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NITROUS OXIDE – CODE OF SAFETY

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ICS 13.100

Chemical Hazards Sectional Committee, CHD 07

Last date for Comments: ------

FOREWORD
(Formal clauses to be added later)

Nitrous oxide (N_2O) has been produced and distributed by the industrial gases industry for many years. It is mainly used for medical purposes (anaesthesia). It is also used in the food and electronic industries. Severe accidents such as violent decomposition of nitrous oxide and the rupture of nitrous oxide tanks have occurred at production, storage and distribution facilities. In addition nitrous oxide gas in elevated concentrations can cause health effects in operators which shall be prevented.

A major cause of accidents and health effects has been insufficient attention to the specific properties of nitrous oxide when designing equipment and developing operating procedures. For that reason, the standard describes the properties and hazards of nitrous oxide.

This standard prescribes safety measures for controlling hazards and provides essential information on symptoms of poisoning etc. in the order and format being applied for all Indian Standards on Code of safety of chemicals.

Regulatory requirements for medical applications shall also be followed, usually specified in the applicable Pharmacopeia for the country of operation.

While preparation of this standard, considerable assistance has been derived from ‘GIA 018_14 Safe Practices for Storage and handling of Nitrous Oxide of Gas Industries Association, India.

NITROUS OXIDE – CODE OF SAFETY

1 SCOPE

1.1 This code describes the properties of nitrous oxide and nature of hazards associated with it. The standard prescribes safety measures for controlling hazards and essential information on symptoms of poisoning, first-aid, medical treatment, storage, handling, labelling and employee safety.

1.2 This code does not, however, deal with specifications for manufacturing of nitrous oxide or quality control and analysis procedures. This standard prescribes guidelines for handling of nitrous oxide.

2 REFERENCES

The Indian Standards listed 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 revisions, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards:

IS No.	*Title*
4155: 1966	Glossary of terms relating to chemical and radiation hazards and hazardous chemicals
8519: 1977	Guide for selection of industrial safety equipment for body protection.
8520: 1977	Guide for selection of industrial safety equipment for eye, face and ear protection.
8807: 1978	Guide for selection of industrial safety equipment for protection of arms and hands.
10667:1983	Guide for selection of industrial safety equipment for protection of foot and leg.

3 TERMINOLOGY

For the purpose of this standard the definition given in IS 4155 and the following shall apply.

3.1 Authorized Person

Trained and qualified person approved or assigned to perform specific types of duties or to be at a specific location.

3.2 Bundle (of cylinders)

Assembly of cylinders that are fastened together and which are interconnected by a manifold and transported as a unit.

3.3 Cryogenic Receptacle

Transportable thermally insulated pressure receptacle for refrigerated liquid gas of a capacity of not more than 1 m^3.

3.4 Cylinder

Transportable pressure receptacle of a water capacity not exceeding 150 l.

3.5 Decomposition

Separation of a chemical compound into smaller elements. Nitrous oxide separates into components in an exothermic reaction that can be accelerated by changes in pressure, temperature, or energy inputs, presence of catalyser or impurities.

3.6 Filling Degree

Percentage of the volume of liquefied gas to the volume of water at 15°C that would fill completely a pressure receptacle or tank.

3.7 Filling Ratio

Ratio of the mass of gas to the mass of water at 15°C that would fill completely a pressure receptacle or tank.

3.8 Liquefied Gas

Gas that when packaged under pressure for carriage is partially liquid at temperatures above –50 °C.

3.9 Minimum Design Metal Temperature (MDMT)

Lowest temperature at which a pressure vessel is designed to safely operate at maximum pressure.

3.10 Oxy-potential

Dimensionless number that indicates the oxidizing power of a gas compared to pure oxygen. The oxy-potential value of 100 percent oxygen is 1.0 and air is 0.21.

3.11 Qualified Nitrous Oxide Technician

Person by reason of education, training and experience knows the properties of nitrous oxide, is familiar with the equipment used to store, transfer, and use nitrous oxide: and understands the precautions necessary to safely use nitrous oxide equipment.

3.12 Pressure Receptacle

Collective term that includes cryogenic receptacles, cylinders and bundles.

3.13 Refrigerated Liquid Gas

Gas that when packaged for carriage is made partially liquid because of its low temperature.

3.14 Stationary Tank

Thermally insulated or non-insulated tank at a stationary place that can be filled with liquefied gas or refrigerated liquid gas under pressure for storage purposes.

3.15 Tank

Collective term that includes stationary tanks and transport tanks.

3.16 Transport Tank

Transportable thermally insulated tank for refrigerated liquid gas having a capacity of more than 450 l.

4 PROPERTIES

4.1 General Information

Nitrous oxide and liquid oxygen are the most commonly used oxidizers in hybrid rocket systems and are commonly used in liquid rocket systems. This is primarily due to their cost, safety, availability and handling advantages compared to the other liquid oxidizers that can be used in propulsion applications. The primary hazard associated with N_2O is related to its exothermic decomposition reaction which can liberate substantial energy.

4.1.1 *Chemical Name* — Nitrous oxide

4.1.2 *Common Name & Synonyms* — laughing gas, dinitrogen monoxide, sweet air, hypo-nitrous acid anhydride, facitious air, protoxide of nitrogen.

4.1.3 *Uses* – Rocket motors

i) Internal combustion engine
ii) Aerosol propellant
iii) Medicine
iv) Recreational use

4.2 Identification

4.2.1 *Chemical Formula* — N_2O

4.2.2 *CAS Number* — 10024-97-2

4.2.3 *EC Number* — 233-032-0

4.2.4 *UN Number* — UN 1070, 14 (compressed), UN 2201, 23 (refrigerated liquid),

4.2.5 *RTECS Number* — QX1350000

4.2.6 *FDA Substance Registration Number* — UNII K50XQU1029

4.2.7 *Signal* — Danger

4.3 Physical Properties

4.3.1 *General*

4.3.2 *Molecular Structure*: linear $^{-}O-N^{+}\equiv N \longleftrightarrow N^{-}=N^{+}=O$

4.3.3 *Physical State*

4.3.3.1 *Colour* none

4.3.3.2 *Odour* Sweet

4.3.3.3 *Taste* Sweet odour and taste [1]

4.3.3.4 *Characteristics* Non-flammable
Supports combustion
Oxidizing gas
Anaesthetic & analgesic
Nitrous Oxide is non-corrosive
Soluble in water, alcohol, ethers, oils and sulphuric acid

4.3.3.5 *Molecular Weight* —44.01

4.3.3.6 *Density of gas at Reference conditions* —1 880 g/m^3

4.3.3.7 *Specific Gravity of Gas Compared to Air* — 1.53

4.3.3.8 *Boiling Point* —88.3 °C

4.3.3.9 *Melting Point* — (-)90.8 °C

4.3.3.10 *Critical Temperature* —36.5 °C

4.3.3.11 *Critical Pressure*— 7 145 KPa

4.3.3.12 *Critical Volume* — 9.55 * 10^{-4} m^3/mol

4.3.3.13 *Vapour Pressure* — 5.72×10^6 Pa (25˚C)

4.3.3.14 *Refractive Index* — 0.000 516

4.4 Chemical properties

4.4.1 *Stability*

Under normal operating conditions, nitrous oxide is a stable compound in both the liquid and gaseous states. Nitrous oxide is classified as a non-flammable gas, with oxidizer as a secondary classification.

4.4.2 *Oxidizing Ability*

Under the action of heat nitrous oxide decomposes into its elements irreversibly and exothermally, to produce a mixture which is richer in oxygen than air. After decomposition nitrous oxide become an oxidizing agent.

$$N_2O \rightarrow N_2 + \frac{1}{2}O_2 + 82 \text{ kJ / mol}$$

As "by-products" of nitrous oxide decomposition toxic nitrogen oxides can be formed. Toxic gases (such as carbon-mono-oxide and oxides of nitrogen) may be released in a fire involving nitrous oxide. After decomposition, nitrous oxide becomes an oxidizing gas with an oxy-potential higher than that of air. Consequently, nitrous oxide is classified in standards and regulations as an oxidizing gas.

4.4.3 *Decomposition Reaction*

Accidents and experiments have shown that nitrous oxide as a result of its positive formation energy can decompose exothermally. This decomposition reaction of nitrous oxide can be self-sustaining and violent. The theoretical pressure ratio at decomposition – final pressure / initial pressure – can reach 10 to 1.

While nitrogen and oxygen are the primary products from nitrous oxide decomposition, the higher nitrogen oxides (NO/NO_2) are also produced. Liquid nitrous oxide is relatively insensitive to high energy sparks or external shocks. Decomposition of the liquid could not be initiated by an exploding wire in the laboratory. Limited decomposition has been induced in the liquid by blasting caps. Laboratory results indicate that nitrous oxide can be safely handled in the liquid state but decomposition hazards exist in the gaseous state at elevated pressure and/or temperature. The reaction can propagate through vapour with liquid present. It is important for those handling nitrous oxide to understand and avoid sources of decomposition and to understand at what conditions the decomposition front will or will not propagate.

4.4.3.1 *Decomposition Sources*

All of the following have been known to initiate nitrous oxide vapour decomposition:

Field decomposition sources

i) Static discharge
ii) Spark (Metal to metal contact)
iii) Adiabatic heat of compression
iv) Secondary exothermic chemical reaction
v) Welding/brazing
vi) Heat generated by a dry running pump
vii) Electric immersion heater
viii) Internal impact
ix) External source of heat

Laboratory decomposition sources

i) Electric spark
ii) Exploding Wire
iii) Glowing wire
iv) Blasting cap
v) Heat of compression

4.4.3.4 *Vessel and Pipe Geometry*

In order for a nitrous oxide decomposition to propagate, the heat generated by the reaction must be sufficient to heat the next element of un-reacted gas to the decomposition temperature. Heat lost to pipe walls reduces the potential for propagating the reaction. Smaller diameter lines have a higher internal surface area to volume. Therefore in smaller diameter pipes, more heat per unit volume is lost to the pipe walls and higher temperatures and pressures are required for a decomposition front to propagate *see* **Fig. 1**.

4.4.3.5 *Propagation Threshold*

The potential for an explosive decomposition to take place is more closely coupled to the quenching characteristics (temperature, pressure, container geometry) of the nitrous oxide system than with the initial decomposition energy, [5]. Fig. 1 is a representation of the testing completed in ref [3]

The propagation threshold shown in Figure 1 should be considered as an approximation but can give the user some indication if they are handling nitrous oxide well above or well below the propagation threshold. When handling nitrous oxide vapour under conditions at which the reaction will propagate, care shall be exercised to avoid any possibility of a decomposition source.

It is desirable to operate below the propagation threshold by controlling pressure, temperature, or line size.

4.4.3.6 *Impurities***-** *inert gases*

Dilution of nitrous oxide vapour with a non-flammable gas such as helium or nitrogen will raise the propagation threshold.

In one study, the propagation threshold of the pure vapour at 20.7 bar (300 psi) was approximately 250°C. Addition of 20 v/v percent nitrogen raised the 20.7 bar (300 psi) threshold to 465°C in the same reactor with the same ignition source. It was not possible to obtain ignition with the addition of 46 V percent nitrogen. [4]

4.4.3.7 *Large Pressure Vessels*

Most nitrous oxide decomposition incidents have occurred in large pressure vessels such as a storage tank or cargo tank. This is worse in an empty or nearly empty tank. The decomposition can be initiated at the vessel wall itself by welding or brazing or on the vessel piping or by heat generated by a dry running pump. If initiated in the piping, the reaction front can travel through the piping and into the vessel if operating above the propagation threshold. Once the reaction front is inside the vessel there is effectively no heat sink to quench the reaction. Since 1.5 mol of gas are created for each mole of decomposed nitrous oxide, the decomposing nitrous oxide compresses and heats the unreacted nitrous oxide as the reaction front moves into the vessel. Eventually the unreacted nitrous oxide reaches high enough temperature and pressure to auto-initiate, resulting in an explosion.

4.4.3.8 *Combustible Materials*

Any combustible material such as hydrocarbon lubricants or combustible gases will promote violent decomposition and lower the propagation threshold. A combustible gas will lower the propagation threshold even if present below the lower explosion limit. All equipment that will be in contact with nitrous oxide shall be cleaned for oxygen service and lubricants shall be oxygen compatible.

4.4.4 *Metals*

Contact of nitrous oxide with aluminium, boron, hydrazine, lithium hydride, phenyl lithium, phosphine, sodium, tungsten carbide, hydrogen, hydrogen sulphide, organic peroxides, ammonia or carbon monoxide may cause violent reactions to occur.

There is no restriction regarding the use of common commercial metallic materials for nitrous oxide installations. Primarily carbon steel, manganese steel, chrome molybdenum steel, stainless steel, brass, copper, copper alloys and aluminium are considered to be suitable for use with nitrous oxide [6, 7,8].

No burning of metals in contact with nitrous oxide has been reported. In theory the only condition that metals could burn is following nitrous oxide decomposition.

4.4.5 *Non-metals*

Ignition of non-metals such as plastics, elastomers and clothing materials in contact with nitrous oxide is possible by the influence of heat (e.g. generated by adiabatic compression) or flame.

4.4.5.1 Examples of non-metallic materials exhibiting the best compatibility with gases having a high oxy-potential [9]:

i) Plastic products such as polytetrafluoroethylene (PTFE), polychlorotrifluoroetylene (PCTFE), Fluorinated Ethylene-Propylene (FEP) polyetheretherketone and ethylene propylene diene monomer (EPDM). Others such as polyvinylchloride (PVC), poly-vinylidenfluoride, polyamide and polypropylene can be used with due regard to the external fire risk.

ii) Certain grades of elastomers such as are known to swell in pressurised nitrous oxide and non-swelling grades are preferred when swelling can be an issue.

iii) Non-metallic materials to be used in high pressure ($p > 30$ bar (435 psi)) nitrous oxide / oxygen mixture application shall conform to specific requirements considering toxicity risks [10].

4.4.6 *Oil and Grease*

Oil and grease are unacceptable contaminants in a nitrous oxide installation and can create a severe fire hazard. Such fires can be ignited due to adiabatic pressure shock or high temperature.

4.4.7 *Flammable Gases*

Flammable gases form explosive mixtures with nitrous oxide as mentioned in the given **Table 1**.

1. The explosion limits are influenced by the specific chemical properties of nitrous oxide:
2. The lower explosion limit of flammable gases is much lower with nitrous oxide than with air or oxygen, since the heat release by decomposition of nitrous oxide supports the combustion of combustible-lean mixtures.
3. The upper explosion limit of flammable gases is much higher with nitrous oxide than with air, since the higher oxy potential of nitrous oxide supports the combustion of combustible-rich mixtures.

Table 1 Explosion Limits for Some Typical Flammable Gases with Nitrous Oxide at Normal Atmospheric Conditions (to be checked with code of safety for H_2 and NH_3)

(*Clause* **4.4.7**)

Sl No.		**Lower explosion limit, mole-percent**			**Upper explosion limit, mole-percent**		
(1)	**(2)**	**in air (3)**	**in oxygen (4)**	**in nitrous oxide (5)**	**in air (6)**	**in oxygen (7)**	**in nitrous oxide (8)**
i)	Methane	4.4	5.15	1.5	16.5	60.5	49.5
ii)	Propane	1.7	2.3	0.7	10.9	52.0	27.0
iii)	Hydrogen	4.1	4.0	2.9	77.0	94.0	82.5
iv)	Ammonia	15.4	15	4.4	33.6	79	65.0

NOTE
Other literature sources may provide slightly different values, but the general conclusion is that nitrous oxide is more oxidizing than air.

4.5 Fire and Explosion Hazard Properties

Personnel handling nitrous oxide should be thoroughly familiar with the hazards associated with this. There are several conditions in which extreme danger to personnel and equipment can exist. The following describes these conditions and offers procedures and guidelines to prevent dangerous conditions from developing. Toxic gases (such as carbon monoxide, and oxides of N_2) may be released in a fire involving nitrous oxide.

4.5.1 *Low Temperature Effects on Materials*

The low temperature effect of nitrous oxide liquid and vapour on the materials in the system can create a hazard. At ambient pressure the temperature of liquid nitrous oxide is at -88°C and many materials used in hose and piping systems can become brittle and fail if highly stressed. Materials used in the construction of nitrous oxide supply systems shall be compatible with nitrous oxide and the temperature and pressure conditions encountered.

Piping systems subject to operating temperatures below ambient will contract. Allowances shall be made in piping and support systems to compensate for these changes in dimensions. Copper tubing that is commonly used will shrink approximately 2.5 cm per 30.5 m for every 55.6°C reduction in temperature.

Upon contact with cold nitrous oxide, materials such as rubber or plastics can become brittle and are likely to break without warning.

4.5.2 *Trapped Liquid*

Liquid nitrous oxide that is forced to occupy a fixed volume (such as between two closed valves or positive shutoff points) will increase in pressure as it warms and expands. As long as there is a vapour space within the volume where the liquid is trapped, the pressure will increase about 632×10^4 g/m^2 per ^{o}C (9 psi per ^{o}C). When the volume becomes liquid full, the hydrostatic pressure increases at a rate of 1076×10^6 g/m^2 per ^{o}C (1530 psi per ^{o}C). As the temperature continues to increase, the pressure of the trapped liquid can exceed what the piping and components can withstand. This can cause the rupture of the piping or components with possible injury or property damage; this is the reason why it is required to install pressure relief device between positive shut off devices.

4.5.3 *Personnel Overexposure*

If sufficient amounts of nitrous oxide are released into the work environment via leaks or venting, operator exposure levels can exceed occupational exposure limits (OELs) and present a potential risk to health. In addition, gaseous nitrous oxide under atmospheric conditions is 1.5 times heavier than air and therefore can be found in greater concentrations at lower levels, potentially displacing oxygen in confined spaces and causing an asphyxiation hazard. Nitrous oxide exposure levels should be controlled so that the health and safety risks to operators are minimised to acceptable levels i.e. below the relevant occupational exposure limits. Nitrous oxide in the gaseous state is colourless and has a sweet odour Ventilation systems should be designed to exhaust from the lowest level and allow make-up air to enter at a higher point.

Nitrous oxide liquid or cold vapour coming in contact with the skin or mouth can cause freezing or frostbite. If frostbite has occurred, obtain medical attention. Do not rub the area, immerse in warm water 38°C to 41°C.

Liquefied nitrous oxide, UN 1070, is handled in cylinders at ambient temperature and a pressure of 50 bar (725 psi) at 21°C. Nitrous oxide refrigerated liquid, UN 2201, is stored in insulated tanks at pressures ranging in North America from 18-22 bar (261-319 psi) at temperatures of -18 to -12°C and in Europe 20 bar to 25 bar (290 psi to 363 psi) at temperature of about – 20°C . Liquid nitrous oxide forms a mixture of extremely cold liquid and gas when discharged to atmospheric pressure. Skin contact with such liquid can cause severe frostbite.

5 HEALTH HAZARD AND TOXICITY INFORMATION

5.1 General

The health effects of nitrous oxide are mostly with regard to operators who are involved in transport, filling and handling of nitrous oxide. The effect of nitrous oxide as medicinal product is not considered.

5.1.1 *Short-term Exposure*

1. Nitrous oxide in the gaseous state is colourless and has a sweet odour. Elevated concentrations of this gas in the air can be reached quickly on loss of containment e.g. via leaks and venting.
2. The short term health effect is primarily the narcotic effect which includes dizziness, nausea, headache and loss of coordination. In addition, gaseous nitrous oxide under atmospheric conditions is 1.5 times heavier than air and so can be found in greater concentrations at low levels and therefore, if allowed to displace oxygen in a confined space, can also be an asphyxiation hazard.
3. Nitrous oxide liquid or cold vapour coming in contact with the skin or mouth can cause freezing or frostbite. If frostbite has occurred, obtain medical attention.
4. Do not rub the area, immerse in warm water 38°C to 41°C.

5.1.2 *Long-term Exposure*

1. Nitrous oxide has been associated with several side effects from long term exposure.
2. The most strongly substantiated effect is neuropathy.
3. Epidemiological studies also suggest feto toxic effects and higher incidents of spontaneous abortion in exposed personnel.

5.2 Toxicity Information

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned nitrous oxide a threshold limit value (TLV) of 50 ppm (90×10^{-6} g/dm^3) as a TWA for a normal 8 hour work day and a 40 hour work week [ACGIH 1994, p.28]. The NIOSH recommended exposure limit for nitrous oxide of 25-ppm parts of air (45×10^{-6} g/dm^3) for a duration of the exposure. [NIOSH 1992]

5.3 Control of Exposure to Nitrous Oxide Gas in the Workplace

Operator exposures (e.g. filling operators) to nitrous oxide gas should be controlled to acceptable levels (i.e. below the relevant OELs). Sources of nitrous oxide can include:

1. 'uncontained' filling equipment allowing some nitrous to be expelled before/after filling;
2. leaking equipment e.g. filling equipment;
3. venting empty cylinders to the open air instead of to a blow down manifold;
4. valves not closed sufficiently on 'empty' and full cylinders to ensure no leakage of product;
5. poorly positioned vents leading to re-entrainment of gas into the building

5.4 Antidote

Methylene Blue, Naloxone

5.5 Health Effects

5.5.1 *Signs and Symptoms*

Exposure to nitrous oxide can cause headache, dizziness, euphoria, excitation, depression and raised intracranial pressure as a result of hypoxia.

5.5.2 *Acute Toxicity*

The most significant hazard associated with this gas is inhalation of oxygen-deficient atmospheres and effects on the central nervous system. Symptoms of oxygen deficiency or central nervous system depression include respiratory difficulty, ringing in ears, headaches, dizziness, indigestion, and nausea. At high concentrations, unconsciousness or death may occur. Contact with cryogenic liquid or rapidly expanding gases may cause frostbite.

5.5.3 *Chronic Toxicity*

Prolonged or repeated overexposures to Nitrous Oxide has produced injury to the nervous system. Symptoms of such overexposure include numbness, tingling of the hands and legs, loss of feeling in the fingers, and muscular weakness. Exposure to Nitrous Oxide may be associated with an increase in spontaneous abortions in humans. Single, prolonged exposures to Nitrous Oxide have resulted in bone marrow damage and adverse effects on the blood. Refer to Section 11 (Toxicological Information) of this MSDS for additional information.

TARGET ORGANS: Respiratory system, central nervous system, blood system, reproductive system.

5.5.4 *Control of Exposure to Nitrous Oxide Gas in the Workplace* — Operator exposures (e.g. filling operators) to nitrous oxide gas should be controlled to acceptable levels (i.e. below the relevant OELs). Sources of nitrous oxide can include:

- 'uncontained' filling equipment allowing some nitrous to be expelled before/after filling;
- leaking equipment e.g. filling equipment;
- venting empty cylinders to the open air instead of to a blow down manifold;
- valves not closed sufficiently on 'empty' and full cylinders to ensure no leakage of product
- poorly positioned vents leading to re-entrainment of gas into the building

6 PERSONAL PROTECTIVE EQUIPMENT (PPE)

6.1 Availability and Use

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 Nitrous oxide, 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.

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 Equipment

6.2.1 *Eye and face Protection*

Chemical splash protection as per IS: 8520 category H-4. Use of goggles along with full face shield is recommended. Face shield should be of sufficient length to cover the neck portion.

6.2.2 *Head Protection*

Hard hats should be worn where there is danger of falling objects. If hard hats are not considered necessary, soft-brimmed hats or caps may be worn to give protection against liquid leaks and splashes.

6.2.3 *Foot and leg Protection*

Leather safety shoes with built-in steel toecaps are recommended for workers handling cylinders and cans of nitrous oxide. Alternately rubber gumboots must be used while handling phosphorus. Leather leg guard is recommended. Shoes should be thoroughly cleaned and ventilated after contamination (*see* IS: 10667).

6.2.4 *Body, Skin and Hand Protection*

Clothing made of leather, asbestos, rubber or other impervious materials may be worn to protect the body against the splashes. Leather or rubber gloves should be worn for hand protection. Fireproof overalls should be worn when operations involving phosphorus fires are encountered (*see* IS: 8519 and IS: 8807).

6.3 *Respiratory Equipment*

Maintain oxygen levels above 19.5 percent in the workplace and below the exposure limits listed in Section 2 (Composition and Information on Ingredients). Use supplied air respiratory protection if oxygen levels are below 19.5 percent or during emergency response to a release of Nitrous Oxide. If respiratory protection is required, follow the requirements of the Federal OSHA Respiratory Protection Standard (29 CFR 1910.134), or equivalent State standards.

7 STORAGE, HANDLING, LABELLING AND TRANSPORT

7.1 General

This is a liquefied, oxidizing gas, stored under pressure. Use piping and equipment adequately designed to withstand pressures to be encountered. Store and use with adequate ventilation at all times. Store away from flammable materials. Cylinders should be stored in dry, well-ventilated areas away from sources of heat. Compressed gases can present significant safety hazards. Store containers away from heavily trafficked areas and emergency exits. Post “No Smoking or Open Flames” signs in storage or use areas.

7.2 Storage

In general, to avoid industrial fires/ materials which are toxic as stored or which can decompose into toxic components due to contact with heat, moisture, acids, or acid fumes, should be stored in a cool, well-ventilated place, out of the direct rays of the sun, away from areas of high fire hazard, and should be periodically inspected and monitored.

1. Incompatible materials should be isolated from each other.
2. Fireproof if in building. Separated from reducing agents and combustible substances.
3. Store in metal cylinders /SRP: do not use aluminium at a temperature not exceeding 36°C in a special room free from inflammable materials. The whole cylinder should be painted blue; the name or the chemical symbol of the gas should be stencilled in paint on the shoulder of the cylinder & clearly & indelibly stamped on the cylinder valve.

7.2.1 *Stationary Tanks*

Stationary tanks are used in nitrous oxide production plants, filling plants and customer installations. This section refers to all types of these tanks.

7.2.1.1 *Storage vessels*

Type: 1) Insulated tanks
- Vacuum insulated
- Non Vacuum

2) Non Insulated high pressure

7.2.1.2 *Insulated tanks*

Insulated tanks are used for the storage of refrigerated liquid nitrous oxide at temperatures below –20 °C and corresponding vapour pressure in the range of 1.8 MPa to 2.5 MPa.

The typical maximum working pressure (MAWP) for nitrous oxide tanks ranges from 1.6 MPa to 2.5 MPa. The normal operating conditions are 1.8 MPa to 2.1 MPa) at corresponding temperatures of –16°C to –12°C. The minimum design metal temperature (MDMT) shall be less or equal to the minimum normal operating temperature. Newly constructed tanks should have an MDMT of –40°C or colder to better handle the low temperature upset conditions caused by loss of tank pressure.

7.2.1.3 *Types*

a. Vacuum insulated tanks — Tanks with the inner tank typically made from stainless steel or fine grain carbon steel and the outer tank from carbon steel. Vacuum insulated tanks have the lowest external heat input to the inner tank; and are therefore less susceptible to external heating caused by fire or ambient heat that could lead to a decomposition of the nitrous oxide.

b. Non-vacuum insulated tanks — Tanks with the inner tank typically made of low alloy carbon steel and the outer cladding made of steel or aluminium.

7.2.1.4 *Insulation material*

1. The insulation system shall be non-combustible or fire resistant, e.g. the material itself shall not continue to burn when the external flame is extinguished.
2. An insulation system made of polyurethane with cladding made of steel or aluminium is considered to be fire resistant.
3. If the insulation system of an existing tank has to be replaced, it should be rebuilt using a fire resistant insulation system (e.g. polyurethane with cladding) or non-combustible material such as glass wool, foam glass or Rockwool. A suitable vapour barrier is required to prevent the insulation from becoming saturated with condensed moisture.

7.2.1.5 *Non-insulated high pressure tanks*

Non-insulated high pressure tanks are typically made of carbon steel, for storage of liquefied nitrous oxide at ambient temperature with corresponding vapour pressure, for example in the range of 4.5 MPa to 6.0 MPa, corresponding to a temperature range of 13°C to 27°C. The high operating pressure of this tank type requires high-pressure filling pumps and sometimes the use of two pumps in series. This increases the hazard of heat production and subsequent decomposition. Furthermore in case of an external fire, the tank content can be heated up rapidly. For these reasons because of the increased potential of decomposition in such condition the use of non-insulated tanks shall be discouraged unless a risk assessment has been completed and mitigation has been provided.

7.2.1.6 *Vessel installation*

Safety requirements for all types of vessels:

i) The tank shall be installed on an engineered foundation that meets all local and national building codes.

ii) Support and foundation of the tanks is recommended to be non-combustible.

iii) Tanks should be installed outdoors. In the very rare cases where indoor installation is necessary, ventilation and access for filling shall be provided. Nitrous oxide or oxygen deficiency levels in the ambient air shall be monitored.

iv) Tanks shall be located away from any potential fire situation.

v) All parts of nitrous oxide tanks shall be bonded to ensure electrical continuity and earthed. The electrical potentials between the tank and the ground should be equalised during service.

vi) Some old nitrous oxide tanks (including old carbon dioxide tanks) were manufactured using course grain low alloy steels that have been shown to have low temperature impact properties.

7.3 Refrigeration Units

1. A mechanical refrigeration unit is typically installed on non-vacuum insulated tanks and on some vacuum insulated tanks.
2. The refrigeration unit is used to reduce the tank pressure by condensing vapour which prevents discharging nitrous oxide to the atmosphere.
3. Installations that fill Cylinders typically require a refrigeration unit sized to overcome the ambient heat input introduced by the filling process. The refrigeration evaporator coil is typically installed in the tank vapour space and shall have as few joints as possible and be all welded or brazed.
4. Mixing of hydrocarbon refrigerants and oils with nitrous oxide can lead to violent reaction within the refrigeration system. Therefore to avoid the risk of refrigeration coil leaks no mechanical fittings inside the tank on the refrigeration evaporator are allowed.
5. It is suggested that when older fluorocarbon refrigeration systems are repaired that they be converted to synthetic lubricants such as polyolester (POE) that have a higher flash point.
6. Refrigeration compressor failure or high pressure throughout the refrigerant circuit can be an indication of a nitrous oxide evaporator coil leak and should be thoroughly investigated.
7. No hot work (brazing) on the refrigeration system is allowed without first emptying and purging the container of nitrous oxide and purging with an inert gas.

7.4 Vaporizers and Heaters

Nitrous oxide is a liquefied gas which means that withdrawal of vapour or liquid from the tank will cause the remaining liquid to partially boil and auto-refrigerate. Continued product withdrawal will cause the pressure and temperature of the remaining liquid to decrease. The temperature of the tank shall not be allowed to decrease below the MDMT. Pressures building or direct to process vaporizers are generally required to provide sufficient external heat to maintain a safe operating pressure.

Vaporizer heat sources such as electric heating elements shall not be installed inside the tank because overheating can cause explosive decomposition of nitrous oxide.

A small ambient air heated pressure build-up coil can be sufficient to maintain the required pressure. In colder climates, an externally heated vaporizer could be required. Liquid is evaporated and the vapour re-introduced at the top of the stationary tank.

An external vaporizer is required in the withdrawal system at customer installations if nitrous oxide is to be used in the gaseous state.

If an external indirect heated vaporizer has to be used, then the heating shall be controlled to limit the temperature to a maximum of 150°C. Direct heating such as warm water, steam and warm air are safer and therefore recommended. Where electrical heating is used additional safeguards are required to ensure a maximum temperature limit of 150°C. Direct electric coils shall not be used.

A back pressure control valve (economizer) may be used to prevent tank from pressure increase, as sometimes the withdrawal rate is less than the boil-off rate.

7.5 Piping, Instrumentation, Valves

The tank shall have a contents pressure gauge and liquid level/weight indicator.

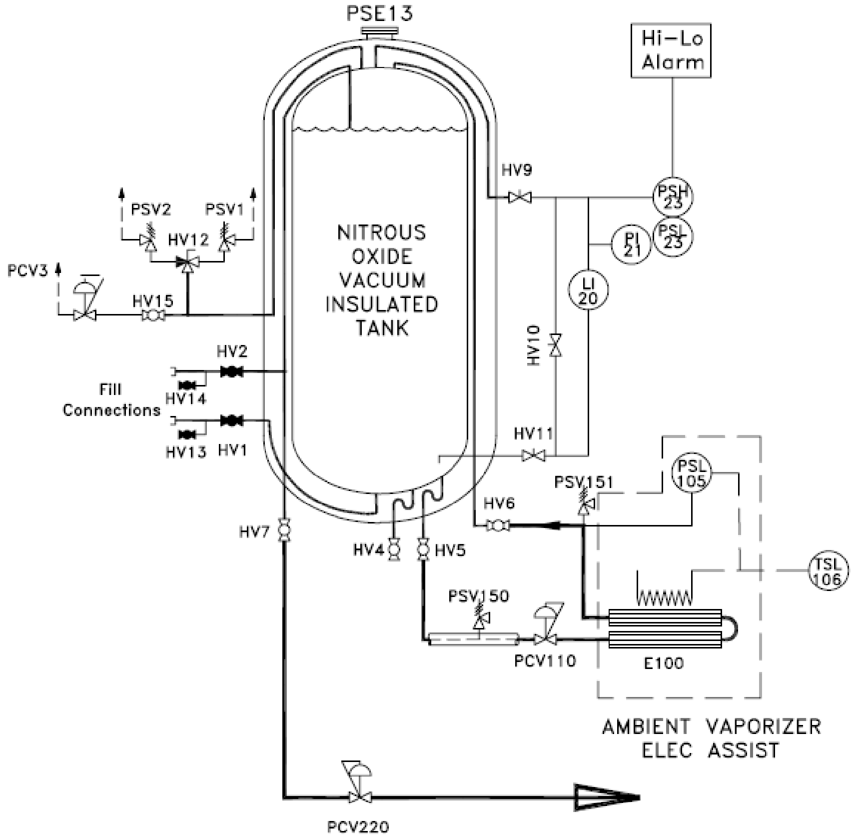
The piping and instrumentation shall enable the following functions:

Filling of liquid into the bottom of the tank is recommended. This would allow a potential decomposition starting at the pump to be quenched in the liquid phase.

Product withdrawal should be by bottom line or via dip tube or through a vapour line if used to maintain tank pressure.

i. Gas return to / from the top to accommodate two hose filling procedure with pressure compensation between stationary tank and transport tank.
ii. Level indicator (e.g. scale, load cell or differential pressure gauge). The admissible filling weight shall be marked. A dip tube intended to prevent a liquid full condition is an acceptable practice in lieu of marking the maximum filling weight. Typical liquid level indicators operate by measuring the differential pressure between the top and bottom of the container. In low ambient temperature conditions such gauges may require heat tracing to prevent re-condensing of the vapour in the sensing lines. Any heat tracing shall use inherently safe methods to prevent temperatures from exceeding 150 °C.
iii. Pressure gauge to monitor the tank pressure. It can be combined with an alarm function for high and low pressure.
iv. Maximum liquid level check by gas return line or full try cock depending upon tank design.
v. Precautions against overpressure as a result of overfilling. Procedures and / or equipment shall be installed after a risk assessment has been performed [13].

An example of a piping and instrumentation (P&I) diagram of a stationary nitrous oxide tank is provided in **Fig. 2**. The piping and instrumentation of nitrous oxide tanks may be different, depending on company standard and user’s demands.



VALVE LEGEND–LN2O TANK	
PSV 1 & 2	VALVE, SAFETY RELIEF
PCV3	VALVE, BACK PRESSURE CONTROL
PSE13	VACUUM SPACE RELIEF DEVICE
PSH 23, PSL 23	SWITCH, HI–LOW PRESSURE
LI 20	GAUGE, LIQUID LEVEL
PI 21	GAUGE, TANK PRESSURE
PCV 3	VALVE, BACK PRESSURE CONTROL
HV 1	VALVE, LIQUID FILL
HV 2	VALVE, VAPOR FILL
HV 3	VALVE, PRESSURE BUILD LIQUID SUPPLY
HV 4	VALVE, LIQUID USE
HV 5	VALVE, PRESSURE BUILD LIQUID USE
HV 6	VALVE, PRESSURE BUILD VAPOR RETURN
HV 7	VALVE, LIQUID USE
HV 9	VALVE, LEVEL GAUGE VAPOR (LP)
HV 10	VALVE, LEVEL GAUGE BYPASS
HV 11	VALVE, LEVEL GAUGE LIQUID (HP)
HV 12	VALVE, SELECTOR RELIEF VALVE
HV 13	VALVE, BLOWDOWN LIQUID FILL
HV 14	VALVE, BLOWDOWN VAPOR FILL
HV 15	VALVE, ISOLATION ECONOMIZER
E 100	VAPORIZER, PRESSURE BUILD
PCV 110	VALVE, VAPORIZER PRESSURE CONTROL
PSL105	SWITCH, VAPORIZER LOW PRESSURE
TSL 106	SWITCH, VAPORIZER LOW TEMPERATURE
PSV 150 & 151	VALVE, THERMAL SAFETY RELIEF
PCV220	VALVE, BACKPRESSURE CONTROL, VAPOR

FIG. 2 P & I DIAGRAM OF A NITROUS OXIDE VACUUM INSULATED STATIONARY TANK

7.6 Handling

Carbon dioxide equipment which has similar temperature and pressure requirements to nitrous oxide, shall not be used for nitrous oxide service UNLESS a conversion procedure has been followed for the change of service, for gas cylinders see ISO 11621 [14].

The procedure shall meet the relevant requirements of this document or any other applicable standard or regulation. Care shall be taken with regard to design, material, insulation, cleanliness, lubricants, seals, and avoiding high temperature.

Unlike carbon dioxide, nitrous oxide shall not be used as a pneumatic energy source to actuate pneumatic cylinders, valve actuators or as an inert gas.

7.6.1 *Pressure Relief Valves*

Each stationary nitrous oxide bulk tank shall have two active safety relief devices sized and designed to meet all local and national regulations. Typically there are two active spring loaded relief valves or one active spring loaded relief valve plus a pressure control valve. They shall conform to regulations and standards e.g. [15, 16].

It is recommended that a 3-way selector valve, sized for the tank operating conditions be provided for the safety relief device(s) to allow servicing and maintenance of the device without requiring the depressurization of the container.

Rupture discs are not usually recommended for use in nitrous oxide tank service. This is because they will not re-seat after the tank pressure has decreased and it will cause the remaining liquid to boil violently and auto-refrigerate to -88 °C. This situation would be critical if the inner vessel is made of carbon steel which would require specific repressurization procedures that have been risk evaluated by a knowledgeable nitrous oxide technician...

7.6.2 *Admissible Filling Degree / Filling Ratio*

The admissible filling degree or filling ratio shall be verified for each stationary nitrous oxide tank as mentioned in the given **Fig. 3**.

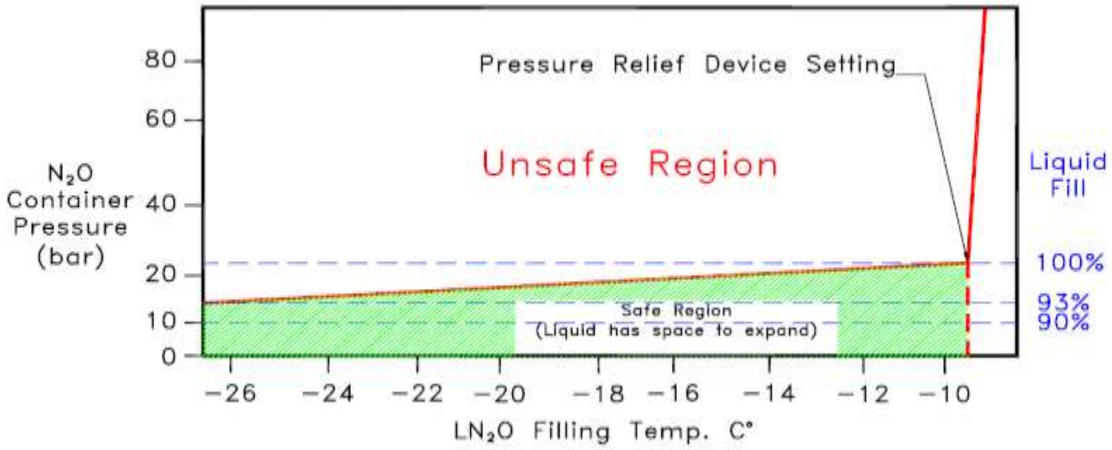


FIG. 3 SAFE FILLING VOLUMES FOR 22 BAR – NITROUS OXIDE STORAGE TANKS

Insulated tanks should be filled to a level that prevents them from reaching a liquid full condition before the vapour pressure is reaching the pressure relief device setting. When liquid nitrous oxide is stored in a tank and there is no product withdrawal, heat leak causes the temperature and pressure to rise and the liquid to expand. If the tank becomes liquid full, the hydrostatic pressure rise can cause its catastrophic failure.

The safe filling degree depends on the temperature of the liquid being transferred into the tank and on the pressure at which the pressure relief device is set to open. The colder the liquid, the more vapour space is required for liquid expansion. According to some national regulations and practical experiences the filling degree of insulated tanks shall not exceed 95 percent.

The maximum filling level can be easily controlled by the gas return line or full try cock depending upon tank design.

7.6.3 *Filling of Stationary Low Pressure Tanks*

When stationary tanks are filled by a pump, for safety reasons, the two-hose procedure should be applied in order to minimize pressure and mechanical stress. Filling shall be made through the bottom fill line. After the distribution supply system has been evaluated and has been determined that there is no possibility of back contamination from the gas phase to the transport tank. Tanks should not be filled by pump through the top equalizing line or any other line to the top. If filling is performed by pressure difference only without the use of a pump, the tank may be filled through the top line.

The differential pressure between the transport tank and the stationary tank shall be maintained at a level normally not exceeding 3 bar diff (44 psid) to ensure a smooth pump operation and to prevent creating any hot spots. Pump discharge pressure or flow shall be monitored to ensure that the pump is operated within the foreseeable performance conditions. The pressure and the level indicator of the stationary tank shall be monitored to avoid overfilling. The full try cock or vapour return shall be opened at the end of filling to verify that the tank is not overfilled.

7.6.4 *Product Return*

If the tank needs to be emptied e.g. for maintenance, it could be necessary to return the product to the supplier.

This can only be performed under supervision of a qualified operator, observing specific procedure. Precautions shall be taken to avoid temperatures lower than the design temperature of the tank (*see* **6.1**). Truck pumps should not be used for emptying stationary tanks. If no suitable pump is available, pressure transfer shall be used.

7.7 Transport

7.7.1 *Supply Equipment*

7.7.1.1 *Cylinders*

It is recommended to dedicate a stock of cylinders to nitrous oxide service. Suitable materials for nitrous oxide cylinders are carbon steel, chrome molybdenum steel, aluminium alloys, and stainless steel, see [7]. Cylinders made of non-metallic materials e.g. full composite (type 4), shall not be used.

Valve outlet connections shall be in accordance with national standards, where available and applicable, to avoid mix up of connections. The design and testing of valves shall follow the standards [39] and valve materials shall meet the requirements in [7, 9].

Dip tubes made of non-metallic materials shall not be used because of the risk of static electricity build up. Where metallic dip tubes are used electrical continuity shall be ensured for all parts of the cylinder and its accessories. It shall also be ensured no risk of separation of the dip tube from the valve during service. For these purposes it is recommended no later than the first retest to weld or to solder the connection between the dip tube and the cylinder valve. The valve shall be mounted such that electrical continuity is guaranteed.

Cylinders should be filled by weight to ensure accurate fill level. To avoid accidental overpressure in the cylinder by overfilling, some regional regulations require valves be fitted with a bursting disk; where this is not the case the use of bursting disk is recommended. The set pressure of the bursting disk is established by local regulations but shall not exceed, including all tolerances, 1.15 times the test pressure of the gas cylinder. Under no circumstances shall disks with fusible metal backing devices be used because they do not protect against cylinder overfilling.

7.7.1.2 *Bundles*

Where bundles are used for transporting and storing nitrous oxide the individual cylinders in the bundle are usually manifolded together and terminate with one connection point for filling and discharge. Bundles are fitted with a main isolation valve. It is recommended that isolation valves are not fitted on each individual cylinder in a bundle to avoid overfilling of individual cylinders.

Where the cylinders are equipped with individual valves each cylinder shall be filled individually.

Where non-closable fittings are used on each cylinder in the bundle only one bursting disc may be used to protect the bundle. If cylinders are equipped with individual valves, these valves and the main valve shall be equipped with a bursting disk.

The bundle shall be designed, manufactured and tested according to any applicable regulatory requirements and where appropriate a design code, for example ISO 10961 [17].

Pipes made of metallic materials should be used for the manifold. Connections within the manifold should preferably be welded or soldered.

7.7.1.3 *Transport tanks*

Insulated transport tanks are used for the transport of nitrous oxide refrigerated liquid. They shall fulfil the requirements of local transport regulations.

Requirements to build such transport tanks are specified for vacuum insulated transport tanks e.g. in ISO 20421 [18] and for non-vacuum insulated transport tanks e.g. in [19].

Transport tank Insulation - Vacuum insulated transport tanks are acceptable for use. If non-vacuum insulated transport tanks are used, the insulation should be “fire resistant”. Where there are connections that could leak, e.g. manhole-flange, pipe flanges, screwed pipe, they shall be separated from any non-fire resistant insulation material. The insulation material shall be completely covered by a protective metal cladding. Suitable materials are aluminium, fine grain carbon steel and stainless steel for the tank including the baffles and accessories. Transport tanks manufactured after 1975 shall have a MDMT of –40 °C or lower and are commonly designed for a maximum working pressure of 24 bar (348 psi).

Material that will come in contact with the transported product should be approved for nitrous oxide. If no data are available on nitrous oxide compatibility, oxygen compatibility rules should be applied, e.g. according to ISO 21010.

7.7.2 *Piping and Instrumentation*

Pipes, valves, flanges, couplings etc. shall be metallic.

The piping and instrumentation shall enable the following functions:

- Filling of liquid into the bottom of the transport tank. This would allow a potential decomposition reaction starting at the pump to be quenched in the liquid phase.
- Product discharge through bottom line.
- Gas return to / from the top for two hose filling procedure with pressure compensation between transport and stationary tank. A spray line in the top shall only be used during the initial cooling of a warm tank with product transfer from differential pressure (without the use of a pump).
- At least one “full try cock” or vapour return line in order to check the filling level limit.
- Level indicator to monitor the tank contents as an option.
- Pressure gauge to monitor the tank pressure.
- Pressure gauge to monitor the pump discharge pressure as an option.
- Connections to allow sampling of liquid phase and as an option gas phase.

7.7.3 *Grounding*

All parts of the transport tank shall be bonded to ensure electrical continuity. This can be achieved by either an earth cable or a conductive hose.

7.7.4 *Pump*

For transfer of refrigerated liquid nitrous oxide the following pump types are currently used:

- Gear pumps.
- Sliding vane pumps.
- Centrifugal pumps.

Any pump should have at least a nominal pressure that is equal to the maximum allowable working pressure of the tank. The pump discharge pressure should be in the range of 5 bar diff (73 psid).

7.8 Labelling

Each container (including tank cars) should carry an identifying label or stencil. Manufacturers name with any label warnings required by regulations or ordinances form part of the label or placard

Signal: Danger
GHS Hazard Statements
H270: May cause or intensify fire; oxidizer [Danger Oxidizing gases]
H280: Contains gas under pressure; may explode if heated [Warning Gases under pressure]
H336: May cause drowsiness or dizziness [Warning Specific target organ toxicity, single exposure; Narcotic effects]
H360: May damage fertility or the unborn child [Danger Reproductive toxicity]
H372: Causes damage to organs through prolonged or repeated exposure [Danger Specific target organ toxicity, repeated exposure]

8 SPILLAGE, LEAKAGE AND WASTE DISPOSAL

8.1 General

8.2 Leak/ Spill in confined space or tanks

Isolate the leak without putting oneself at risk. If possible, orientate leaking containers such that the gas escapes rather than the liquid.

Isolate the area affected by the spill or leak for at least 25 to 50 m in all directions, keep unauthorized persons away and stay upwind. In the event of large spills consider initial downwind evacuation for at least 500 m.

Try to prevent the leaking gas / liquid from reaching low lying areas and try to prevent entry into drains, sewers, basements or confined spaces.

Ventilate and check confined spaces and rooms before entering. The check shall be conducted by competent personnel who are trained to detect potential atmospheric hazards.

Entry into a confined space requires the utmost caution and confined space entry regulatory requirements and procedures shall be followed.

In the event of large nitrous oxide spills, use water sprays to disperse vapours or divert vapour cloud drift. Do not direct water at the spill or at the source of the leak. Avoid water contact with pressure relief valves, as icing can occur.

Do not touch or walk through spilled liquid.

Try to prevent contact of cold nitrous oxide (liquid or gas) with materials, which are sensitive to cold, such as rubber or plastics.

Never use any absorbents, especially sawdust or other absorbent materials on liquid nitrous oxide spills.

Control measures should be in place to prevent nitrous oxide leaking or being vented into the workplace. If nitrous oxide is stored or filled in insufficiently ventilated rooms a gas monitoring system should be installed in order to monitor the room concentration of nitrous oxide.

Nitrous oxide has a multitude of beneficial applications such as an anaesthetic or as a food propellant that ultimately improve the quality of people's lives. When misused, abused, or handled improperly it can harm people, and potentially cause death.

8.3 Leak/Spill during Transport

8.3.1 *Minor Leaks*

In the event of minor leaks, whenever possible, and if no hazards are involved, check and close any valves to isolate the point of leakage.

If there seems to be no damage to nitrous oxide tank or pipework that could develop into more serious failures, report to the company and, unless instructed otherwise, drive transport tank to the nearest company premises. Check tank pressure regularly during the journey.

If leakage appears to be increasing, stop in a suitable place away from built-up areas, and proceed as detailed below for major leaks.

8.3.2 *Major Leaks*

If possible, In the event of major leaks drive to a suitable place well away from built-up areas, major roads, railways, tunnels etc.

The object of this manoeuvre is to ensure that the prevailing wind carries any nitrous oxide gas further away, allowing it to disperse without danger.

In the event that a large release can come in contact with the tractor engine, pull to the side of the road and immediately shutoff the engine and exit the vehicle keeping all personnel away until the emergency services arrives

Notify the police and report the situation to the company. Inform emergency service about the nature of the leak.

Stay in attendance throughout any discharge of nitrous oxide. Warn others of danger, ensure no one in the vicinity is working in cellars, basements or trenches and consider initial downwind evacuation for at least 500 m.

Keep material out of water sources and sewers. Attempt to stop leak if without undue personnel hazar d. Use water spray to knock-down vapours.

8.4 Waste disposal

8.4.1 *Environmental Issues*

N_2O gives rise to NO on reaction with O atoms and this NO reacts with ozone. As a result it is the main naturally occurring regulatory of stratospheric ozone. It is a major green house gas and air pollutant. It has 265-310 times more impact per uniy mass than CO_2.

The emission of nitrous oxide from commercial production is estimated to be approximately 1 percent of total emissions. In some parts of the world the releases of nitrous oxide to the atmosphere are restricted by regulation.

8.4.2 Prevention of Contamination

Hoses and filling connections or other pieces of equipment that are not continually connected, shall be protected against the ingress of dirt and moisture by caps and / or nuts, when not in use.

9 FIRE PREVENTION AND FIRE FIGHTING

9.1 Fire Prevention

Temperatures above 150°C shall be avoided by all practical means, to reduce the likelihood of an explosive decomposition of the nitrous oxide.

Electric heating devices in direct contact with nitrous oxide are prohibited. Only indirect electric heaters are allowed with sufficient safety controls to prevent exceeding 150°C are allowed. Water bath heaters, low pressure steam, or other temperature self-limiting devices are recommended;

All pumps, compressors, or other equipment with rotating or sliding components shall be protected by automatic controls against loss of prime and excessive operating temperatures. Pumps shall not be allowed to operate with no flow or loss of prime. A numbers of serious accidents have been attributed to overheated equipment.

Best practice for liquid transfer pumps is to install the pump with a flooded suction line and a liquid return connection to help quench a decomposition reaction. Strainers should be installed on the suction and discharge of liquid pumps to provide a heat sink that assists in quenching a decomposition flame front.

Hot work shall not be performed on any equipment containing nitrous oxide. All equipment shall be purged with an inert gas or air prior to hot work. Be aware that thermal conduction from hot work areas can migrate to piping containing nitrous oxide and lead to an explosion or fire.

Medical installations could require to be purged with medically certified gases per some local regulations during any hot work to prevent the formation of oxides.

Hot work should not be performed within 1 m of a section of piping that still contains nitrous oxide. Hot work close to a nitrous oxide installation can also require removal of nitrous oxide and purging, depending on the risks and type of work. Such work shall require a work permit issued in accordance with all regulatory and supplier requirements [21];

Heat from an open flame or a hot air gun shall not be applied to any part of a nitrous oxide installation de-icing, releasing threaded couplings, or for increasing pressure in cylinders. However, hot air guns are acceptable when systems are at atmospheric pressure; use of water as a warming agent is acceptable

Thermal mass flow meters shall not be used due to the internal heater element, unless a risk assessment is carried out to ensure that there is no risk of thermal decomposition. One application is the use of mass flow meters to measure any emissions to atmosphere through vents.

Nitrous oxide installations shall be earthed in accordance with local regulatory requirements before use in order to dissipate any electrostatic charges.

Strainers or filters shall be located in order to avoid migration of particles within specific devices (e.g., compressor, pump).

Ball valves and other quick opening valves should be opened slowly. The high temperature caused by adiabatic compression can provide an ignition source that could lead to the rapid decomposition of nitrous oxide.

9.2 Fire Fighting

9.3.1 *Fires Involving Combustible Materials with Nitrous Oxide*

Nitrous oxide can strongly support the combustion of materials such as wood, paper, oil, clothing, etc.

In dealing with any fire situation these materials shall be kept at a safe distance from the fire.

Materials burning in nitrous oxide can produce irritating and toxic gases. Emergency responders should use respiratory protection while extinguishing fires.

Use a suitable extinguishing agent for the type of fire in question such as dry chemical, carbon dioxide or water spray.

9.3.2 *Fire in the area of Nitrous Oxide Tanks*

Tanks and pressure receptacles that are exposed to fire or extreme heat can rupture due to increase of temperature and pressure. In addition, nitrous oxide tanks and pressure receptacles can be subject to explosive decomposition. This can occur in spite of pressure relief equipment. Fragments of metal will be ejected through the air.

Transport tanks and pressure receptacles should be removed from the immediate fire area, if this can be achieved without risk to personnel. If this is not possible, the concerned equipment should be immediately cooled with water jets directed from a safe position, e. g. from behind heavy machinery or solid wall.

If fire involves any tanks or pressure receptacles it shall be fought from a safe position or by using unmanned water monitors. Water-cooling of the equipment should be continued after the fire has been extinguished. Retreat immediately if the pressure relief equipment emits a hissing sound or discoloration of the tank or pressure receptacle is observed. Consider initial evacuation around an 800 m perimeter.

9.3.3 *Fire During Transport*

If the transport tank is involved in a fire, notify the police and emergency service and report the situation to the company.

The company should assist the fire brigade by providing information about the hazards and properties of nitrous oxide.

Caution should be given for explosive decomposition hazards

Water should not be used as it reacts with water and becomes Dangerously explosive. In case of fire or explosion all the affected containers should be cooled with flooding quantities of water from far off distance. (AAR, 1999)

10 TRAINING

Plant personnel should be restricted to fight only minor fires if trained and equipped for such occurrences. Professional fire fighters are trained to deal with large fires. Evacuation of plant is recommended if there is a fire in the nitrous oxide area.

Do not weld, braze, or strike an arc on any pipe, cylinder, or vessel that contains nitrous oxide.

The use of quick acting valves such as ball valves should be evaluated by a risk assessment.

Users and operators handling nitrous oxide should be trained to open and/or close valves gradually.

Heat generated by adiabatic compression at elevated pressures can and has initiated nitrous oxide decomposition.

11 FIRST AID- HEALTH MANAGEMENT FIRST AID AND MEDICAL TREATMENT

11.1 In the event of inhalation of nitrous oxide

Move the victim to fresh air, call the emergency medical services. Apply artificial respiration if the victim is not breathing; administer oxygen if difficulty is experienced with breathing.

11.2 In the event of contact with Liquid Nitrous Oxide

Remove and isolate contaminated clothing and shoes. Clothing frozen to the skin should be thawed before being removed. Thaw the frosted parts with lukewarm water. Spray with water for at least 15 min, apply a sterile dressing, keep victim warm and calm and obtain medical assistance.

Ensure that medical personnel are aware of the product involved and take precautions to protect themselves.

11.3 Ingestion of Nitrous Oxide

Ingestion is not considered a potential route of exposure.

12 ADDITIONAL INFORMATION

12.1 Equipment and Procedures

12.1.1 *Principles*

The equipment used to handle nitrous oxide shall be designed, constructed and tested in accordance with the regulatory requirements in the country in which the equipment is operated. The equipment shall be designed to withstand the maximum pressures and temperatures to which it is to be operated and also to minimise the release of nitrous oxide.

Because of the properties and hazards of nitrous oxide consideration shall be given to avoid combustible materials and any uncontrolled heat input.

General rules described apply to nitrous oxide systems where the pressure is below 72 bar (1045 psi)/(36.45°C). Above this pressure, i.e. in the supercritical state of nitrous oxide, rules defined for pure oxygen concerning material compatibility, equipment selection should be considered for nitrous oxide as well. The oxygen rules are also applicable to nitrous oxide / oxygen mixtures irrespective of the partial pressure or percentage of nitrous oxide is.

12.1.2 *Valves*

Materials for high pressure nitrous oxide valves such as cylinder valves shall be selected according to [18, 20]. Commonly used metals are brass, copper alloys, carbon steel. Acceptable non-metallic materials are the plastics PTFE, PCTFE, polyamides and the elastomer silicon rubber.

Valves for refrigerated liquefied nitrous oxide shall meet the requirements regarding design, testing and marking for the intended service. Metallic and non-metallic materials for such valves shall have passed a test for oxygen compatibility according to [20]. Ball valves used for liquefied nitrous oxide are recommended to be bored or otherwise designed for pressure relief towards the tank to prevent trapping liquid inside the ball.

12.1.3 *Filters*

Filters or strainers shall be designed considering the oxidizing properties of nitrous oxide. Mesh filters or strainers made from high nickel alloys such as nickel 200 alloys or high copper alloys such as brass are preferred due to increased resistance to oxidizer fires. No glue or similar combustible material shall come into contact with nitrous oxide at pressure greater than 10 bar (145 psi).

Liquid nitrous oxide should be filtered as fine as possible. Hole size of the filter is a compromise between allowable pressure drop, space available and acceptable thermal mass of the filter body [23].

Gaseous nitrous oxide should be filtered using mesh sizes between 30 and 100 corresponding approximately to a 500 to 150 micron particle size capture [15].

12.1.4 *Cleaning of Installation*

Any equipment and installation designed for nitrous oxide service shall be cleaned for oxygen service according to [24, 25]. Where it is necessary to change the product service of equipment from any gas to nitrous oxide, same rules apply for cleaning. Pressure receptacles which are to be changed to nitrous oxide service shall be cleaned using an appropriate procedure. For cylinders see [14] and for transport tanks *see* [26].

The surfaces that come into contact with nitrous oxide shall be cleaned to remove all combustible particles and oil and grease that could have been introduced into the system during its construction, fabrication or maintenance. The equipment shall be cleaned, as for oxygen service, using detergents or suitable cleaning agents that are free from non-metallic or metallic particles.

The maximum quantities of foreign matter (oil, grease, organic materials) in the installation shall not exceed 0.5 g/m^2. Visible particles, fibres or drops of water shall not be accepted [24].

12.1.5 *Restriction of Flow Velocity*

Nitrous oxide flow could cause localized heating of a material by particle impact or flow friction, particularly in areas with narrow passages. This heat can initiate a local decomposition / combustion if the decomposition temperature of the material in contact with nitrous oxide is reached. The nitrous oxide velocity should therefore be limited to avoid this temperature being achieved.

When designing or modifying an installation, a conservative guide would be to use the velocity limits which are defined for oxygen [15],

12.1.6 *Operating Procedures*

As with any operation associated with a hazardous substance, written operating procedures shall be prepared. Operators shall be trained regarding these procedures.

Management shall ensure operators understand that the equipment has to be operated within its design parameters, so as not to cause a hazard to personnel or damage to the equipment or environment.

Included in the procedures shall be a statement to indicate that no part of the installation shall be heated higher than the normal operating temperature.

12.1.7 *Maintenance Procedures*

Nitrous oxide equipment shall be maintained by qualified and trained personnel in a routine, controlled and safe manner following written procedures.

Any non-routine maintenance work shall be subject to a work permit procedure [21].

Modifications to a nitrous oxide installation shall not be made without a risk assessment [27].

Particular consideration shall be given to ensuring that the integrity of the cleanliness of the system is maintained and that spare parts and lubricants that come in contact with nitrous oxide are compatible with nitrous oxide.

Pressure equipment shall be depressurised prior to any maintenance or repair (if welding or other hot work is to be performed the system shall be purged with air or inert gas).

12.2 Security

Security measures should be implemented to restrict access to nitrous oxide by authorized personnel only.

A policy for the sale of nitrous oxide shall be in place. It shall be ensured by a thorough review before the purchase being approved and the delivery being made that the customer has a valid reason to purchase nitrous oxide and that the tracking records for nitrous oxide shipments shall be maintained.

12.2.1 *Isolation from Flammable Gases*

To ensure that there is no hazard of inadvertent mixing of nitrous oxide with flammable gases or liquids, nitrous oxide equipment and pressure containers shall be dedicated to nitrous oxide service.

Where nitrous oxide has to be mixed with other gases, precautions shall be taken to ensure that no flammable gas is unintentionally mixed with nitrous oxide, *see* [30]. Mixtures of nitrous oxide with flammable gases shall only be produced if the concentration lies outside the explosion limits.

Mixing of nitrous oxide with self-igniting gases such as silane shall be prevented under all circumstances, since immediate ignition and explosion can occur.

NOTE

1 bar = 10^5 Pa
1°C + 273.15 = 274.15 K
1 psi = 6894.76 Pa

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11. ISO 21009/1-2Cryogenic vessels – Static vacuum insulated vessels – Design, fabrication, inspection and tests / Operational requirements
12. AIGA 030/13 Storage of cryogenic air gases at user's premises
13. AIGA 054/08 Prevention of excessive pressure during filling of cryogenic vessels
14. ISO 11621 Gas cylinders - Procedures for change of gas service
15. AIGA 021/12 Oxygen pipeline and pipeline systems
16. ISO 21013-1 Cryogenic vessels – Pressure relief accessories for cryogenic service. Part 1: Reclosing pressure relief valves [40] ISO 10961 Gas cylinders. Cylinder bundles – Design, construction and testing
17. ISO 10961 Gas cylinders. Cylinder bundles – Design, construction and testing
18. ISO 20421/1-2Cryogenic vessels – Large transportable vacuum insulated vessels – Fundamental requirements / Design, fabrication, inspection and testing / Operational requirements
19. EN 14398/1-3 Cryogenic vessels – Large transportable non-vacuum insulated vessels – Fundamental requirements / Design, fabrication, inspection and testing / Operational requirements
20. ISO 21010 Cryogenic vessels – Gas / materials compatibility
21. AIGA 011/04 Work permit systems
22. ISO 21011 Cryogenic vessels – Valves for cryogenic service

23. AIGA 048/12 Reciprocating cryogenic pumps & pump installation
24. AIGA 012/04 Cleaning of equipment for oxygen service
25. ISO 23208 Cryogenic vessels – Cleanliness for cryogenic service
26. EIGA Doc. 87 Conversion of cryogenic transport tanks to oxygen service
27. AIGA 010/04 Management of change
28. AIGA 055/08 Installation guide for stationary, electrical-motor driven, centrifugal liquid oxygen pumps
29. ISO 24490 Cryogenic vessels – Pumps for cryogenic service
30. AIGA 047/08 Safe preparation of gas mixtures