body to come in contact with uninsulated pipes or equipment containing cryogenic product. The extreme cold will cause flesh to stick fast and potentially tear on withdrawal. Use only oxygen-compatible materials and lubricants.

7.3.2 If there is any difficulty in operating the container valve or container connections, discontinue use and contact the vendor. Do not remove or interchange connections. Use only the properly assigned connections. Do not use adapter. Use only transfer lines and equipment designed for use with cryogenic liquids. Some elastomers and metals, such as carbon steel, may become brittle at extremely low temperatures and may easily fracture. These materials must be avoided in cryogenic service. It is recommended that all vents be piped to the exterior of the building. On gas withdrawal systems, use check valves or other protective apparatus to prevent reverse flow into the container. On liquid systems, pressure relief devices must be used in lines where there is the potential to trap liquid between valves.

7.3.3 If these liquids are vaporized in a sealed container, they can produce enormous pressures that could rupture the container. For this reason pressurized cryogenic containers are normally protected with multiple devices for prevention of over-

pressurization. Common pressure relief devices are a pressure relief valve for primary protection and a rupture disc for secondary protection.

7.3.4 Vaporization of liquid oxygen in an enclosed area can create an oxygen enriched atmosphere.

7.3.5 Always handle cryogenic liquids carefully. Their extremely low temperatures can produce cryogenic burns of the skin and freeze underlying tissue. When spilled on a surface, they tend to spread as far as the quantity of liquid spilled and the physical confines of the area permit. They can cool large areas. The vapours coming from these liquids are also extremely cold and can produce burns.

7.3.6 Exposure to these cold gases, which is too brief to affect the skin of the face or hands, may affect delicate tissues, such as the eyes.

7.3.7 Stand clear of boiling and splashing liquid and the cold vapors that are released. Boiling and splashing always occur when charging a warm container or when inserting objects into the liquid. Always perform these operations slowly to minimize the splashing and boiling.

7.3.8 Never allow any unprotected part of your body to touch uninsulated pipes or vessels containing cryogenic liquids.

7.3.9 The extremely cold material may stick fast to skin and tear the flesh when you attempt to withdraw it. Even non-metallic materials are dangerous to touch at these low temperatures. Use tongs to immerse and remove objects from cryogenic liquids.

7.3.10 In addition to the hazards of frostbite or flesh sticking to cold materials, objects that are soft and pliable at room temperature, such as rubber or plastics, are easily broken because they turn brittle at low temperatures and may break when stressed.

7.3.11 Use only oxygen-compatible materials and lubricants.

7.3.12 If there is any difficulty in operating the container valve or container connections discontinue use and contact the vendor. Do not remove or interchange connections. Use only the properly assigned connections. Do not use adapters.

7.4 Labelling

7.4.1 Each container (including tankers) should carry an identifying label or stencil as depicted in Fig. 9 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.

Manufacturers name with label warnings required by regulations or ordinances form part of the label or placard.

7.4.2 Each tanker and each railroad car carrying one or more containers shall be labelled as:

In case of leakage/fire: Keep away flames and oil/grease. Use water fog or water spray for cooling or dilution. Evacuate upwind from cold liquid and white water vapor.

7.5 Transport

7.5.1 *Transportation of Container*

7.5.1.1 Liquid containers must only be unloaded from or loaded onto a delivery vehicle by means of a crane, fork truck, or a power-assisted tailgate. Liquid containers may be moved using a forklift if they are secured on a pallet, in a cradle, or some other device designed for this purpose. When the container is removed from a pallet, it should only be moved using a specially designed four-wheel handcart.

7.5.1.2 Liquid containers should only be transported in an upright position and should never be laid on their side. For proper ways to handle a liquid container is as given in **Fig 1**. Never roll these containers on their side. Liquid containers equipped with wheels should always be moved by pushing the container, never pulling it. This reduces the possibility of the container falling on co-worker in the event it becomes unstable. Pushing the liquid container up any type of grade will increase the force necessary to move it. A grade as low as 5 percent (5-inch rise in 10 feet of travel) will increase the force necessary to start to push the container by as much as 50 percent.

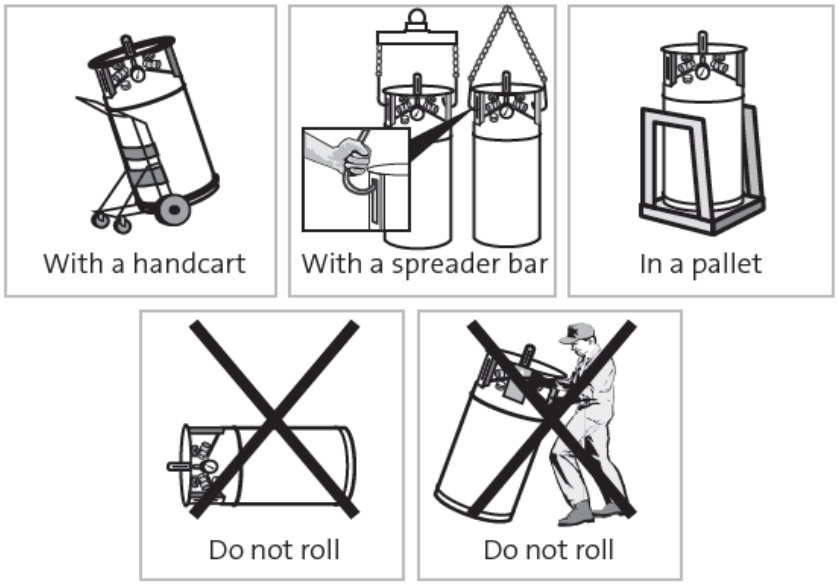

FIGURE 1. HOW TO HANDLE LIQUID CONTAINERS

7.5.2 *Elevator Transport*
7.5.2.1 Care must be exercised when transporting liquid containers in elevators. If possible, transport the container only on a freight elevator that is not generally used for personnel transport.

7.5.2.2 After the container is placed in the elevator, the elevator should be locked out to all other users. The sender should remain outside the elevator and activate it. Another person should be available on the receiving floor to take the liquid container off the elevator at its destination. If a freight elevator is not available, a passenger elevator can be used provided it is locked out to all other users. If it is absolutely necessary to have an attendant in the elevator with the container, an escape pack supplemental breathing apparatus must be carried in the elevator. Do not transport a liquid container at any time in an elevator with any other personnel in the car.

7.5.3 Tankers should be periodically inspected, and they must be maintained with proper care and caution and the insulation of the container of the tanker must be checked regularly.

7.5.4 The Safety Relief Valve (SRV) in the truck should be periodically tested. All other tanker accessories including temperature and pressure gauges should be in good condition and must be calibrated at regular intervals.

7.5.6 Containers should be clearly identified so that only the correct contents may be filled or withdrawn. Mixing liquid oxygen with another liquefied atmospheric gas may be hazardous; in certain instances, the oxygen concentration may increase as time progresses due to the evaporation of lower boiling point liquids such as nitrogen and argon. Unknown concentrations of oxygen always represent a hazardous condition. If liquid oxygen is introduced into a liquid nitrogen refrigerator, the oxygen may cause any organic material in the refrigerator to burst into flame.

7.5.7 Obtain clearance certificate where it is necessary for work to be carried out involving a flame or arc in which case there is likely to be oxygen enrichment of the surrounding atmosphere.

7.5.8 Make certain that there is adequate ventilation and circulation of air where oxygen cutting, gas welding, brazing or arc welding is required to be carried out in a confined space.

7.5.9 Make certain that all assemblies and components, including piping, which will be in contact with gaseous or liquid oxygen, are thoroughly degreased and entirely free from oil or grease of any description.

7.5.10 Only pressure gauges marked ‘OXYGEN - USE NO OIL’ are to be used for any oxygen service and on no account are these gauges to be used on other services where there is a possibility of the gauge becoming contaminated with oil or any other foreign matter.

7.5.11 Never use oxygen as a substitute for compressed, air or nitrogen.

7.5.12 Oxygen is not to be used for clearing fumes in a confined space. Such use has caused fatal accidents through the worker's clothing getting ignited.

7.5.13 No painting is to be carried out around an oxygen plant when the latter is in operation.

7.5.14 Make certain that all pressure is relieved from the system before attempting to remove any fittings or commencing a repair.

7.5.15 The liquid should be disposed of by pouring it gently, avoiding splashing on to the ground, which is free from any holes or pockets or preferably in the open, well away from other personnel, naked lights, lighted cigarattes,

7.5.16 *Driver*

Only driver trained in handling should be employed for transportation of liquid oxygen. 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

Do not touch or walk through spilled material. Stop leak if you can do it without risk. Use water spray to reduce vapors or divert vapor cloud drift. Avoid allowing water runoff to contact spilled material. Do not direct water at spill or source of leak. If possible, turn leaking containers so that gas escapes rather than liquid. Prevent entry into waterways, sewers, basements or confined areas. Allow substance to evaporate. Ventilate the area.

CAUTION — When in contact with refrigerated/cryogenic liquids, many materials become brittle and are likely to break without warning.

8.2 Spillage

8.2.1 *Genera/Information*

Spillage of liquid oxygen can be extremely hazardous due to its highly reactive nature. It is essential to approach any spillage of liquid oxygen with extreme caution and prioritize safety to minimize the potential risks and consequences associated with such incidents.

8.2.2 Emergency procedures shall be prepared by the site operator to include action to be taken in the event of spillage of liquid oxygen. Local emergency services shall be party to the preparation of the emergency procedures. Works employees likely to be affected shall know the actions required to minimize the adverse effects of a spillage. Consideration shall be given to the carrying out of practical exercises.

8.2.3 The following are guidelines, which should be used for formulating emergency procedures:
a) Raise the alarm

b) Summon help and emergency services
c) Isolate the source of oxygen, if appropriate and where safely possible
d) Evacuate all persons from the danger area and seal it off
e) Alert the public to possible dangers from vapor clouds in the immediate vicinity and evacuate when necessary.

8.2.4 After the liquid spillage has been isolated, oxygen enrichment checks should be carried out in any enclosed areas where the vapor cloud may have entered. This includes basements, pits and confined spaces.

8.2.5 Oxygen itself does not pose a hazard to the environment. However, because of extreme cold of the liquid, damage to ecology can occur in the immediate environs of the spill. Beware of oxygen-enriched atmospheres encountering readily combustible materials.

8.2.6 *Small Spills*- Shut off the source of escaping oxygen. Ventilate the area.

8.2.7 *Large Spills*- Evacuate the area. Shut off the source of the spill if this can be done without risk. Restrict access to the area until completion of the clean-up procedure. Ventilate the area using forced draught if necessary.

8.2.8 If liquid oxygen spills on asphalt or other surfaces contaminated with combustibles, do not walk on or roll equipment over the area of the spill. Keep sources of ignition away for 30 min after all frost or fog has disappeared.

8.3 Waste Disposal

8.3.1 Return unused product in original cylinder to supplier. Contact supplier if guidance is required.

8.3.2 Small amounts may be allowed to evaporate into the atmosphere. In case of large spills consult an expert and allow evaporation. Large amounts should only be handled by gas supplier.

8.3.3 Disposal of Packaging: The disposal of containers must only be handled by the gas supplier.

9 FIRE PREVENTION AND FIRE FIGHTING

The liquid oxygen itself does not burn. Use extinguishing media appropriate for surrounding fire.

9.1 General

9.1.1 Smoking or open flames or naked light shall not be permitted in any area where liquid oxygen is stored, handled, or where it is loaded or unloaded. Post ‘NO SMOKING’ signs conspicuously in all such areas and on storage tanks.

9.1.2 Organic material or flammable substance of any kind shall not be permitted to come in contact with liquid oxygen. Some of the materials that can react violently with oxygen under certain conditions of pressure and temperature are oil, grease, asphalt, kerosene, cloth, wood, paint, tar and dirt which may contain oil or grease. Under certain conditions, mixtures of powdered organic materials with liquid oxygen may detonate.

9.1.3 Combustibles in contact with liquid oxygen may explode on ignition or impact. Some materials which are noncombustible in air may burn in the presence of an oxidizer. Contact with organic and most inorganic materials may cause fire. Vapor cloud may obscure visibility. Move away from container and cool with water from a protected position. Do not direct water spray at container vent. If possible, stop flow of product.

9.2 Prevention

9.2.1 When organic materials are exposed to liquid oxygen, they will burn violently if ignited, even several minutes after they have been in contact with the liquid. Any clothing that has been splashed or soaked with liquid oxygen should be removed immediately and aired away from sources of ignition for at least an hour until it is completely free of oxygen.

9.2.2 Any person working with liquid oxygen should ensure that his clothing's are aired before approaching any source of ignition.

9.3 Fighting Fires Involving Liquid Oxygen

Since oxygen itself does not burn, fire 1s not caused unless combustible materials also present. In any fire involving liquid oxygen, the oxygen plays the same part as oxygen from the air in an ordinary fire. However, the presence of additional oxygen will make any fire burn much faster and more violently. The following tire fighting procedures should be observed:

a) Remove every one not actively engaged in fighting the fire;

b) If possible, shut off the Row of oxygen.

c) Use large quantities of fire extinguishing agent, such as water, preferably in the form of a spray, below the ignition point. to cool the burning material If electrical equipment is involved in the fire, do not use water, use carbon dioxide or dry chemical.

10 TRAINING

10.1 All personnel directly involved in the commissioning, operation and maintenance of liquid oxygen storage systems shall be fully informed regarding the hazards associated with oxygen and oxygen enrichment 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 oxygen;

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 oxygen 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 oxygen 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 oxygen 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 Health Monitoring

Periodic medical examination aim to detect susceptible workers for whom corrective actions are required before they develop overt occupational diseases. Meanwhile safety and health measures at work should be reviewed for necessary remedial actions.

11.2 First Aid

11.2.1 *General Principles*

If any of the liquefied oxygen contact the eyes or skin, immediately flood the affected area with large quantities of unheated water and then apply cold compress. If the skin is blistered or if there is any chance that the eyes have been affected, take the patient immediately to a doctor treatment.

11.2.2 *Contact with Skin*

For skin contact with liquid oxygen, remove any clothing that may restrict circulation to the frozen area. Do not rub frozen parts, as tissue damage may result. As soon as practical, place the affected area in a warm water bath with a temperature not exceeding 105°F (40°C) for at least for 15 min. Never use dry heat. Call a physician as soon as possible. Cover wound with sterile dressing.

Frozen tissue is painless and appears waxy with a possible yellow color. It will become swollen, painful, and prone to infection when thawed. If the frozen part of the body has been thawed, cover the area with a dry sterile dressing with a large bulky protective covering, pending medical care.

11.2.3 *Contact with Eyes*

In the case of contact with eyes, rinse immediately with plenty of Luke warm water <40C /105F for at least for 15 min and seek medical advice.

11.2.4 *Ingestion*

Ingestion is not considered a potential route of exposure.

11.2.5 *Inhalation*

Consult a physician after significant exposure. Move to fresh air.

1l.2.6 In case of massive exposure, remove clothing while showering the victim with warm water. Call a physician immediately.

12 ADDITIONAL INFORMATION

Workers involved in emergency activities must not allow emotions to override safe work procedures and training. Only trained, qualified personnel equipped with necessary safety equipment should attempt a rescue and or firefighting, arresting of leakages in accordance with safe procedures.

SECTION 2 LIQUID NITROGEN

13 PROPERTIES LIQUID NITROGEN

13.1 General Information

13.1.1 Liquid Nitrogen is tasteless, colorless, odorless, noncorrosive, non-flammable, and extremely cold. Nitrogen content is approximately 78% of the earth's atmosphere. It is extremely inert.

13.1.2 Since Nitrogen is inert, special materials of construction are not required. However, materials of construction must be selected to withstand the low temperature of liquid Nitrogen. Although used more commonly in the gaseous state, nitrogen is commonly stored and transported as a liquid, affording more cost-effective way of providing product supply

13.1.3 Liquid nitrogen is a cryogenic liquid. Liquid nitrogen has a boiling point of –321°F (–196°C). The temperature difference between the product and the surrounding environment, even in winter, is substantial. Keeping this surrounding heat from the product requires special equipment to store and handle cryogenic liquids.

13.1.1 *Chemical Name* - N_2

13.1.2 *Common Name & Synonyms* - Nitrogen (refrigerated), Liquid Nitrogen, LIN, Cryogenic Liquid Nitrogen, Nitrogen

13.1.3 *Uses*

Industrial and professional use. Perform risk assessment prior to use. Used as coolant for superconductors, vacuum pumps, and other materials and equipment. Use in cryotherapy to remove skin abnormalities. It is also used for preservation of biological samples and shielding of materials for oxygen exposure. Nitrogen to be used as a gas is often stored and transported as a liquid for economy and convenience. Liquid nitrogen is used for deep refrigeration storage, and a refrigerant in shrink-fitting metal part sand in cold traps, and for various laboratory applications

13.2 Identification

13.2.1 *Formula* - N_2

13.2.2 *CAS Number* - 7727-37-9

13.2.3 *UN Number* - 1977

13.2.4 *UN Class* - 2, Subsidiary Risk -2.2

13.3 Physical Properties

13.3.1 Liquid nitrogen is tasteless, colourless, odorless, noncorrosive, non-flammable, and extremely cold.

13.3.2 *Molecular Mass* - 28 g/mol

13.3.3 *Physical State* - Liquefied gas.

13.3.4 *Colour* - Colorless.

13.3.5 *Odour* - No odor warning properties.

13.3.6 *Boiling Point* - -321 °F (-196 °C)

13.3.7 *Melting Point* - -346 °F (-210 °C)

13.3.8 *Vapour Density* (Air=1) ~ 0.97 (air = 1) Lighter or similar to air.

13.3.9 *Specific Gravity*

a) Liquid (water = 1) - 0.8

13.3.10 *Viscosity at 30°C* - No data available.

13.3.11 *Vapour Pressure at* 76.6 °C -Not applicable.

13.3.12 *Refractive Index at* 25 °C - No data available.

13.3.13 *Solubility in Water* – 0.02 g/l

13.4 Chemical Propertie

13.4.1 *Reactivity* - No reactivity hazard other than the effects described in sub-sections below.

13.4.2 *Polymerisation* – No data available.

13.4.3 *Allotrope formation* – No data available.

13.4.4 *Corrosion properties* –. No data available.

13.5 Fire and Explosion Hazard Properties

13.5.1 *Ignition Temperature* - Non flammable.

13.5.2 *Auto Ignition Temperature* - Non flammable.

13.5.3 *Flash Point* - Not applicable for gases and gas mixtures.

13.5.4 *Upper Explosive Limit* - Not applicable.

13.5.5 *Lower Explosive Limit* - Not applicable.

13.5.6 *Fire Risk*

Liquid nitrogen is not flammable, neither pressure nor a reduction in temperature makes nitrogen any more flammable. Take a look at this in action: However, as liquid nitrogen is pressurized in canisters, there is an explosion risk of the canisters are heated appreciably as the liquid nitrogen can expand and destroy the canister.

14 HEALTH HAZARD & TOXICITY INFORMATION

14.1 General Information

14.1.1 Being odourless, colourless, tasteless, and non-irritating, nitrogen has no warning properties. Humans possess no senses that can detect the presence of nitrogen. nitrogen is nontoxic and largely inert. It can act as a simple asphyxiant by displacing the oxygen in air to levels below that required to support life..

14.1.2 For more information on oxygen deficient atmospheres, Extensive tissue damage or cryogenic burns can result from exposure to when using inert gas systems, always provide adequate air movement and ventilation, such as exhaust or floor fans. Be aware that increases in gas consumption rates may require additional ventilation.

14.1.3 Oxygen-deficient atmospheres may exist in poorly ventilated areas, confined spaces, areas immediately outside confined spaces, enclosures and low-grade areas. When working in confined spaces, all the requirements of confined space regulations must be strictly followed. Effective emergency procedures for entry and rescue can avoid serious injuries or fatalities. Low oxygen levels can also exist in “open areas,” including areas with ventilation, laboratories, buildings and outside near equipment.

14.1.4 Visual or odor indicators cannot detect an oxygen deficient atmosphere. The only way to detect low oxygen concentrations is with real-time monitoring. Use of a continuous oxygen monitor is strongly recommended in work areas where high concentrations of gas can accumulate.

14.1.5 A release of a cold vapor, such as from cryogenic liquid nitrogen, can form a visible vapor cloud or plume created by the condensation of atmospheric moisture. As the released gas warms up to ambient temperature, the visible vapor cloud may disappear before the oxygen concentration returns to a sufficient level. Do not rely on the absence of a visible vapor cloud as safe breathable atmosphere.

14.2 Routes of entry

14.2.1 *Eyes*

Contact with liquid may cause cold burns/frostbite.

14.2.2 *Ingestion*

Ingestion is not considered a potential route of exposure.

14.2.3 *Inhalation*

In high concentrations may cause asphyxiation. Symptoms may include loss of mobility/consciousness. Victim may not be aware of asphyxiation. Asphyxiation may bring about unconsciousness without warning and so rapidly that victim may be unable to protect themselves. Inhalation of nitrogen in excessive amounts can cause dizziness, nausea, vomiting, loss of consciousness, and death. Death may result from errors in judgment, confusion, or loss of consciousness that prevents self-rescue. At low oxygen concentrations, unconsciousness and death may occur in seconds and without warning

14.3 Toxicity information

a) Time Weighted Average (TWA) — No Data Available
b) Short Term Exposure Limit (STEL) — No Data Available
c) Immediately Dangerous to Life and Health (IDLH) – No Data Available
d) Lethal Dose (LD_{50}) — No Data Available

e) Inhalation (Rat) Lethal Concentration (LC) — No Data Available

14.4 Antidote

There is no antidote.

14.5 Health Effects

14.5.1. *Signs and Symptoms*

The sign and symptoms related to oxygen-deficient atmosphere is as prescribed in Table 1.

Table 1 Effects of Oxygen-Deficient Exposure

(Clause 14.5.1*)*

S No.	Oxygen Concentration (% vol)	Health Effects of Persons at Rest
(1)	(2)	(3)
i)	19	Some adverse physiological effects occur, but they may not be noticeable.
ii)	15–19	Impaired thinking and attention. Increased pulse and breathing rate. Reduced coordination. Decreased ability to work strenuously. Reduced physical and intellectual performance without awareness.
iii)	12–15	Poor judgment. Faulty coordination. Abnormal fatigue upon exertion. Emotional upset
iv)	10–12	Very poor judgment and coordination. Impaired respiration that may cause permanent heart damage. Possibility of fainting within a few minutes without warning. Nausea and vomiting.
v)	<10	Inability to move. Fainting almost immediate. Loss of consciousness. Convulsions. Death

14.5.2 *Acute Toxicity* - No data is available on the product itself.

The following acute (short-term) health effects may occur immediately or shortly exposure to nitrogen:

a) Contact with liquefied nitrogen may can cause frostbite

b) Exposure to very high levels of pure nitrogen can cause dizziness and lightheadness and replaces oxygen in air causing loss of consciousness and death.

14.5.3 *Chronic Toxicity*

No chronic (long- term) health effects are known at this time.

15 PERSONAL PROTECTIVE EQUIPMENT

15.1 Availability and Use

15.1.1 While personal protective equipment is not an adequate substitute for good, safe working conditions, adequate ventilation and intelligent conduct on the part of employees working with liquid nitrogen, it is in many instances the only practical means of protecting the worker, particularly in emergency situations. One should keep firmly in mind that personal protective equipment protects only the worker wearing it, and other unprotected workers in the area maybe exposed to danger.

15.1.2 Eyes are most sensitive to the extreme cold of liquid nitrogen and its vapors. The recommended personal protective equipment when handling or using liquid nitrogen is a full face shield over safety goggles; loose-fitting thermal insulated or leather gloves; and long sleeved shirts and pants without cuffs, especially whenever the possibility of exposure or a spill exists. In addition, safety shoes are recommended for those involved with the handling of liquid nitrogen containers.

15.2 Non-Respiratory Equipment

15.2.1 *Eye and face Protection* - Safety glasses recommended when handling cylinders. Protect eyes, face and skin from liquid splashes. Wear goggles and a face shield when transfilling or breaking transfer connections (*see* IS 8250).

15.2.2 *Head Protection*

Suitable industrial safety helmets should be used see IS 2925.

15.2.3 *Foot and leg Protection*

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

15.2.4 *Body, Skin and Hand Protection*

Wear work gloves when handling gas containers.

If the operation involves possible exposure to a cryogenic liquid, wear loose fitting thermal insulated or cryo-gloves. 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. Safety shoes are recommended when handling cylinders.

15.3 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:

15.3.1 *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.

15.3.2 Positive pressure airline with mask are to be used in oxygen-deficient atmosphere. Air purifying respirators will not provide protection. Users of breathing apparatus must be trained.

16 STORAGE, HANDLING, LABELLING AND TRANSPORT

16.1 General

16.2 Storage

16.2.1 *Storage in Containers*

16.2.1.1 Liquid nitrogen is stored, shipped, and handled in several types of containers, depending upon the quantity required by the user. The types of containers in use are the dewar, cryogenic liquid cylinder, and cryogenic storage tank. Storage quantities vary from a few liters to many thousands of gallons.

16.2.1.2 Since heat leak is always present, vaporization takes place continuously. Rates of vaporization vary, depending on the design of the container and the volume of stored product. Containers are designed and manufactured according to the applicable codes and specifications for the temperatures and pressures involved.

16.2.2 *Storage in Dewars*

A loose-fitting dust cap over the outlet of the neck tubes prevents atmospheric moisture from pugging the neck and allows gas produced from vaporized liquid to escape. This type of container is a non-pressurized container. The unit of measure for the capacity of a Dewar is typically the liter. 5 l to 20 l Dewars are available. Product may be removed from small Dewars by pouring, while larger sizes will require a transfer tube. Cryogenic liquid cylinders that are pressurized vessels are sometimes incorrectly referred to as Dewars.

16.2.3 *Storage in Cryogenic liquid cylinders*

Cryogenic liquid cylinders are insulated, vacuum jacketed pressure vessels. They come equipped with safety relief valves and rupture discs to protect the cylinders from pressure build up. These containers operate at pressures up to 350 psig and have capacities between 80 l and 450 l of liquid.. Liquid nitrogen may be withdrawn as a gas by passing liquid through an internal vaporizer or as a liquid under its own vapor pressure.

16.2.4 Do not allow storage temperature to exceed 50°C (122°F).

16.2.5 Containers should be stored in a purpose build compound which should be well ventilated, preferably in the open air. Full containers should be stored so that oldest stock is used first. Do not store in a confined space. Full and empty cylinders should be segregated.

16.2.6 Store containers in location free from fire risk and away from sources of heat and ignition.

16.2.7 Return empty containers in a timely manner.

16.2.8 Stored containers should be periodically checked for general condition and leakage.

16.2.9 Protect containers stored in the open against rusting and extremes of weather.

16.2.10 Containers should not be stored in conditions likely to encourage corrosion.

16.2.11 Cryogenic containers are equipped with pressure relief devices to control internal pressure.

16.2.12 Under normal conditions these containers will periodically vent product. All vents should be piped to the exterior of the building. Observe all regulations and local requirements regarding storage of containers.

16.3 Handling

16.3.1 Liquid nitrogen shall be stored and used only in a well-ventilated place. If enough nitrogen gas evaporates from the liquid in an unventilated space, the percentage of oxygen in the air may become dangerously low making anybody present there, symptoms, such as dizziness, unconscious without any warning. Remaining in this atmosphere long enough may become fatal.

16.3.2 Nitrogen build-up is most likely to occur when a room is closed, overnight for example. If there is any doubt about the amount of oxygen in a room, the room shall be ventilated completely before entering it. Waste nitrogen shall not be disposed of in a confined area or a place where someone else may enter.

16.3.3 Liquid nitrogen is colder than liquid oxygen. Therefore, if it is exposed to the air, oxygen from the air may condense into the liquid nitrogen. If this is allowed to continue for any length of time, the oxygen content of the liquid nitrogen may become appreciable and the liquid will require the same precautions as for handling liquid oxygen. However, most liquid nitrogen containers are entirely closed except for a small neck area and the nitrogen gas issuing from the surface of the liquid forms a barrier which keeps air away from the liquid and prevents oxygen contamination.

16.3.4 Before entering any large liquid nitrogen storage tank, it shall be made sure that all pipes to the tank are blanked or positively closed off. The tank shall then be purged with air. If a check with instruments shows that the atmosphere normal air, it shall be safe to enter. Unless all lines are physically isolated, inside atmosphere shall be checked frequently with instruments during work. If, for any reason, the supply of fresh air in the tank is doubtful, breathing apparatus shall be used with its own supply of oxygen or air. Whenever anybody enters a tank, he should make sure that he is equipped with a life line and that an observer is stationed outside to check on his reactions while working. It is a good practice to have the ventilating equipment rapidly changing the air in tanks at all times when personnel are working inside them.

16.3.5 Only experienced and properly instructed persons should handle compressed gases/cryogenic liquids.

16.3.6 Do not remove or deface labels provided by the supplier for the identification of the cylinder contents.

16.3.7 Before connecting the container, check the complete gas system for suitability, particularly for pressure rating and materials.

16.3.8 Before connecting the container for use, ensure that back feed from the system into the container is prevented. Close container valve after each use and when empty, even if still connected to equipment. Never attempt to repair or modify container valves or safety relief devices. Damaged valves should be reported immediately to the supplier.

16.3.9 If user experiences any difficulty operating cylinder valve discontinue use and contact supplier. Do not remove or interchange connections. Ensure the complete gas system has been checked for leaks before use. Prevent entrapment of cryogenic liquid in closed systems not protected with relief device. A small quantity of liquid produces large volumes of vaporized gas at atmospheric pressure.

16.3.10 Containers used in shipment, storage, and transfer of cryogenic liquid are specially designed, well-insulated containers equipped with a pressure relief device and valves to control pressure. Under normal conditions, these containers will periodically vent product to limit pressure buildup. Ensure that the container is in a well–ventilated area to avoid creating an oxygen–deficient atmosphere.

16.3.11 Use adequate pressure relief in systems and piping to prevent pressure buildup; liquid in a closed container can generate extremely high pressures when vaporized by warming. Employ suitable pressure regulating devices on all containers when the gas is being emitted to systems with lower pressure rating than that of the container. Only transfer lines designed for cryogenic liquids shall be used.

16.3.12 Do not subject containers to abnormal mechanical shock. When moving cylinders, even for short distances, use a cart (trolley, hand truck, etc.) designed to transport cylinders. When doubt exists as to the correct handling procedure for a particular gas, contact the supplier.

16.3.13 Liquid nitrogen is extremely cold. Cryogenic liquids and their vapours can rapidly freeze human tissue and can cause many common materials such as carbon steel, rubber, and plastics to become brittle or even break under stress.

16.3.14 Cryogenic liquids in containers and piping at temperatures at or below the boiling point of liquefied Nitrogen [–321°F (–196°C)] can cause cold burn if touched.

16.3.15 All cryogenic liquids produce large volumes of gas when they vaporize. For example, one volume of liquid nitrogen vaporizes to 840 volumes of nitrogen gas at 68°F (20°C) at 1 atm. A cryogenic liquid cannot be indefinitely maintained as a liquid, even in well-insulated containers.

16.3.16 If these liquids are vaporized in a sealed container, they can produce enormous pressures that could rupture the container. For this reason pressurized cryogenic containers are normally protected with multiple devices for over-pressure prevention. Common pressure relief devices are a pressure relief valve for primary protection and a rupture disc for secondary protection.

16.3.17 Vaporization of a cryogenic liquid in an enclosed area can cause asphyxiation by displacing the air.

16.3.18 The cold “boil-off” gases condense the moisture in the surrounding air, creating a highly visible fog. This fog can also be formed around cold equipment when no release of the cold liquid or vapors has occurred. Fog clouds do not define the vapor cloud. They define the area where the vapors are still cold enough to condense the moisture in the air.

16.3.19 The vapors can extend well beyond the fog cloud, depending on the product and atmospheric conditions.

16.3.20 Although fog clouds may be indicative of a release, they must never be used to define the leak area and should not be entered by anyone. The dense fog clouds associated with the handling or transfer of cryogenic liquids can obstruct visibility.

Care should be exercised so that any clouds do not interfere with vehicle traffic or safety escape routes.

16.3.21 Always handle cryogenic liquids carefully. Their extremely low temperatures can produce cryogenic burns of the skin and freeze underlying tissue.

16.3.22 When spilled on a surface, they tend to spread as far as the quantity of liquid spilled and the physical confines of the area permit.

16.3.23 They can cool large areas. The vapors coming from these liquids are also extremely cold and can produce burns.

16.4 Labelling

16.4.1 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.

Manufacturers name with label warnings required by regulations or ordinances form part of the label or placard.

16.4.2 Each tanker and each railroad car carrying one or more containers shall be labelled as:

In case of leakage/fire: Keep away flames and oil/grease. Use water fog or water spray for cooling or dilution. Evacuate upwind from cold liquid and white water vapor.

16.4.3 Each tanker and each railroad car carrying one or more containers must labelled as:

In case of leakage/fire: Keep away flames . Use water fog or water spray for cooling or dilution. Evacuate upwind from cold liquid and white water vapor.

16.5 Transport

16.5.1 Transportation of Container

16.5.1.1 Liquid containers must only be unloaded from or loaded onto a delivery vehicle by means of a crane, fork truck, or a power-assisted tailgate. Liquid containers may be moved using a forklift if they are secured on a pallet, in a cradle, or some

other device designed for this purpose. When the container is removed from a pallet, it should only be moved using a specially designed four-wheel handcart.

16.5.1.2 Liquid containers should only be transported in an upright position and should never be laid on their side. For proper ways to handle a liquid container is as given in **Fig 1**. Never roll these containers on their side. Liquid containers equipped with wheels should always be moved by pushing the container, never pulling it. This reduces the possibility of the container falling on co-worker in the event it becomes unstable. Pushing the liquid container up any type of grade will increase the force necessary to move it. A grade as low as 5 percent (5-inch rise in 10 feet of travel) will increase the force necessary to start to push the container by as much as 50 percent.

17 SPILLAGE, LEAKAGE AND WASTE DISPOSAL

17.1 General

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

17.2 Spillage

17.2.1 *Small Spills*

Evacuate all personnel from the area likely to be affected. Ventilate the area.

17.2.2 *Large Spills*

In case of large spill follow the following steps:

a) Evacuate all personnel from the area likely to be affected;

b) Never allow anyone to enter the evolved gas – it could burn;

c) Close interior doors to stop gas flowing to vulnerable areas eg ducts, basements;

d) Open exterior doors and windows to encourage evaporation of the liquid / dispersal of gas;

e) Allow the liquid to evaporate naturally; and

f) Never allow anyone to enter the area until the nitrogen gas has dispersed. Check with an oxygen monitor if necessary.

17.4 Waste Disposal

17.4.1 Return unused product in original cylinder to supplier. Contact supplier if guidance is required.

17.4.2 Small amounts may be allowed to evaporate into the atmosphere. In case of large spills consult an expert and allow evaporation. Large amounts should only be handled by gas supplier.

18 FIRE PREVENTION AND FIRE FIGHTING

18.1 General

18.2 The liquid nitrogen itself does not burn. Use extinguishing media appropriate for surrounding fire.

18.3 In case of fire, stop leak if safe to do so. Continue water spray from protected position until container stays cool. Use extinguishers to contain the fire. Isolate the source of the fire or let it burn out.

18.4 Do not use water jet to extinguish.

18.5 Spill will rapidly vaporize forming an oxygen deficient vapor cloud. Vapor cloud may obscure visibility. Do not direct water spray at container vent. Move away from container and cool with water from a protected position. Keep containers and surroundings cool with water spray.

18.6 Promptly isolate the scene by removing all persons from the vicinity of the incident if there is a fire. No action shall be taken involving any personal risk or without suitable training. Contact supplier immediately for specialist advice. Move containers from fire area if this can be done without risk. Use water spray to keep fire-exposed containers cool.

18.7 Wear self-contained breathing apparatus for fire-fighting if necessary.

19 TRAINING

19.1 All personnel directly involved in the commissioning, operation and maintenance of liquid nitrogen storage systems shall be fully informed regarding the hazards associated with nitrogen and oxygen deficient 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.

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

a) Potential hazards of oxygen;

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.

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

19.4 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.

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

19.6 Safety in handling liquid nitrogen 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 nitrogen 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.

19.7 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.

20 HEALTH MANAGEMENT, FIRST-AID AND MEDICAL TREATMENT

20.1 First Aid

20.1.1 *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.

20.1.2 *Contact with Skin*

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

20.2.3 *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.

20.2.4 *Ingestion*

Ingestion is not considered a potential route of exposure.

20.2.5 *Inhalation*

Move to fresh air. 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. In case of shortness of breath, give oxygen.

20.2.6 The following first-aid notice shall be hung prominently in the area of handling:

FIRST-AID NOTICE
If a person seems to become dizzy or loses consciousness while working with liquid nitrogen, get him to a well-ventilated area immediately. If breathing has stopped, apply artificial respiration. Whenever a person loses consciousness, summon medical aid immediately.

21 ADDITIONAL INFORMATION

Eating, drinking and smoking should be prohibited in areas where this material is handled, stored and processed. Workers should wash hands and face before eating, drinking and smoking. Remove contaminated clothing and protective equipment before entering eating areas.

SECTION 3 LIQUID ARGON

22 PROPERTIES LIQUID ARGON

22.1 General Information

22.1.1 Liquid argon is tasteless, colorless, odorless, noncorrosive, non-flammable, and extremely cold. Belonging to the family of rare gases, argon is the most plentiful, making up approximately 1 percent of the earth's atmosphere. It is monatomic and extremely inert, forming no known chemical compounds.

22.1.2 Since argon is inert, special materials of construction are not required. However, materials of construction must be selected to withstand the low temperature of liquid argon.

22.1.3 Although used more commonly in the gaseous state, argon is commonly stored and transported as a liquid, affording more cost-effective way of providing product supply

22.1.4 Liquid argon is a cryogenic liquid. Cryogenic liquids are liquefied gases that have a normal boiling point below –130 °F (–90 °C). Liquid argon has a boiling point of –303 °F (–186 °C). The temperature difference between the product and the surrounding environment, even in winter, is substantial. Keeping this surrounding heat from the product requires special equipment to store and handle cryogenic liquids.

22.1.5 *Chemical Name* – Ar

22.1.6 *Common Name & Synonyms* - Argon (refrigerated), Cryogenic Liquid Argon, Liquid Argon, LAR

22.1.7 *Uses*

Argon is most commonly used in its gaseous state. It is widely used in the lighting industry for filling bulbs and with combinations of other rare gases for the filling of special bulbs and tubes for special color effects. The welding industry uses argon as a shielding gas to protect metal from oxidation during welding. Argon is also used extensively in the semiconductor manufacturing process as a purge gas.

22.2 Identification

22.2.1 *Formula* - Ar

22.2.2 *CAS Number* - 7440-37-1

22.2.3 *UN Number* - 1951

22.2.4 *UN Class* - 2.2 (Non-Flammable, non-Poisonous Gas) Subsidiary Risk: no data available

22.3 Physical Properties

22.3.1 Liquid argon is tasteless, colourless, odorless, noncorrosive, non-flammable, and extremely cold

22.3.2 *Molecular Mass* - 39.95 g/mol

22.3.3 *Physical State* - Liquefied gas.

22.3.4 *Colour* - Colorless.

22.3.5 *Odour* - No odor warning properties.

22.3.6 *Boiling Point* - -302 °F (-185.8 °C)

22.3.7 *Melting Point* - -309 °F (-189.3 °C)

22.3.8 *Vapour Density (Air=1)* - 1.38 (air = 1) Heavier than air.

22.3.9 *Specific Gravity*

a) Liquid (water = 1) ~ No data available

22.3.10 *Viscosity at* 30 °C - Not applicable.

22.3.11 *Vapour Pressure at* 76.6 °C - Not applicable.

22.3.12 *Heat of Combustion* - No data available.

22.3.13 *Refractive Index at* 25 °C - No data available.

22.3.14 *Solubility in Water* – 0.0 673 g/l

22.3.15 *Solubility in other solvents* – No data available.

22.3.16 *Light Sensitivity* - No data available.

22.4 Chemical Properties

22.4.1 *Reactivity* - No data available.

22.4.2 *Polymerisation* – No data available

22.4.3 *Allotrope formation* – No data available

22.4.4 *Corrosion properties* –. No data available

22.5 Fire and Explosion Hazard Properties

22.5.1 *Ignition Temperature* - No data available.

22.5.2 *Auto Ignition Temperature* - No data available.

22.5.3 *Flash Point* - Not applicable.

22.5.4 *Upper Explosive Limit* - Not applicable.

22.5.5 *Lower Explosive Limit* - Not applicable.

22.5.6 *Fire Risk*

If tank, rail car or tank truck is involved in a fire, ISOLATE for minimum 800 m in all directions; also, consider initial evacuation for 800 m in all directions.

23 HEALTH HAZARD & TOXICITY INFORMATION

23.1 General Information

23.1.1 Health effects

23.1.1.1 Being odourless, colourless , tasteless, and non-irritating, argon has no warning properties. Humans possess no senses that can detect the presence of argon. Argon is nontoxic and largely inert. It can act as a simple asphyxiant by displacing the oxygen in air to levels below that required to support life. Inhalation of argon in excessive amounts can cause dizziness, nausea, vomiting, loss of consciousness, and death. Death may result from errors in judgment, confusion, or loss of consciousness that prevents self-rescue. At low oxygen concentrations, unconsciousness and death may occur in seconds and without warning.

23.1.1.2 For more information on oxygen deficient atmospheres. Extensive tissue damage or cryogenic burns can result from exposure to when using inert gas systems, always provide adequate air movement and ventilation, such as exhaust or floor fans. Be aware that increases in gas consumption rates may require additional ventilation.

23.1.1.3 Oxygen-deficient atmospheres may exist in poorly ventilated areas, confined spaces, areas immediately outside confined spaces, enclosures and low-grade areas. When working in confined spaces, all the requirements of confined space regulations must be strictly followed. Effective emergency procedures for entry and rescue can avoid serious injuries or fatalities. Low oxygen levels can also exist in "open areas," including areas with ventilation, laboratories, buildings and outside near equipment.

23.1.1.4 Visual or odor indicators cannot detect an oxygen deficient atmosphere. The only way to detect low oxygen concentrations is with real-time monitoring. Use of a continuous oxygen monitor is strongly recommended in work areas where high concentrations of gas can accumulate.

23.1.1.5 A release of a cold vapor, such as from cryogenic liquid Argon, can form a visible vapor cloud or plume created by the condensation of atmospheric moisture. As the released gas warms up to ambient temperature, the visible vapor cloud may disappear before the oxygen concentration returns to a sufficient level. Do not rely on the absence of a visible vapor cloud as safe breathable atmosphere.

23.2 Routes of entry

23.2.1 *Skin*

Contact with liquid may cause cold burns/frostbite. May cause severe frostbite.

23.2.2 *Eyes*

Contact with liquid may cause cold burns/frostbite.

23.2.3 *Ingestion*

Ingestion is not considered a potential route of exposure.

23.2.4 *Inhalation*

In high concentrations may cause asphyxiation. Symptoms may include loss of mobility / consciousness. Victim may not be aware of asphyxiation. Asphyxiation may bring about unconsciousness without warning and so rapidly that victim may be unable to protect themselves.

23.2.5 *Long term effects* - No data available

23.3 Toxicity information

a) TLV (TWA): No data available

b) STEL: No data available

c) IDLH: No data available

d) LD50 (rat), Dermal: No data available

e) LD_{Lo} (human) Oral: No data available

f) Inhalation (Rat) LC: No data available

23.4 Antidote: Not applicable

23.5 Health Effects

23.5.1. *Signs and Symptoms*
The sign and symptoms related to oxygen-deficient atmosphere is as prescribed in Table 1.

23.5.2 *Acute Toxicity*

No data is available on the product itself.

23.5.2.1. *Systemic effects*

No data is available on the product itself.

23.5.2.2 *Local effects*

No data is available on the product itself.

23.5.3 *Chronic Toxicity*

No data is available on the product itself.

23.5.3.1 *Systemic effects*

No data is available on the product itself.

23.5.3.2 *Local effects*

No data is available on the product itself.

24 PERSONAL PROTECTIVE EQUIPMENT

24.1 Availability and Use

24.1.1 While personal protective equipment is not an adequate substitute for good, safe working conditions, adequate ventilation and intelligent conduct on the part of employees working with liquid argon, it is in many instances the only practical means of protecting the worker, particularly in emergency situations. One should keep firmly in mind that personal protective equipment protects only the worker wearing it, and other unprotected workers in the area maybe exposed to danger.

24.1.2 Eyes are most sensitive to the extreme cold of liquid argon and its vapors. The recommended personal protective equipment when handling or using liquid argon is a full face shield over safety goggles; loose-fitting thermal insulated or leather gloves; and long sleeved shirts and pants without cuffs, especially whenever the possibility of exposure or a spill exists. In addition, safety shoes are recommended for those involved with the handling of liquid argon containers.

24.2 Non-Respiratory Equipment

24.2.1 *Eye and face Protection*

Eyes are most sensitive to the extreme cold of liquid argon and its vapors. The recommended personal protective equipment when handling or using liquid argon is a full face shield over safety goggles (see IS 8250).

24.2.2 *Head Protection*

Safety helmet with face shield is recommended while handling the liquid argon see IS 2925.

24.2.3 *Foot and leg Protection*

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

24.2.4 ***Body, Skin and Hand Protection***

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.

24.2.4.1 *Hand Protection*: loose-fitting thermal insulated or leather glove

24.2.4.2 *Body Protection***:** long sleeved shirts and pants without cuffs, especially whenever the possibility of exposure or a spill exists.

24.3 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:

15.3.1 *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.

25 STORAGE, HANDLING, LABELLING AND TRANSPORT

25.1 General

Follow the latest applicable Gas Cylinder Rules, Static & Mobile Pressure Vessel (U) Rules, Motor Vehicle Act & Rules and other Act, Rules & Code as applicable for Storage, Handling, labelling and Transportation procedure. While referring to the statutes, the stipulations given in the subsequent amendments of those statutes shall be taken into account.

25.2 Storage

25.2.1 *Storage in Containers*

25.2.1.1 Liquid argon is stored, shipped, and handled in several types of containers, depending upon the quantity required by the user. The types of containers in use are the dewar, cryogenic liquid cylinder, and cryogenic storage tank. Storage quantities vary from a few liters to many thousands of gallons.

25.2.1.2 Since heat leak is always present, vaporization takes place continuously. Rates of vaporization vary, depending on the design of the container and the volume of stored product. Containers are designed and manufactured according to the applicable codes and specifications for the temperatures and pressures involved.

25.2.3 *Storage in Dewars*

A loose-fitting dust cap over the outlet of the neck tubes prevents atmospheric moisture from pugging the neck and allows gas produced from vaporized liquid to escape. This type of container is a non-pressurized container. The unit of measure for the capacity of a Dewar is typically the liter. 5 l to 20 l Dewars are available. Product may be removed from small Dewars by pouring, while larger sizes will require a transfer tube. Cryogenic liquid cylinders that are pressurized vessels are sometimes incorrectly referred to as Dewars.

25.2.4 *Storage in Cryogenic liquid cylinders*

Cryogenic liquid cylinders are insulated, vacuum jacketed pressure vessels. They come equipped with safety relief valves and rupture discs to protect the cylinders from pressure build up. These containers operate at pressures up to 350 psig and have capacities between 80 l and 450 l of liquid. Liquid argon may be withdrawn as a gas by passing liquid through an internal vaporizer or as a liquid under its own vapor pressure.

25.2.5 *Storage in Cryogenic storage tanks and Connected Transfer Lines*
Tanks may be spherical or cylindrical in shape. They are mounted in fixed locations as stationary vessels or on railroad car or truck chassis for easy transportation. Sizes range from 500 to 420,000 gallons, and all tanks are powder- and vacuum-insulated in the annular space. Tanks are equipped with various circuits to control product fill, pressure build up, pressure relief, product withdrawal, and tank vacuum.

25.2.5.1 *Transfer lines connected to storage*
A liquid transfer line is used to safely remove liquid product from Dewars or cryogenic liquid cylinders. A typical transfer line for Dewars is connected to a bayonet that provides a means of using product vapor pressure buildup or an external pressure source to remove the liquid. For cryogenic liquid cylinders, the transfer line is connected to the cylinder’s liquid withdraw a valve. Liquid product is typically removed through insulated withdrawal lines to minimize the loss of liquid product to gas. Insulated flexible or rigid lines are used to withdraw product from storage tanks. Connections on the lines and tanks vary by manufacturer.

25.2.6 *Storage place if inside a Building*

Because of the large expansion ratio of liquid to gas, it is very important to provide adequate ventilation in areas using liquid argon. A minimum of six air changes per hour are suggested in these areas. Provide monitoring for areas where oxygen displacement may occur. 19.5 percent oxygen concentration as the minimum for working without supplied air should be ascertained.

25.2.7 Use a back flow preventative device in the piping. Do not change or force fit connections. Always keep container in upright position. Open/close valve slowly. Close when not in use.

25.2.8 Do not allow storage temperature to exceed 50°C (122°F). Containers should be stored in a purpose build compound which should be well ventilated, preferably in the open air.

25.2.9 Full containers should be stored so that oldest stock is used first. Do not store in a confined space. Full and empty cylinders should be segregated.

25.2.10 Store containers in location free from fire risk and away from sources of heat and ignition. Return empty containers in a timely manner.

25.2.11 Stored containers should be periodically checked for general condition and leakage. Protect containers stored in the open against rusting and extremes of weather.

25.2.12 Containers should not be stored in conditions likely to encourage corrosion. Cryogenic containers are equipped with pressure relief devices to control internal pressure.

25.2.13 Under normal conditions these containers will periodically vent product. All vents should be piped to the exterior of the building. Observe all regulations and local requirements regarding storage of containers.

25.3 Handling

25.3.1 Liquid argon shall be stored and used only in a well-ventilated place. If enough nitrogen gas evaporates from the liquid in an unventilated space, the percentage of oxygen in the air may become dangerously low making anybody present there, symptoms, such as dizziness, unconscious without any warning. Remaining in this atmosphere long enough may become fatal.

25.3.2 Argon build-up is most likely to occur when a room is closed, overnight for example. If there is any doubt about the amount of oxygen in a room, the room shall be ventilated completely before entering it. Waste nitrogen shall not be disposed of in a confined area or a place where someone else may enter.

25.3.3 Liquid argon is colder than liquid oxygen. Therefore, if it is exposed to the air, oxygen from the air may condense into the liquid argon. If this is allowed to continue for any length of time, the oxygen content of the liquid nitrogen may become appreciable and the liquid will require the same precautions as for handling liquid argon. However, most liquid nitrogen containers are entirely closed except for a small neck area and the nitrogen gas issuing from the surface of the liquid forms a barrier which keeps air away from the liquid and prevents oxygen contamination.

25.3.4 Before entering any large liquid argon storage tank, it shall be made sure that all pipes to the tank are blanked or positively closed off. The tank shall then be purged with air. If a check with instruments shows that the atmosphere normal air, it shall be safe to enter. Unless all lines are physically isolated, inside atmosphere shall be checked frequently with instruments during work. If, for any reason, the supply of fresh air in the tank is doubtful, breathing apparatus shall be used with its own supply of oxygen or air. Whenever anybody enters a tank, he should make sure that he is equipped with a life line and that an observer is stationed outside to check on his reactions while working. It is a good practice to have the ventilating equipment rapidly changing the air in tanks at all times when personnel are working inside them.

25.3.5 Only experienced and properly instructed persons should handle compressed gases/cryogenic liquids.

25.3.6 Do not remove or deface labels provided by the supplier for the identification of the cylinder contents.

25.3.7 Before connecting the container, check the complete gas system for suitability, particularly for pressure rating and materials.

25.3.8 Before connecting the container for use, ensure that back feed from the system into the container is prevented. Close container valve after each use and when empty, even if still connected to equipment. Never attempt to repair or modify container valves or safety relief devices. Damaged valves should be reported immediately to the supplier.

16.3.9 If user experiences any difficulty operating cylinder valve discontinue use and contact supplier. Do not remove or interchange connections. Ensure the complete gas system has been checked for leaks before use. Prevent entrapment of cryogenic liquid in closed systems not protected with relief device. A small quantity of liquid produces large volumes of vaporized gas at atmospheric pressure.

25.3.10 Containers used in shipment, storage, and transfer of cryogenic liquid are specially designed, well-insulated containers equipped with a pressure relief device and valves to control pressure. Under normal conditions, these containers will periodically vent product to limit pressure buildup. Ensure that the container is in a well–ventilated area to avoid creating an oxygen–deficient atmosphere.

25.3.11 Use adequate pressure relief in systems and piping to prevent pressure buildup; liquid in a closed container can generate extremely high pressures when vaporized by warming. Employ suitable pressure regulating devices on all containers when the gas is being emitted to systems with lower pressure rating than that of the container. Only transfer lines designed for cryogenic liquids shall be used.

25.3.12 Do not subject containers to abnormal mechanical shock. When moving cylinders, even for short distances, use a cart (trolley, hand truck, etc.) designed to transport cylinders. When doubt exists as to the correct handling procedure for a particular gas, contact the supplier.

25.3.13 Liquid Argon is extremely cold. Cryogenic liquids and their vapours can rapidly freeze human tissue and can cause many common materials such as carbon steel, rubber, and plastics to become brittle or even break under stress.

25.3.14. Cryogenic liquids in containers and piping at temperatures at or below the boiling point of liquefied Argon [–302.6°F (–185°C)] can cause clod burn if touched.

25.3.15 All cryogenic liquids produce large volumes of gas when they vaporize. For example, one volume of liquid nitrogen vaporizes to 840 volumes of Argon gas at 68°F (20°C) at 1 atm. A cryogenic liquid cannot be indefinitely maintained as a liquid, even in well-insulated containers.

25.3.16 If these liquids are vaporized in a sealed container, they can produce enormous pressures that could rupture the container. For this reason pressurized cryogenic containers are normally protected with multiple devices for over-pressure prevention. Common pressure relief devices are a pressure relief valve for primary protection and a rupture disc for secondary protection.

25.3.17 Vaporization of a cryogenic liquid in an enclosed area can cause asphyxiation by displacing the air.

25.3.18 The cold “boil-off” gases condense the moisture in the surrounding air, creating a highly visible fog. This fog can also be formed around cold equipment when no release of the cold liquid or vapors has occurred. Fog clouds do not define

the vapor cloud. They define the area where the vapors are still cold enough to condense the moisture in the air.

25.3.19 The vapors can extend well beyond the fog cloud, depending on the product and atmospheric conditions.

25.3.20 Although fog clouds may be indicative of a release, they must never be used to define the leak area and should not be entered by anyone. The dense fog clouds associated with the handling or transfer of cryogenic liquids can obstruct visibility. Care should be exercised so that any clouds do not interfere with vehicle traffic or safety escape routes.

25.3.21 Always handle cryogenic liquids carefully. Their extremely low temperatures can produce cryogenic burns of the skin and freeze underlying tissue.

25.3.22 When spilled on a surface, they tend to spread as far as the quantity of liquid spilled and the physical confines of the area permit.

25.3.23 They can cool large areas. The vapors coming from these liquids are also extremely cold and can produce burns.

25.2.24 Exposure to these cold gases, which is too brief to affect the skin of the face or hands, may affect delicate tissues, such as the eyes.

25.2.25 Stand clear of boiling and splashing liquid and the cold vapors that are released. Boiling and splashing always occur when charging a warm container or when inserting objects into the liquid. Always perform these operations slowly to minimize the splashing and boiling.

25.2.26 Never allow any unprotected part of your body to touch uninsulated pipes or vessels containing cryogenic liquids.

25.2.27 The extremely cold material may stick fast to skin and tear the flesh when you attempt to withdraw it. Even non-metallic materials are dangerous to touch at these low temperatures. Use tongs to immerse and remove objects from cryogenic liquids.

25.2.28 In addition to the hazards of frostbite or flesh sticking to cold materials, objects that are soft and pliable at room temperature, such as rubber or plastics, are easily broken because they turn brittle at low temperatures and may break when stressed.

25.4 Labelling

25.4.1 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.

Manufacturers name with label warnings required by regulations or ordinances form part of the label or placard.

25.4.2 Each tanker and each railroad car carrying one or more containers shall be labelled as:

In case of leakage/fire: Keep away flames and oil/grease. Use water fog or water spray for cooling or dilution. Evacuate upwind from cold liquid and white water vapor.

25.5 Transport

25.5.1 Transportation of Container

25.5.1.1 Liquid containers must only be unloaded from or loaded onto a delivery vehicle by means of a crane, fork truck, or a power-assisted tailgate. Liquid containers may be moved using a forklift if they are secured on a pallet, in a cradle, or some other device designed for this purpose. When the container is removed from a pallet, it should only be moved using a specially designed four-wheel handcart.

25.5.1.2 Liquid containers should only be transported in an upright position and should never be laid on their side. For proper ways to handle a liquid container is as given in **Fig 1**. Never roll these containers on their side. Liquid containers equipped with wheels should always be moved by pushing the container, never pulling it. This reduces the possibility of the container falling on co-worker in the event it becomes unstable. Pushing the liquid container up any type of grade will increase the force necessary to move it. A grade as low as 5 percent (5-inch rise in 10 feet of travel) will increase the force necessary to start to push the container by as much as 50 percent.

25.5.1.3 Care must be exercised when transporting liquid containers in elevators. If possible, transport the container only on a freight elevator that is not generally used for personnel transport.

25.5.1.4 After the container is placed in the elevator, the elevator should be locked out to all other users. The sender should remain outside the elevator and activate it. Another person should be available on the receiving floor to take the liquid container off the elevator at its destination. If a freight elevator is not available, a passenger elevator can be used provided it is locked out to all other users. If it is absolutely necessary to have an attendant in the elevator with the container, an escape pack supplemental breathing apparatus must be carried in the elevator. Do not transport a liquid container at any time in an elevator with any other personnel in the car.

25.5.2 *Driver*

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

26 SPILLAGE, LEAKAGE AND WASTE DISPOSAL

26.1 General

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

26.2 Spillage

26.2.1 Do not touch or walk through spilled material

26.2.2 Stop leak if you can do it without risk.

26.2.3 Use water spray to reduce vapors or divert vapor cloud drift.

26.2.4 Avoid allowing water runoff to contact spilled material.

26.2.5 Do not direct water at spill or source of leak.

26.2.6 If possible, turn leaking containers so that gas escapes rather than liquid. Prevent entry into waterways, sewers, basements or confined areas.

26.2.7 Allow substance to evaporate. Ventilate the area.

CAUTION – When in contact with refrigerated/cryogenic liquids, many materials become brittle and are likely to break without warning.

26.4 Waste Disposal

26.4.1 Return unused product in original cylinder to supplier. Contact supplier if guidance is required.

26.4.2 Small amounts may be allowed to evaporate into the atmosphere. In case of large spills consult an expert and allow evaporation. Large amounts should only be handled by gas supplier.

27 FIRE PREVENTION AND FIRE FIGHTING

27.1 General

The liquid argon itself does not burn. Use extinguishing media appropriate for surrounding fire.

27.2 Fire fighting

27.2.1 Spill will rapidly vaporize forming an oxygen deficient vapor cloud. Vapor cloud may obscure visibility.

27.2.2 Do not direct water spray at container vent. Move away from container and cool with water from a protected position. Keep containers and surroundings cool with water spray. Wear self-contained breathing apparatus for firefighting if necessary.

27.2.3 Use extinguishing agent suitable for type of surrounding fire. Move containers from fire area if you can do it without risk. Damaged cylinders should be handled only by specialists

27.3 Fire Involving Tanks

Fight fire from maximum distance or use unmanned hose holders or monitor nozzles. Cool containers with flooding quantities of water until well after fire is out. Do not direct water at source of leak or safety devices; icing may occur. Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank. Always stay away from tanks engulfed in fire

28 TRAINING

28.1 All personnel directly involved in the commissioning, operation and maintenance of liquid argon storage systems shall be fully informed regarding the hazards associated with liquid argon 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.

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

a) Potential hazards of liquid argon;

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.

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

28.4 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.

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

28.6 Safety in handling liquid argon 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 argon 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 argon is being handled.

28.7 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.

29 HEALTH MANAGEMENT, FIRST-AID AND MEDICAL TREATMENT

29.1 First Aid

29.1.1 *General Principles*

Persons exposed to oxygen-deficient atmospheres should be quickly moved to fresh air. If the victim is not breathing, artificial respiration should be administered immediately. If the victim is breathing, give supplemental oxygen.

29.1.2 *Contact with Skin*

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

29.1.3 *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.

29.1.4 *Ingestion*

Ingestion is not considered a potential route of exposure.

29.1.5 *Inhalation*

Move to fresh air. 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. In case of shortness of breath, give oxygen.

30 ADDITIONAL INFORMATION

Workers involved in emergency activities must not allow emotions to override safe work procedures and training. Only trained, qualified personnel equipped with supplied air and necessary safety equipment should attempt a rescue in accordance with safe rescue procedures. You cannot hold your breath and safely enter areas with low oxygen levels. Tragically, without supplied air equipment, attempts to save someone in an oxygen-deficient atmosphere most often result in additional victims.

SECTION 4 LIQUID HELIUM

31 PROPERTIES LIQUID HELIUM

31.1 General Information

31.1.1 Liquid helium is inert, colorless, odorless, noncorrosive, extremely cold, and nonflammable. Helium will not react with other elements or compounds under ordinary conditions. Since helium is noncorrosive, special materials of construction are not required. However, materials must be suitable for use at the extremely low temperatures of liquid helium. Vessels and piping must be selected and designed to withstand the pressure and temperatures involved and comply with applicable codes for transport and use.

31.1.2 Most of commercial helium is recovered from natural gas through a cryogenic separation process. Normally, helium is present in less than 1 percent by volume in natural gas. Helium is recovered, refined, and liquefied. Liquid helium is typically shipped from production sources to storage and trans-fill facilities.

31.1.3 Tankers, ranging in size from 5 000 gallons to 11 000 gallons, contain an annular space insulated with vacuum, nitrogen shielding, and multilayer insulation. This design reduces heat leak and vaporization of liquid helium during transportation.

31.1.4 Being odorless, colorless, tasteless, and nonirritating, helium has no warning properties. Humans possess no senses that can detect the presence of helium. Although helium is nontoxic and inert, it can act as a simple asphyxiant by displacing the oxygen in air to levels below that required to support life. Inhalation of helium in excessive amounts can cause dizziness, nausea, vomiting, loss of consciousness and death. Death may result from errors in judgment, confusion, or loss of consciousness that prevents self-rescue.

31.1.5 At low oxygen concentrations, unconsciousness and death may occur in seconds and without warning.

31.1.6 *Chemical Name* - He

31.1.7 *Common Name & Synonyms* - Helium (refrigerated), Cryogenic Liquid Helium, Liquid Helium, Lhe

31.1.8 *Uses* – General Industrial.

The extremely low temperature of liquid helium is utilized to maintain the superconducting properties of magnets in applications such as MRI, NMR spectroscopy, and particle physics research. The main application for gaseous helium is for inert shielding gas in metal arc and laser welding. Helium provides a protective atmosphere in the production of reactive metals, such as titanium and zirconium. Gaseous helium is used as a coolant during the drawing of optical fibers, as a carrier gas for chromatography, and as a leak detection gas in a variety of industries. Being both lighter than air and nonflammable, helium is used to inflate balloons and airships.

31.2 Identification

31.2.1 *Formula* - He

31.2.2 *CAS Number* - 7440-59-7

31.2.3 *UN Number* - UN1963

31.2.4 *UN Class* - 2.2.

31.3 Physical Properties

Liquid helium is inert, colorless, odorless, noncorrosive, extremely cold, and nonflammable. Helium will not react with other elements or compounds under ordinary conditions. Since helium is noncorrosive.

31.3.1

31.3.2 *Molecular Mass* - 4 g/mol

31.3.3 *Physical State* - Liquefied gas

31.3.4 *Colour* - Colorless.

31.3.5 *Odour* - No odor warning properties.

31.3.6 *Boiling Point* - -452 °F (-269 °C)

31.3.7 *Melting Point* - -458 °F (-272 °C)

31.3.8 *Vapour Density (Air=1)* - 0.138 (air = 1) Lighter or similar to air.

31.3.9 *Specific Gravity*

a) Liquid (water = 1) – No data available

31.3.10 *Viscosity at* 30 °C - Not applicable.

31.3.11 *Vapour Pressure at* 76.6 °C - Not applicable.

31.3.12 *Heat of Combustion* - No data available

31.3.13 *Refractive Index at* 25 °C - No data available

31.3.14 *Solubility in Water* – 0.0 015 g/l

31.3.15 *Solubility in other solvents* – No data available

31.3.16 *Light Sensitivity* - No data available

31.4 Chemical Properties

31.4.1 *Reactivity* - No data available.

31.4.2 *Polymerization* – No data available

31.4.3 *Allotrope formation* – No data available

31.4.4 *Corrosion properties* –. No data available

31.5 Fire and Explosion Hazard Properties

31.5.1 *Ignition Temperature* - No data available.

31.5.2 *Auto Ignition Temperature* - No data available.

31.5.3 Flash Point - No data available.

31.5.4 *Upper Explosive Limit* - Not applicable.

31.5.5 *Lower Explosive Limit* - Not applicable.

31.5.6 *Fire Risk*

Since helium is nonflammable, special firefighting equipment and instructions are not needed. As a note of caution, however, water streams must not be directed toward venting helium, as the water will freeze and plug the pressure relief vent and may result in a container failure.

32 HEALTH HAZARD & TOXICITY INFORMATION

32.1 General Information

32.1.1 Being odorless, colorless, tasteless, and nonirritating, helium has no warning properties. Humans possess no senses that can detect the presence of helium. Although helium is nontoxic and inert, it can act as a simple asphyxiant by displacing the oxygen in air to levels below that required to support life. Inhalation of helium in excessive amounts can cause dizziness, nausea, vomiting, loss of consciousness and death. Death may result from errors in judgment, confusion, or loss of consciousness that prevents self rescue.

32.1.2 At low oxygen concentrations, unconsciousness and death may occur in seconds and without warning.

32.1.3 Personnel, including rescue workers, should not enter areas where the oxygen concentration is below 19.5 percent unless provided with a self-contained breathing apparatus or air-line respirator. For more information on oxygen deficient atmospheres. Extensive tissue damage or burns can result from exposure to liquid helium or cold helium vapors.

32.2 Routes of entry

32.2.1 *Skin*

Contact with liquid may cause cold burns/frostbite. May cause severe frostbite.

32.2.2 *Eyes*

Contact with liquid may cause cold burns/frostbite.

32.2.3 *Ingestion*

Ingestion is not considered a potential route of exposure.

32.2.4 *Inhalation*

In high concentrations may cause asphyxiation. Symptoms may include loss of mobility/consciousness. Victim may not be aware of asphyxiation. Asphyxiation may bring about unconsciousness without warning and so rapidly that victim may be unable to protect themselves.

32.3 Toxicity information

a) Time Weighted Average (TWA) — No Data Available
b) Short Term Exposure Limit (STEL) — No Data Available
c) Immediately Dangerous to Life and Health (IDLH) – No Data Available
d) Lethal Dose (LD_{50}) — No Data Available
e) Inhalation (Rat) Lethal Concentration (LC) — No Data Available

32.4 Antidote

There is no antidote.

32.5 Health Effects

32.5.1. *Signs and Symptoms*

The sign and symptoms related to oxygen-deficient atmosphere is as prescribed in Table 1.

33 PERSONAL PROTECTIVE EQUIPMENT

33.1 Availability and Use

33.1.1 While personal protective equipment is not an adequate substitute for good, safe working conditions, adequate ventilation and intelligent conduct on the part of employees working with liquid nitrogen, it is in many instances the only practical means of protecting the worker, particularly in emergency situations. One should keep firmly in mind that personal protective equipment protects only the worker wearing it, and other unprotected workers in the area maybe exposed to danger.

33.1.2 Eyes are most sensitive to the extreme cold of liquid helium and its vapors. The recommended personal protective equipment when handling or using liquid helium is a full face shield over safety goggles; loose-fitting thermal insulated or leather gloves; and long sleeved shirts and pants without cuffs, especially whenever the possibility of exposure or a spill exists. In addition, safety shoes are recommended for those involved with the handling of liquid helium containers.

33.2 Non-Respiratory Equipment

33.2.1 *Eye and face Protection*

Eyes are most sensitive to the extreme cold of liquid helium and its vapors. The recommended personal protective equipment when handling or using liquid helium is a full face shield over safety goggles (see IS 8520).

33.2.2 *Head Protection*

Safety helmet with face shield is recommended while handling the liquid helium see IS 2925.

33.2.3 *Foot and leg Protection*

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

33.2.4 *Body, Skin and Hand Protection*

33.2.4.1 Wear work gloves when handling gas containers. If the operation involves possible exposure to a cryogenic liquid, wear loose fitting thermal insulated or cryo-gloves.

33.2.4.2 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. Safety shoes are recommended when handling cylinders.

33.3 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:

33.3.1 *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.

34 STORAGE, HANDLING, LABELLING AND TRANSPORT

34.1 General

34.2 Storage

34.2.1 Do not change or force fit connections.

34.2.2 Always keep container in upright position.

34.2.3 Close valve after each use and when empty.

34.2.4 Use insulated hose and piping to prevent condensation of oxygen-rich liquid air. Use a back flow preventative device in the piping.

34.2.5 Do not allow storage temperature to exceed 50°C (122°F). Containers should be stored in a purpose build compound which should be well ventilated, preferably in the open air.

34.2.6 Full containers should be stored so that oldest stock is used first. Do not store in a confined space. Full and empty cylinders should be segregated. Store containers in location free from fire risk and away from sources of heat and ignition.

34.2.7 Return empty containers in a timely manner. Stored containers should be periodically checked for general condition and leakage. Protect containers stored in the open against rusting and extremes of weather.

34.2.8 Containers should not be stored in conditions likely to encourage corrosion. Cryogenic containers are equipped with pressure relief devices to control internal pressure. Under normal conditions these containers will periodically vent product. All vents should be piped to the exterior of the building. Observe all regulations and local requirements regarding storage of containers.

34.3 Handling

34.3.1 Liquid helium shall be stored and used only in a well-ventilated place. If enough helium gas evaporates from the liquid in an unventilated space, the percentage of oxygen in the air may become dangerously low making anybody present there, symptoms, such as dizziness, unconscious without any warning. Remaining in this atmosphere long enough may become fatal.

34.3.2 Helium build-up is most likely to occur when a room is closed, overnight for example. If there is any doubt about the amount of oxygen in a room, the room shall be ventilated completely before entering it. Waste helium shall not be disposed of in a confined area or a place where someone else may enter.

34.3.3 Liquid helium is colder than liquid oxygen. Therefore, if it is exposed to the air, oxygen from the air may condense into the liquid helium. If this is allowed to continue for any length of time, the oxygen content of the liquid helium may become appreciable and the liquid will require the same precautions as for handling liquid helium. However, most liquid nitrogen containers are entirely closed except for a small neck area and the nitrogen gas issuing from the surface of the liquid forms a barrier which keeps air away from the liquid and prevents oxygen contamination.

34.3.4 Before entering any large liquid nitrogen storage tank, it shall be made sure that all pipes to the tank are blanked or positively closed off. The tank shall then be purged with air. If a check with instruments shows that the atmosphere normal air, it shall be safe to enter. Unless all lines are physically isolated, inside atmosphere shall be checked frequently with instruments during work. If, for any reason, the supply of fresh air in the tank is doubtful, breathing apparatus shall be used with its own supply of oxygen or air. Whenever anybody enters a tank, he should make sure that he is equipped with a life line and that an observer is stationed outside to check on his reactions while working. It is a good practice to have the ventilating equipment rapidly changing the air in tanks at all times when personnel are working inside them.

34.3.5 Only experienced and properly instructed persons should handle compressed gases/cryogenic liquids.

34.3.6 Do not remove or deface labels provided by the supplier for the identification of the cylinder contents.

34.3.7 Before connecting the container, check the complete gas system for suitability, particularly for pressure rating and materials.

34.3.8 Before connecting the container for use, ensure that back feed from the system into the container is prevented. Close container valve after each use and when empty, even if still connected to equipment. Never attempt to repair or modify container valves or safety relief devices. Damaged valves should be reported immediately to the supplier.

34.3.9 If user experiences any difficulty operating cylinder valve discontinue use and contact supplier. Do not remove or interchange connections. Ensure the complete gas system has been checked for leaks before use. Prevent entrapment of cryogenic liquid in closed systems not protected with relief device. A small quantity of liquid produces large volumes of vaporized gas at atmospheric pressure.

34.3.10 Containers used in shipment, storage, and transfer of cryogenic liquid are specially designed, well-insulated containers equipped with a pressure relief device and valves to control pressure. Under normal conditions, these containers will periodically vent product to limit pressure buildup. Ensure that the container is in a well–ventilated area to avoid creating an oxygen–deficient atmosphere.

34.3.11 Use adequate pressure relief in systems and piping to prevent pressure buildup; liquid in a closed container can generate extremely high pressures when vaporized by warming. Employ suitable pressure regulating devices on all containers when the gas is being emitted to systems with lower pressure rating than that of the container. Only transfer lines designed for cryogenic liquids shall be used.

34.3.12 Do not subject containers to abnormal mechanical shock. When moving cylinders, even for short distances, use a cart (trolley, hand truck, etc.) designed to transport cylinders. When doubt exists as to the correct handling procedure for a particular gas, contact the supplier.

34.3.13 Liquid nitrogen is extremely cold. Cryogenic liquids and their vapours can rapidly freeze human tissue and can cause many common materials such as carbon steel, rubber, and plastics to become brittle or even break under stress.

34.3.14 Liquid Helium is extremely cold. Cryogenic liquids and their vapours can rapidly freeze human tissue and can cause many common materials such as carbon steel, rubber, and plastics to become brittle or even break under stress.

34.3.15. Cryogenic liquids in containers and piping at temperatures at or below the boiling point of liquefied helium [–302.6°F (–185°C)] can cause clod burn if touched.

34.3.16 All cryogenic liquids produce large volumes of gas when they vaporize. A cryogenic liquid cannot be indefinitely maintained as a liquid, even in well-insulated containers.

34.3.17 If these liquids are vaporized in a sealed container, they can produce enormous pressures that could rupture the container. For this reason pressurized cryogenic containers are normally protected with multiple devices for over-pressure prevention. Common pressure relief devices are a pressure relief valve for primary protection and a rupture disc for secondary protection.

34.3.18 Vaporization of a cryogenic liquid in an enclosed area can cause asphyxiation by displacing the air.

34.3.19 The cold “boil-off” gases condense the moisture in the surrounding air, creating a highly visible fog. This fog can also be formed around cold equipment when no release of the cold liquid or vapors has occurred. Fog clouds do not define the vapor cloud. They define the area where the vapors are still cold enough to condense the moisture in the air.

34.3.20 The vapors can extend well beyond the fog cloud, depending on the product and atmospheric conditions.

34.3.21 Although fog clouds may be indicative of a release, they must never be used to define the leak area and should not be entered by anyone. The dense fog clouds associated with the handling or transfer of cryogenic liquids can obstruct visibility. Care should be exercised so that any clouds do not interfere with vehicle traffic or safety escape routes.

34.3.22 Always handle cryogenic liquids carefully. Their extremely low temperatures can produce cryogenic burns of the skin and freeze underlying tissue.

34.3.23 When spilled on a surface, they tend to spread as far as the quantity of liquid spilled and the physical confines of the area permit.

34.3.24 They can cool large areas. The vapors coming from these liquids are also extremely cold and can produce burns.

34.4 Labelling

34.4.1 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.

Manufacturers name with label warnings required by regulations or ordinances form part of the label or placard.

34.4.2 Each tanker and each railroad car carrying one or more containers shall be labelled as:

In case of leakage/fire: Keep away flames and oil/grease. Use water fog or water spray for cooling or dilution. Evacuate upwind from cold liquid and white water vapor.

34.5 Transport

34.5.1 General

The vessel for transporting shall always be fitted with adequate relief devices. General precautions to be observed for both full and empty vessels are as follows:

a) Container shall be kept vertical.

b) Containers are not to be rolled-on a tilted axis (milk churning).

c) Sudden mechanical shocks shall be avoided.

d) Immediately before transport, it should be made sure that the vents are free from blockage and that the relief devices are in working order.

e) If the container is of the type which requires liquid nitrogen shielding, it should be ensured that the liquid nitrogen reservoir is full.

f) It should be ensured that gas is following from the vent immediately after the filled vessels are received and daily thereafter.

g) With containers of the liquid nitrogen jacketed type, liquid nitrogen reservoir is to be topped up daily.

h) Proper filling and transfer tube equipment shall be used.

i) A brass or copper rod shall be kept available for freeing any solid gas blockage. To use, slide the rod gently down to the plugged area, exerting only sufficient force to free the obstruction.

j) Recipients of liquid helium should designate staff familiar with liquid handling techniques to be responsible for ensuring that correct handling procedures are adopted.

k) In any unusual emergency, the liquid helium suppliers shall be contacted immediately.

34.5.2 *Driver*

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

35.2.3 *Air Transportation*

35.2.3.1 Air transportation of liquid helium requires special safety measures

in addition to those required for general shipment.

35.2.3.2 Liquid helium may only be transported by air when the container is specially equipped for air transportation and satisfies the appropriate legal requirements with regard to safety as well as packaging, labelling and documentation.

35 SPILLAGE, LEAKAGE AND WASTE DISPOSAL

35.1 General

All personal attending to spill/leak should use proper personal protective equipment and firefighting equipment while handling.

35.2 Spillage

35.2.1 Evacuate personnel to safe areas. Ventilate the area. Monitor oxygen level. Wear self-contained breathing apparatus when entering area unless atmosphere is proved to be safe.

35.2.2 Prevent further leakage or spillage. 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.

35.2.3 Ventilate the area.

35.2.4 If possible, stop flow of product. Increase ventilation to the release area and monitor oxygen level. Vapor cloud may obscure visibility. Do not spray water directly

at leak. 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 and safely vent the pressure before attempting repairs.

35.3 Waste Disposal

35.3.1 Return unused product in original cylinder to supplier. Contact supplier if guidance is required.

35.3.2 Small amounts may be allowed to evaporate into the atmosphere. In case of large spills consult an expert and allow evaporation. Large amounts should only be handled by gas supplier.

36 FIRE PREVENTION AND FIRE FIGHTING

36.1 The liquid helium itself does not burn. Use extinguishing media appropriate for surrounding fire.

36.2 Spill will rapidly vaporize forming an oxygen deficient vapor cloud. Vapor cloud may obscure visibility. Do not direct water spray at container vent. Move away from container and cool with water from a protected position. Keep containers and surroundings cool with water spray.

36.3 Wear self-contained breathing apparatus for firefighting if necessary.

37 TRAINING

37.1 All personnel directly involved in the commissioning, operation and maintenance of liquid helium storage systems shall be fully informed regarding the hazards associated with helium and oxygen deficient 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.

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

a) Potential hazards of helium;

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.

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

37.4 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.

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

37.6 Safety in handling liquid helium 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 helium 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 helium is being handled.

37.7 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.

38 HEALTH MANAGEMENT, FIRST-AID AND MEDICAL TREATMENT

38.1 First Aid

38.1.1 *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.

38.1.2 *Contact with Skin*

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

38.1.3 *Contact with Eye*

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

38.1.4 *Ingestion*

Ingestion is not considered a potential route of exposure.

38.1.5 *Inhalation*

Move to fresh air. 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. In case of shortness of breath, give oxygen.

39 ADDITIONAL INFORMATION

39.1 Transfer of Liquid Helium

39.1.1 Purging of cryogenic liquid vessels prior to use is essential to remove any matter considered undesirable to product purity, injurious to equipment functioning or hazardous to personnel. When purging a vessel, knowledge of the freezing and boiling points of all likely contaminants is important. When liquid helium vessels are involved, it shall be recognized that all other liquids and gases will solidify at liquid helium temperatures. Entrance, therefore, of any gas except pure, dry helium into a helium-cooled vessel will cause formation of solid deposits on internal cold surfaces, thus creating a very hazardous condition.

39.1.2 To purge such contaminants from a vessel at liquid helium temperature, it is necessary to remove any liquid helium present, and warm the vessel to the

temperature corresponding to the highest boiling point of any of the contaminants suspected. Therefore, if air has been drawn into the vessel, the vessel shall be warmed to at least - 183°C (the boi1in.g point of oxygen) in order to purge the vessel of the air constituent having the highest boiling point. If moist air were drawn into the vessel, it would be necessary to warm the vessel to above the freezing point of water so that the water could be evaporated and the vessel purged with warm dry air or dry nitrogen.

39.1.3 It should be borne in mind that it is not possible to purge a vessel at liquid helium temperature (- 269°C) directly with nitrogen, since the purging fluid will immediately freeze upon contact with the helium cold vessel surfaces. However, once a vessel is warmed to above liquid nitrogen temperature, pure nitrogen gas at ambient temperature or above may be used for purging to speed the warming of the vessel. Likewise, if it is possible to utilize pure helium gas economically (such as in a recoverable system), it may be circulated directly through the liquid helium-cold vessel, warming it in one operation to the warmest boiling point temperature of any contaminant.

39.1.4 During purging, the temperature of the vessel may be best approximated at any given time by monitoring the temperature of the existing purge gas, which will normally be close to that of the inner vessel.

39.1.5 If a small vessel contains only pure helium gas, it may be filled directly with liquid helium without concern of contamination. However, if the vessel was first precooled with liquid nitrogen to conserve helium losses during filling, if would require complete removal of all nitrogen by purging the nitrogen-cold container with pure, dry helium gas before being filled with liquid helium.

39.2 Precooling

39.2.1 Depending upon economy, a ‘warm’ vessel (above liquid nitro□gen temperature) may be cooled directly with cold helium gas produced from flash-off of liquid helium, or may be precooled with another cryogenic liquid, ‘preferably liquid nitrogen for safety reasons.

39.2.2 If nitrogen precooling is used, the quantity of liquid nitrogen for cool-down should be no’ greater in weight than the full liquid helium capacity of the vessel to prevent over-load- vessels suspension system. Equipment shall be provided for transferring the liquid nitrogen both into and out of the vessels, since the normal filling and withdrawal procedures for liquid helium containers may not work satisfactorily with the heavier, warmer liquid nitrogen.

39.2.3 Cool-down of transfer lines should always be accomplished wherever possible by trickling liquid helium into the line immediately prior to transfer,’ thereby making maximum use of the sensible heat of the cold vapour to cool the line. Any attempt to cool the line with large quantities of liquid helium will result in abnormally high evaporation loss from cool-down.

39.2.4 Liquid nitrogen should never be used to precool a flexible helium transfer line; nitrogen is difficult to remove from the convolutions of the flexible line, and will later freeze and cause plugging.

39.3 Withdrawing Liquid Helium

39.3.1 Because of its very low latent heat of vaporization, liquid helium shall always be transferred through well-insulated., vacuum-jacketed lines. Non-vacuum insulation will result in total loss of liquid. The general procedures given in 39.3.1.1 to 39.3.1.7 should be used while withdrawing liquid from any helium container.

39.3.1.1 The transfer line and receiving vessel shall be adequately purged with pure, dry helium gas. Care shall be exercised to purge all joints before assembly of transfer components, and to purge any dead-ended or auxiliary parts of lines which will be helium cooled.

39.3.1.2 When withdrawal dip tubes are used, the dip tube should be inserted into a vessel through a section of rubber hose that may be clamped to the dip tube and container neck (unless other sealing provision is made) to prevent helium leakage about the tube. This is important to prevent loss of transfer ~pressure and also to avoid condensed air on the exposed portion of the dip tube from running into the vessel during removal of the tube.

39.3.1.3 Pressure for transfer may be provided by normal evaporation pressure build-up or by addition of pure helium gas from a regulated cylinder. The unusual properties of helium make low pressure transfer preferable. Transfers are generally made at a differential pressure of about 0.07 kg/cm^2 to 0.14 kg/cm^2 on gauge.

39.3.1.4 To prevent air, carbon dioxide or atmospheric moisture from freezing and causing restrictions in inlet and exhaust lines, a positive pressure shall be maintained at all times in the supplying and receiving vessels. When the ratio of venting falls off, a relief valve or other restriction should be added to retain positive pressure in the helium system.

39.3.1.5 In terminating transfer, the flow of external pressurizing gas (if used) should be immediately stopped so as not to add more warm gas to the supply vessel. The liquid withdrawal line should be immediately removed from open neck-tube type containers, or the liquid withdrawal valve of containers .so equipped, immediately closed. Any backflow of vapour through a withdrawal line will bubble up through the liquid and cause unnecessary evaporation of the remaining liquid helium.

39.3.1.6 Where protective caps are provided on transfer connections, they should be replaced immediately after transfer to prevent condensation of moisture on the cold connections.

39.3.1.7 When fill or withdrawal dip-tubes are removed from open neck-tube type helium containers, a closure containing a relief valve should be immediately secured over the opening.

39.4 Filling Small Vessels with Liquid Helium

39.4.1 The vacuum jacketed transfer tube should extend down into the vessel to or below the level at which liquid temperature is finally desired.

39.4.2 Liquid helium should not be impinged on the mass to be cooled. It should be directed toward the bottom of the vessel to prevent excessive boiling and splashing.

39.4.3 Openings into these vessels should be restricted or relief devices added after filling in order to maintain positive pressure in the vessel.

39.4.4 After a small helium vessel has-been precooled to liquid nitrogen temperature, it is more efficient to insert the transfer line into the small Dewar after cold helium vapour starts issuing from the transfer line. Otherwise, the expanding warm gas during cool-down of the transfer line may build up too much back pressure in a small Dewar.

39.4.5 After a small helium vessel has been filled, it is essential to remove the transfer line while liquid is still issuing from the line. If the transfer is stopped by reducing the pressure on the supply Dewar, the superheated liquid and gas in the transfer line may flash all the liquid in the small helium vessel before the transfer line is removed.

SECTION 5 LIQUID HYDROGEN

40 PROPERTIES LIQUID HYDROGEN

40.1 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.

40.1.1 *Chemical Name* - H_2

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

40.1.3 *Uses* – General Industrial.

40.2 Identification

40.2.1 *Formula* - H_2

40.2.2 *CAS Number* - 1333-74-0

40.2.3 *UN Number* - 1966

40.2.4 *UN Class* - 2.1

40.3 Physical Properties

40.3.1 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.

40.3.2 *Molecular Mass* - 2 g/mol

40.3.3 *Physical State* - Liquefied gas

40.3.4 *Colour* - Colorless

40.3.5 *Odour* - Odorless.

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

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

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

40.3.9 *Specific Gravity*

a) Liquid (water = 1) – 0.070 81

40.3.10 *Viscosity at* 30 °C - Not applicable.

40.3.11 *Vapour Pressure at* 76.6 °C - Not applicable.

40.3.12 *Heat of Combustion* – Not applicable

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

40.3.14 *Solubility in Water* – 0.001 6 g/l

40.3.15 *Solubility in other solvents* – Not available

40.3.16 *Light Sensitivity* - Not available

40.4 Chemical Properties

40.4.1 *Reactivity* - No data available.

40.4.2 *Polymerisation* – Not available

40.4.3 *Allotrope formation* – Not available

40.4.4 *Corrosion properties* –. Not available

40.5 Fire and Explosion Hazard Properties

40.5.1 *Ignition Temperature* - No data available.

40.5.2 *Auto Ignition Temperature* - 560 °C

40.5.3 *Flash Point* - Not applicable.

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

40.5.5 *Lower Explosive Limit* - 4 % (V)

40.5.6 *Fire Risk*

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 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.

41 HEALTH HAZARD & TOXICITY INFORMATION

41.1 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.

41.2 Routes of entry

41.2.1 *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).

41.2.2 *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.

41.2.3 *Ingestion*

Ingestion is not considered a potential route of exposure.

41.2.4 *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.

41.3 Toxicity information

No data is available on the product itself.

41.4 Antidote

41.5 Health Effects

41.5.1. *Signs and Symptoms*

41.5.2 *Acute Toxicity*

No data is available on the product itself.

41.5.3 *Chronic Toxicity*

No data is available on the product itself.

42 PERSONAL PROTECTIVE EQUIPMENT

42.1 Availability and Use

42.2 Non-Respiratory Equipment

42.2.1 *Eye and face Protection*

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

42.2.2 *Head Protection*

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

42.2.3 *Foot and leg Protection*

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

42.2.4 *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.

42.3 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:

42.3.1 *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.

43 STORAGE, HANDLING, LABELLING AND TRANSPORT

43.1 General

43.2 Storage

43.2.1 It is desirable to convert liquid hydrogen to the stable paraform 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 nonreturn 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.

43.2.2 Superinsulated 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.

43.2.3 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.

43.2.4 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.

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

43.3 Handling

43.3.1 Safety precautions to be observed in areas where hydrogen is handled is briefly given in **43.3.1.1** to **43.3.1.5**.

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

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

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

43.3.1.4 All electrical equipment located in the area shouId.be of the type, approved by the Chief Inspector of Explosives in India.

43.3.1.5 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.

43.3.2 Safety precautions to be observed while working with the equipment that deals with hydrogen is briefly given in **43.3.2.1** to **43.2.2.6**.

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

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

43.3.2.3 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.

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

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

43.3.2.6 Persons 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.

43.3.3 The precautions given in **43.3.3.1** to **43.3.3.5** shall be taken to control static charges.

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

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

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

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

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

43.4 Labelling

43.4.1 Each tanker and each railroad car carrying one or more containers must bear the placard in addition.

43.5 Transport

43.5.1 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.

43.5.2 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.

43.5.3 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.

43.5.4 *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.

44 SPILLAGE, LEAKAGE AND WASTE DISPOSAL

44.1 General

All personal attending to spill/leak should use proper personal protective equipment and fire fighting equipment while handling

44.2 Spillage

44.2.1 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.

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

44.2.3 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.

44.2.4 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 litres of liquid hydrogen are spilled on 50 cm below an open flame, the mixture is ignited almost immediately, after about o.5 second the flame reaches the height of nearly 8.5 m with a maximum width of 6 m.

44.2.5 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.

44.3 Leakages

44.3.1 *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.

44.3.2 *Leak from the Truck*

The consequences of the accidental leakage of LH2 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.

44.3.3 *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.

44.3.4 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) .

44.4 Waste Disposal

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

44.4.2 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.

44.4.3 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.

44.4.4 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.

44.4.5 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.

44.4.6 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.

45 FIRE PREVENTION AND FIRE FIGHTING

45.1 General

45.1.1 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_2 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.

45.1.2 Wear self-contained breathing apparatus for firefighting if necessary.

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

45.2 Fire Prevention

45.2.1 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.

45.2.2 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.

45.2.3 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.

45.2.4 *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.

45.3 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.

46 TRAINING

46.1 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.

46.2 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.

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

46.4 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.

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

46.6 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.

46.7 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.

47 HEALTH MANAGEMENT, FIRST-AID AND MEDICAL TREATMENT

47.1 First Aid

47.1.1 *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.

47.1.2 *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).

47.1.3 *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.

47.1.4 *Ingestion*

Ingestion is not considered a potential route of exposure.

47.1.5 *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.

ANNEX-A

(*Clause* 2)

Referred Indian Standards