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DRAFT BELIZE STANDARD
SPECIFICATION FOR NITROUS OXIDE

This is a Draft and should not be regarded or used as a Belize Standard.

Last date for comments: TBD

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DRAFT
BELIZE STANDARD SPECIFICATION FOR AIR

Committee Representation

The preparation of this standard for the Standards Advisory Council established under the Standards Act 1992 was carried out under the supervision of the Belize Bureau of Standards' Medical and Industrial Gases Technical Committee, which at the time comprised the following members:

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BELIZE STANDARD SPECIFICATION FOR AIR

0 FOREWORD

0.1 This standard provides a description of nitrous oxide characteristics, safety, storage and handling practices, when it is used mainly for medical, food packaging and electronic industries applications.

0.2 In preparing this draft, assistance was received from the following documents:

a) CGA G-8.2 - Commodity Specification for Nitrous Oxide
b) CGA G-8.3 - Safe Practices for Storage and Handling of Nitrous Oxide
c) CGA SB-6 - Nitrous Oxide Security and Control
d) CGA G-8.5 - Standard for nitrous oxide security and control
e) USP / NF 29 - United States Pharmacopeia / Nitrous Oxide
f) 49 CFR Parts 100-180
g) BZS 1: Part 8 - BZS 1: Part 8 Belize Standard Specification for Labelling Part 8: Labelling and Marking of Medical Gas Cylinders
h) CGA V-1 - Standard for CompressedGas Cylinder Valve Outlet and Inlet Connections
i) ISO 11114-2 - Gas cylinders – Compatibility of cylinder and valve materials with gas contents – Part 2: Non-metallic materials
j) EIGA SI 02 - Handling of gas cylinders during and after exposure to heat or fire
k) CGA P-52 - Security Standard for Qualifying Customers Purchasing Compressed Gases
l) ISO 10961 - Gas cylinders—Cylinder bundles—Design, manufacture, testing and inspection.
m) CGA S-1.1 - Pressure Relief Device Standards–Part 1–Cylinders for Compressed Gases
n) CGA P-50 - Standard for site security

1 SCOPE

1.1 This standard specifies minimum requirements for describes the specification requirements for nitrous oxide manufactured by various processes.

1.2 It provides information regarding nitrous oxide properties, hazards and safe handling practices.

1.3 It addresses the safe use in the industrial and medical gases industry for the design, engineering, construction, and operation of nitrous oxide, storage, and supply installations.

1.4 It is intended for nitrous oxide users, manufacturers and distributors.

1.5 It also provides recommendations for nitrous oxide security, in order to prevent theft and abuse.

2 NORMATIVE REFERENCES

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

a) BZS 1: Part 8 - Belize Standard Specification for Labelling Part 8: Labelling and Marking of Medical Gas Cylinders

b) CGA G-8.2 - Commodity Specification for Nitrous Oxide

c) CGA G-8.3 - Safe Practices for Storage and Handling of Nitrous Oxide

d) CGA SB-6 - Nitrous Oxide Security and Control

e) CGA V-1 - Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections

f) CGA G-8.5 - Standard for nitrous oxide security and control

g) CGA P-52 - Security Standard for Qualifying Customers Purchasing Compressed Gases

h) CGA S-1.1 - Pressure Relief Device Standards - Part 1 - Cylinders for Compressed Gases

i) CGA P-50 - Standard for site security

j) USP / NF 29 - United States Pharmacopeia / Nitrous Oxide

k) ISO 11114-2 - Gas cylinders - Compatibility of cylinder and valve materials with gas contents - Part 2: Non-metallic materials

l) ISO 10961 - Gas cylinders - Cylinder bundles - Design, manufacture, testing and inspection.

m) EIGA SI 02 - Handling of gas cylinders during and after exposure to heat or fire

3 DEFINITIONS

For the purpose of this standard, the following definitions shall apply.

3.1 **Authorized person** means a 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)** means an assembly of cylinders that are fastened together and are interconnected by a manifold and transported as aunit.

3.3 **Container** means portable compressed gas cylinders and liquid containers.

3.4 **Cryogenic receptacle** means a transportable thermally insulated pressure receptacle for refrigerated liquid gas of a capacity of not more than 264 gal (1000 L).

3.6 **Cylinder** means a transportable pressure receptacle of a water capacity not exceeding 40 gal (150 L).

3.7 **Decomposition** means 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, energy inputs, presence of catalyzer, or impurities.

3.8 **Filling degree** means percentage of the volume of liquefied gas to the volume of water at 59 °F (15°C) that would completely fill a pressure receptacle or tank.

3.9 **Filling ratio** means ratio of the mass of gas to the mass of water at 59 °F (15°C) that would completely fill a pressure receptacle or tank.

3.10 **Knowledgeable nitrous oxide technician** means a person by reason of education, training, and experience that 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.

3.11 **Liquefied gas** means gas that when packaged under pressure for carriage is partially liquid at temperatures above –58 °F (–50 °C).

3.12 **Lot** means an amount of a product produced during a period of time indicated by a specific code or some other unique identifying characteristic.

3.13 **Maximum allowable working pressure (MAWP)** means the maximum effective gauge pressure permissible at the top of the shell of a loaded tank in its operating position including the highest effective pressure during filling and discharge.

3.14 **Minimum design metal temperature (MDMT)** means the lowest temperature at which a pressure receptacle is designed to safely operate at maximum allowable working pressure (MAWP).

3.15 **Oxypotential** means a dimensionless number that indicates the oxidizing power of a gas compared to pure oxygen. The oxypotential value of 100% oxygen is 1.0 and air is 0.21.

3.16 **Pressure** means psi (bar or kPa) which shall indicate gauge pressure unless otherwise noted (i.e., psia [bara or kPa, abs] for absolute pressure and psid [bar, dif or kPa, dif] for differential pressure).

3.17 **Pressure receptacle** means a collective term that includes cryogenic receptacles, cylinders, and bundles.

3.18 **Refrigerated liquid gas** means gas that when packaged for carriage is made partially liquid because of its low temperature.

3.19 **Stationary tank** means 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.

3.20 **Tank** means a collective term that includes stationary tanks and transport tanks.

3.21 **Transport tank** means a transportable thermally insulated tank for refrigerated liquid gas having a capacity of more than 450 L (118 gal).

4 NITROUS OXIDE PROPERTIES AND HAZARDS

4.1 Physical Properties and Hazards

4.1.1 Specific hazards

Personnel handling nitrous oxide shall be trained in the hazards associated with this product. There are several conditions in which danger to personnel and equipment can exist. The following subsections describe these conditions and offers procedures and guidelines to prevent dangerous conditions from developing.

4.1.1.1 Low temperature effects on materials

a) The low temperature effect of nitrous oxide liquid and vapor on the materials in the system can create a hazard. At atmospheric pressure, the temperature of liquid nitrous oxide is –127 °F (–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.

b) Piping systems subject to operating temperatures less than ambient can contract. Allowances shall be made in piping and support systems to compensate for these changes in dimensions. Copper tubing, which is commonly used, shrinks approximately 1 in per 100 ft for every 100 °F (2.5 cm per 30.5 m for every 55.6 °C) reduction in temperature.

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

4.1.1.2 Trapped liquid

Liquid nitrous oxide that is forced to occupy a fixed volume (such as between two closed valves or positive shutoff points)

increases in pressure as it warms and expands. As long as there is a vapor space within the volume where the liquid is trapped, the pressure increases approximately 5 psi per °F (62 kPa per °C). When the volume becomes liquid full, the hydrostatic pressure increases at a rate of 850 psi per °F (10 550 kPa per °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. For this reason, a pressure relief device (PRD) shall be installed between positive shutoff devices.

4.1.1.3 Personnel overexposure

a) If sufficient amounts of nitrous oxide are released into the work environment via leaks or venting, personnel exposure levels can exceed occupational exposure limits (OELs) and present a potential risk to health.

b) 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.

c) Nitrous oxide exposure levels shall be controlled so that the health and safety risks to personnel are minimized to acceptable levels, i.e., less than the relevant OELs.

d) Nitrous oxide in the gaseous state is colorless and has a sweet odor. Ventilation systems, if required, shall be designed to exhaust from the lowest level and allow make-up air to enter at a higher point.

e) Liquid nitrous oxide forms a mixture of extremely cold liquid and gas when discharged to atmospheric pressure. Nitrous oxide liquid, or cold vapor, that comes into contact with the skin or mouth can cause freezing or severe frostbite. If frostbite occurs, seek medical attention. Do not rub the area. Immerse in warm water (100 °F to 105 °F [38 °C to 41 °C]).

f) Liquefied nitrous oxide, UN 1070, is handled in cylinders at a pressure of 735 psi at 70 °F (5070 kPa at 21 °C). Nitrous oxide refrigerated liquid, UN 2201, is stored in insulated tanks at pressures ranging from 260 psi to 315 psi at temperatures of 0 °F to 10 °F or 20 bar to 25 bar at temperatures of –20 °C to –13 °C.

4.2 Chemical properties and hazards

4.2.1 Oxidizing ability

a) Under the action of heat, nitrous oxide decomposes into its elements irreversibly and exothermally to produce a mixture that is richer in oxygen than air.

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

b) As by-products of nitrous oxide decomposition, toxic nitrogen oxides can be formed.

c) After decomposition, nitrous oxide becomes an oxidizing gas with an oxypotential higher than that of air. Consequently, nitrous oxide is classified in standards and regulations as an oxidizing gas, see Annex 1 - Table 4.

4.2.1.1 **Metals**

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

4.2.1.12 **Nonmetals**

Ignition of nonmetals (such as plastics, elastomers, and clothing materials) in contact with nitrous oxide is possible by the influence of heat (for example, generated by adiabatic compression) or flame.

4.2.1.3 **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 compression or high temperature.

4.2.1.3 **Flammable gases**

Flammable gases form explosive mixtures with nitrous oxide, see Annex 1 - Table 5. The explosion limits are influenced by the specific chemical properties of nitrous oxide:

i. The lower explosion limit of flammable gases is much lower with nitrous oxide than with air or oxygen, since the heat released by decomposition of nitrous oxide supports the combustion of combustible-lean mixtures; and

ii. The upper explosion limit of flammable gases is much higher with nitrous oxide than with air, since the higher oxypotential of nitrous oxide supports the combustion of combustible-rich mixtures.

4.2.2 Stability

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

b) 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.

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

d) If improperly handled, nitrous oxide can decompose irreversibly, and potentially explosively, into nitrogen and oxygen:

$2N_2O \rightarrow 2N_2 + O_2 + \text{Heat}$

e) While nitrogen and oxygen are the primary products from nitrous oxide decomposition, higher nitrogen oxides (NO/NO2) are also produced.

f) Decomposition of nitrous oxide is a homogeneous, first order reaction. Nitrous oxide releases 800 Btu/lb (1860.8 kJ/kg) upon decomposition. Nitrous oxide decomposition progresses as a purely thermal process, whereas a propane-air flame front proceeds by a combination of thermal and chain carrier processes. The propagation speed of nitrous oxide decomposition reaction is 30 times slower than the flame propagation speed for propane-air and the reaction is relatively easy to quench.

g) Liquid nitrous oxide is relatively insensitive to high energy sparks or external shocks. Decomposition of the liquid cannot 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 vapor with liquid present.

4.2.3 Decomposition sources

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

a) field decomposition sources:
   i. static discharge
   ii. spark (due to metal to metal contact)
   iii. adiabatic heat of compression
   iv. secondary exothermic chemical reaction (due to contamination)
   v. welding/brazing
   vi. heat generated by a dry running pump
   vii. electric immersion heater
   viii. internal impact
   ix. external source of heat; and

b) laboratory decomposition sources:
   i. electric spark
   ii. exploding wire
   iii. glowing wire
   iv. blasting cap
   v. heat of compression.

4.2.3.1 Temperature and pressure

a) Nitrous oxide decomposition will not propagate at relatively low temperatures and pressures, see Annex 2 - Figure 1. Three outcomes are possible after a decomposition ignition source has been applied to a pipe or vessel containing nitrous oxide vapor. In order of progressively higher temperature and pressure, they are:
   i. nothing happens;

   ii. decomposition is initiated, but the reaction is quenched (below the propagation threshold); and

   iii. decomposition is initiated and the decomposition front propagates through the pipe or vessel (above the propagation threshold).

b) At extreme conditions, for example 575 °F at 51.4 psi (301 °C at 354.6 kPa), nitrous oxide vapor is capable of auto-ignition without an external decomposition source.

4.2.3.2 Vessel and pipe geometry

In order for nitrous oxide decomposition to propagate, the heat generated by the reaction has to be sufficient to heat the next element of unreacted 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 Annex 2 - Figure 1.

4.2.3.3 Propagation threshold

a) 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.

b) The propagation threshold shown in Annex 2 - Figure 1 shall be considered as an approximation, but can give the user some indication, if they are handling nitrous oxide greater than or less than the propagation threshold. When handling nitrous oxide vapor under conditions at which the reaction can propagate, care shall be taken to avoid any possibility of a decomposition source.

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

4.2.3.4 Impurities

a) Inert gases - Dilution of nitrous oxide vapor with a nonflammable gas such as helium or nitrogen raises the propagation threshold.

b) Combustible materials - Any combustible material, such as hydrocarbon lubricants or flammable mixtures can promote violent decomposition and lower the propagation threshold. A flammable mixture can lower the propagation threshold even if present below the lower explosion limit. All equipment that can be in contact with nitrous oxide shall be cleaned for oxygen service and lubricants shall be oxygen compatible.

4.2.3.5 Large pressure vessels

a) Most nitrous oxide decomposition incidents have occurred in large pressure vessels, such as storage tanks or cargo tanks. As the vapor volume and temperature increase, the risk of disassociation increases. Decomposition can be initiated by a variety of ignition sources.

b) The decomposition can also be initiated by external heat (such as welding or brazing) on the vessel or vessel piping, or 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 moles 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.

c) Eventually, the unreacted nitrous oxide reaches a high enough temperature and pressure to auto-initiate, resulting in an explosion.

d) Safety practices include:

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

ii. Ball valves and other quick opening valves shall be opened slowly. High temperature caused by adiabatic compression could cause nitrous oxide decomposition;

iii. Nitrous oxide transfer pumps shall be provided with an interlock to prevent dry running;

iv. Piping should operate below the propagation threshold, when possible (see Annex 2 - Figure 1). Use the smallest practical line size;

NOTE: Experience has shown that most large diameter vessels operating greater than the propagation threshold have been used safely, because safeguards noted in this publication have been taken (for example, avoiding decomposition initiators).

v. Clean all surfaces in direct contact with nitrous oxide as for oxygen;

vi. Oxygen compatible lubricants shall be used when potentially in contact with nitrous oxide; and

vii. Direct contact electric immersion heaters shall not be used. This requirement also applies to existing facilities and equipment.

4.3 Occupational exposure

The health effects of nitrous oxide are discussed only regarding personnel who are involved in transport, filling, and handling of nitrous oxide. The effect of nitrous oxide as a medicinal product is not considered.

4.3.1 Short-term exposure

a) Nitrous oxide in the gaseous state is colorless and has a sweet odor.

b) Elevated concentrations of this gas in the air can be reached quickly on loss of containment, for example, via leaks and venting. The short-term health effect is primarily the narcotic effect, which includes dizziness, nausea, headache, and loss of coordination.

c) In addition, gaseous nitrous oxide under atmospheric conditions is 1.5 times heavier than air and 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.

d) Nitrous oxide liquid or cold vapor 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 100 °F to 105 °F (38 °C to 41 °C).

4.3.2 Long-term exposure

Nitrous oxide has been associated with several side effects from long-term exposure. The most strongly substantiated effect is neuropathy. Epidemiological studies also suggest fetotoxic effects and higher incidents of spontaneous abortion in exposed personnel. Although no cause and effect relationship has been firmly established, exposure to the gas should be minimized. National regulations vary the 8-hour time-weighted average (TWA) exposure ranges from 25 ppm to 100 ppm. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends limiting exposure to 50 ppm on an 8-hour TWA basis.

4.3.3 Control of exposure to nitrous oxide gas in the workplace

a) Personnel exposures (for example, filling operators) to nitrous oxide gas should be controlled to acceptable levels (i.e., less than the relevant OELs). Sources of nitrous oxide can include:

   i. uncontained filling equipment allowing some nitrous to be expelled before/after filling;

   ii. leaking equipment, for example, filling equipment;

iii. empty cylinders venting to the open air instead of to a blow-down manifold;

iv. valves not closed sufficiently on empty and full cylinders to ensure no leakage of product; and

v. poorly positioned vents leading to re-entrainment of gas into the building.

b) Control measures shall be in place to prevent nitrous oxide leaking or being vented into the workplace. Examples include:

EXAMPLE 1: venting cylinders to a dedicated manifold rig (including purging and vacuum capabilities) that is contained and vented away from the work area;

EXAMPLE 2: ensuring the filling system is designed so that nitrous oxide is not released into the work environment via venting or leaking;

EXAMPLE 3: locating vents outside buildings and above roof level;

EXAMPLE 4: preventative maintenance program to prevent leaks; and

EXAMPLE 5: written operating procedures, for example, ensuring empty cylinder valves are closed prior to transporting them into the filling area.

c) If nitrous oxide is stored or filled in insufficiently ventilated rooms, a gas monitoring system shall be installed to monitor the concentration of nitrous oxide in the room.

4.4 Environmental issues

a) The emission of nitrous oxide from commercial production is estimated to be approximately 6% of total emissions.

b) In some parts of the world, the release of nitrous oxide to the atmosphere is restricted by regulation.

c) In the United States, the Emergency Planning and Community Right-to-Know Act [EPCRA] (or Superfund Amendments and Reauthorization Act [SARA] Title III) Section 311 and 312 regulations apply to nitrous oxide, if the quantity that is present at one time on the site exceeds 10 000 lb.

4.5 Security

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

b) Security measures shall be implemented to restrict access to nitrous oxide to authorized personnel only.

c) Security is an issue primarily because nitrous oxide is frequently subject to inhalation abuse. This abuse can result in asphyxiation or long-term exposure health effects, requiring stricter methods to control access and potential abuse.

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

5 CLASSIFICATION

5.1 Types

Nitrous oxide in containers at ambient temperatures is in both gaseous and liquid states. Liquid nitrous oxide at subambient temperatures in bulk containers is in both gaseous and liquid states.

5.2 Quality verification levels

a) Annex 1 - Table 6 presents the component maxima in parts per million (ppm (v/v) for the QVLs of nitrous oxide. The absence of a value in a listed QVL indicates that the test is not required for compliance with the specification. Typical uses are listed in Annex 1 - Table 6.

b) Filled nitrous oxide containers contain both liquid and vapor phases at cylinder temperatures below 97.7 °F (36.5 °C), the critical temperature.

NOTE: A gas/liquid equilibrium shall be established in the cylinder before verification of the limiting characteristics.

5.3 Quality tests

a) The supplier shall ensure by standard practice the QVL of nitrous oxide. If required, alternative control procedures are described in this standard. Other control procedures not listed in this specification are acceptable if agreed to by the supplier and the customer.

WARNING: Nitrous oxide can be an asphyxiant and can displace life-supporting oxygen. The misuse of nitrous oxide can reduce the oxygen necessary to support life.

b) Determination for conformance of test data offered as conforming to the specifications cited in Annex 1 - Table 2 shall be agreed to by the supplier and the customer.

6 APPLICATIONS OF NITROUS OXIDE

Nitrous oxide finds beneficial use in a number of legitimate applications such as:

a) medical/dental anesthesia and analgesia;

b) food processing propellant;

c) semiconductor manufacturing;

d) analytical chemistry;

e) chemical manufacturing; and

f) auto racing engine injection.

7 QUALITY VERIFICATION SYSTEM

7.1 Production qualification tests

a) These tests are a single test or a series of analyses performed on the product to ensure the reliability of the production facility to supply nitrous oxide of the required QVL.

b) This production qualification can be verified by the analytical records of product from the supplier or, if required, by the analysis of representative samples of the product from the facility at appropriate intervals as agreed to by the supplier and the customer. Production qualification tests can be performed by the supplier or by a laboratory agreed to by the supplier and the customer.

7.2 Analytical requirements of the production qualification tests

Analytical requirements of the production qualification tests include the determination of all the limiting characteristics of nitrous oxide.

7.3 Compliance with U.S. Pharmacopeia and National Formulary

To comply with the General Notices requirements of the U.S. Pharmacopeia and National Formulary (USP–NF), tests suitable for detecting the occurrence of other impurities, the presence of which is inconsistent with applicable

manufacturing practice or good pharmaceutical practice, should be used in addition to the tests provided in the USP monograph.

7.4 Lot acceptance tests

7.4.1 These tests are analysis performed on the nitrous oxide in a shipping container, or a sample thereof, that is representative of the lot subject to regulatory requirements, which could include, but are not limited to, the following:

a) nitrous oxide supplied during a specific time period;

b) nitrous oxide supplied in one shipment;

c) nitrous oxide in the container(s) filled from one unreplenished bulk container; or

d) nitrous oxide supplied or containers filled during an uninterrupted filling sequence.

7.4.2 The number of samples per lot shall be in accordance with one of the following:

a) one sample per lot; or

b) any number of samples agreed to by the supplier and the customer.

8 SAMPLING

8.1 Sample size

a) The quantity of nitrous oxide in a single sample container shall be sufficient to perform the analyses for all the limiting characteristics. The filled sample container must be allowed to reach ambient temperature before testing.

b) Withdraw the sample for the tests with the least possible release of nitrous oxide consistent with proper purging of the sampling apparatus.

CAUTION 1: The American Conference of Governmental Industrial Hygienists (ACGIH) recommends a Threshold Limit Value–Time-Weighted Average (TLV®–TWA) of 50 ppm (90 mg/m3) for nitrous oxide and The National Institute for Occupational Safety and Health (NIOSH) recommends a TWA of 25 ppm. The TLV–TWA is the time- weighted average concentration for a normal 8-hour workday and a 40-hour workweek to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

CAUTION 2: For safety reasons, sample cylinders shall conform to ASME code specifications, or DOT regulations and shall

not be filled to a quantity greater than 68% of their water capacity by weight, the maximum allowable fill density. The minimum service pressure rating of the cylinders shall be 1800 psi (12 410 kPa).

8.2 Gaseous samples

8.2.1 Gaseous samples shall be representative of the nitrous oxide supply. Samples shall be obtained in accordance with one of the following:

a) By selecting the first container filled as the representative container from the containers filled in the lot. The container should be checked by weight to be sure that it is filled to the maximum allowable fill density (68% water capacity by weight);

b) By connecting the gaseous phase of the container being sampled directly to the analytical equipment using suitable pressure regulation to prevent over pressurizing this equipment; or

CAUTION: For safety reasons the sampling system shall have a rated service pressure at least equal to the pressure in the supply container.

c) By filling the sample cylinder from the vapor phase. The sample cylinder shall be double ended with a valve on each end. There shall be a purge valve on the sample line immediately before the sample cylinder to purge the sample line. Fill the sample cylinder by first opening the inlet valve, then the discharge valve. After adequate purging, close the discharge valve and then the inlet valve.

8.3 Liquid samples

Liquid samples shall be representative of the nitrous oxide supply. Samples shall be obtained in accordance with one of the following:

a) By selecting a representative container from the containers filled in the lot. The container should be checked by weight to be sure that it is filled to the maximum allowable fill density (68% water capacity by weight). Connect the liquid phase directly to the analytical equipment using suitable flash vaporization and pressure regulation;

b) By filling the sample cylinder using standard cylinder filling equipment (equipped with suitable pressure relief devices and a high pressure gauge), and adequately purging the system by filling other containers or other- wise flowing liquid through the system. The cylinder shall be checked immediately by weight to be sure that it is not filled to more than 68% of its water capacity by weight;

c) By filling the sample cylinder from the liquid phase. The sample cylinder shall be double-ended with a valve on each end. There shall be a purge valve on the sample line immediately before the sample cylinder to purge the

sample line. Fill the sample cylinder in a horizontal position by first opening the inlet valve, then the discharge valve. When nitrous oxide escapes, close the discharge valve, then immediately close the inlet valve. Disconnect the cylinder and promptly check its weight. If filled to more than 68% of the water capacity by weight, immediately vent liquid from the cylinder until the correct weight is achieved;

d) By connecting a properly prepared sample cylinder to a liquid line and closing the sample cylinder valve as soon as flow into the cylinder stops. The sample cylinder may be precooled to increase the volume of the sample. The cylinder shall be checked by weight to be sure it is not filled to more than 68% of its water capacity by weight. If overfilled, immediately vent liquid from the cylinder until the correct weight is achieved ; or

e) By direct connection between the liquid phase of nitrous oxide and the analytical equipment using suitable flash vaporization. This sampling technique is not recommended for determining water or dew point.

CAUTION: Provide adequate pressure relief devices to prevent possible hydrostatic rupture from liquid-filled lines and overfilled sampling cylinders.

9 ANALYTICAL PROCEDURES

9.1 Parameters of analysis

The parameters for analytical techniques contained in this section are as follows.

9.1.1 U.S. Pharmacopeia

U.S. Pharmacopeia (USP) refers to the test requirements for nitrous oxide contained in the most recent edition of the USP–NF.

9.1.2 Food Chemicals Codex

The Food Chemicals Codex (FCC) refers to the test requirements for nitrous oxide contained in the most recent edition of the FCC.

9.1.3 Calibration gas standards

a) Calibration gas standards containing the applicable gaseous components are required to calibrate the analytical instruments that are used to determine the limiting characteristic levels of nitrous oxide.

b) If required by the customer, the accuracy of the measuring equipment used in preparing these standards shall be traceable to the national or international standards.

9.1.4 Analytical equipment

Analytical equipment shall be operated and properly calibrated in accordance with the manufacturer's instructions.

9.1.5 Sample containers

Sample containers shall reach ambient temperature before withdrawing portions for analysis.

9.1.6 Analytical methods

a) This standard provides several analytical methods for testing limiting characteristics in nitrous oxide.

b) The method specified by USP or FCC shall be used when testing nitrous oxide for conformance with the USP or FCC monograph. Alternative methods may be used, if agreed to by the supplier and the customer.

9.1.1 Analyzer operation

Analyzers shall be operated in a manner that accurately measures the limiting characteristics as defined previously.

9.2 Ammonia content

Ammonia content shall be determined by one of the following procedures:

a) By an apparatus using a detector tube filled with a color-reactive chemical. The degree of accuracy is de- pendent on the precision of the measurements and the analytical bias of the tube;

b) By an automated wet-chemical colorimetric analyzer specific to ammonia. The system shall be calibrated at appropriate intervals by the use of calibration gas standards;

c) By an analyzer in which the ammonia reacts to form a compound that is subsequently measured. The analyzer shall be calibrated at appropriate intervals by the use of calibration gas standards. The range used shall be no greater than 10 times the specified maximum ammonia content; or

d) By a gas chromatograph (GC), that can be used not only for ammonia determination, but also for the determination of any other limiting characteristic gaseous component. The analyzer must be capable of separating and detecting the component with a sensitivity of 0.1 ppm or 10% of the specified maximum amount of the component, whichever is greater. Appropriate impurity concentrating techniques may be used to attain the sensitivity. The analyzer shall be calibrated at appropriate intervals using calibration gas standards.

9.3 Carbon dioxide content

The carbon dioxide content shall be determined by one of the following procedures:

a) By an apparatus using a detector tube filled with a color-reactive chemical. The degree of accuracy is dependent on the precision of the measurements and the analytical bias of the tube;

b) By an analyzer in which the carbon dioxide reacts to form a compound that is subsequently measured. The analyzer shall be calibrated at appropriate intervals using calibration gas standards. The range used shall be no greater than 10 times the specified maximum carbon dioxide content; or

c) By a gas chromatograph.

NOTE: The analysis of carbon dioxide serves as an identity test to satisfy USP requirements.

9.4 Carbon monoxide content

The carbon monoxide content shall be determined by one of the following procedures:

a) By an apparatus using a detector tube filled with a color-reactive chemical. The degree of accuracy is dependent on the precision of the measurements and the analytical bias of the tube;

b) By an analyzer in which the carbon monoxide reacts to form a compound that is subsequently measured. The analyzer shall be calibrated at appropriate intervals by the use of calibration gas standards. The range used should be no greater than 10 times the specified maximum carbon monoxide content;

c) By a gas chromatograph; or

d) By a fuel cell analyzer specific to carbon monoxide. The analyzer shall be calibrated at appropriate intervals using calibration gas standards.

9.5 Halogen content

The halogen content shall be determined by one of the following procedures:

a) By an apparatus using a detector tube filled with a color-reactive chemical. The degree of accuracy is dependent on the precision of the measurements and the analytical bias of the tube; or

b) By an analyzer in which the halogens react to form compounds that are subsequently measured. The analyzer shall be calibrated at appropriate

intervals using calibration gas standards. The range used shall be no greater than 10 times the specified maximum halogen content.

9.6 Hydrocarbon content (C1-C5)

The hydrocarbon content (C1-C5) defined as methane, ethane, ethylene, propane, acetylene, propylene, n-butane, and n-pentane shall be determined by a gas chromatograph.

9.7 Nitrogen content

The nitrogen content shall be determined by a gas chromatograph.

9.8 Nitrogen and oxygen (air) content

The nitrogen and oxygen (air) content shall be determined by a gas chromatograph. The technique shall be specific for the separation and analysis of air that does not require separation of nitrogen and oxygen.

9.9 Nitrogen oxides content (NO and NO2)

The nitric oxide (NO) and the nitrogen dioxide (NO2) content shall be determined as an aggregate or individually by one of the following procedures:

a) By an apparatus using a detector tube filled with a color-reactive chemical. The degree of accuracy is dependent on the precision of the measurements and the analytical bias of the tube;

b) By an automated wet-chemical colorimetric analyzer specific to nitrogen oxides. The system shall be calibrated at appropriate intervals using calibration gas standards; or

c) By an analyzer using chemiluminescence. The analyzer shall be calibrated at appropriate intervals using calibration gas standards. The range used shall be no greater than 10 times the specified maximum amount of the component of interest. Nitrous oxide can interfere with chemiluminescence measurement for nitrogen oxide.

9.10 Oxygen content

The oxygen content shall be determined by one of the following procedures:

a) By a gas chromatograph. The technique shall be specific for the separation and analysis of oxygen; or

b) By an electrochemical analyzer that is calibrated at appropriate intervals using calibration gas standards.

9.11 Percent nitrous oxide

The percent nitrous oxide shall be determined by one of the following procedures:

a) By a gas chromatograph capable of separating and determining the component of interest (air);

b) By the pressure differential between the sample cylinder and a standard container charged with nitrous oxide of 99.9% or higher purity at the same filling density and at the same temperature. It is recommended that both cylinders be of the same size; or

c) By measurement of the concentrations of the other components of interest by their respective analytical methods. The percent nitrous oxide is calculated by subtracting the combined concentrations of the components of interest from 100%.

9.12 Water content

The water content shall be determined by one of the following procedures:

a) By a pressure chamber in which an adiabatic expansion from various measured pressure drops can be visually observed until a fog is formed by condensation of the water;

b) By a dew point analyzer in which the temperature of a viewed surface is measured at the time moisture condensation first begins to form;

c) By a piezoelectric oscillating quartz crystal hygrometer;

d) By an apparatus using a detector tube filled with a color-reactive chemical. The degree of accuracy is dependent on the precision of the measurements and the analytical bias of the tube;

e) By an electrolytic hygrometer having an indicator graduated in ppm (v/v) on a range that is no greater than 10 times the specified maximum moisture content; or

f) By a metal-oxide capacitor-equipped analyzer on a range that is no greater than 10 times the specified maximum moisture content.

9.13 Identity

The identity of the sample shall be checked as specified in the current USP–NF, by one of the following methods.

a) With the container temperatures the same and maintained between 15 °C (59 °F) and 25 °C (77 °F), concomitantly read the pressure of the Nitrous Oxide container and of a container of USP Nitrous Oxide RS.

NOTE: Do not use the USP Nitrous Oxide RS if it has been depleted to less than half of its full capacity. The pressure of the Nitrous Oxide container is within 50 psi of that of the USP Nitrous Oxide RS.

b) Pass 100 ± 5 mL released from the vapor phase of the contents of the Nitrous Oxide container through a carbon dioxide detector tube at the rate specified for the tube: no color change is observed (distinction from carbon dioxide).

c) Collect about 100 mL of the gas under test in a 100-mL tube fitted at the top with a stopcock. Open the stopcock, and quickly add a freshly prepared solution of 500 mg of pyrogallol in 2 mL of water and a freshly prepared solution of 12 g of potassium hydroxide in 8 mL of water. Immediately close the stopcock, and mix: the gas is not absorbed, and the solution does not become brown (distinction from oxygen).

d) Prepare a gas chromatograph as directed in the Assay and inject USP Nitrous Oxide RS and a sample of Nitrous Oxide into the gas chromatograph. The retention time of the major peak in the chromatogram of the Nitrous Oxide sample corresponds to that in the chromatogram of the USP Nitrous Oxide RS.

10 CONTAINERS

10.1 Nitrous oxide containers

Nitrous oxide containers offered in transportation shall comply with the regulations of the appropriate authority, DOT regulations (49 CFR Parts 100-180) describe how containers shall be manufactured, maintained, filled, packaged, marked, labeled, and shipped to comply with current regulations.

10.2 Container preparation

a) Container preparation shall be as necessary to ensure that the container contents meet the requirements of the specified QVL of nitrous oxide.

b) Container preparation shall be in accordance with an acceptable technique that encompasses evacuation, purging, or cleaning procedures to ensure that the containers, closures, and other component parts are suitable for their intended use. The containers shall be prepared so they are not reactive, additive, or absorptive to an extent that significantly affects the identity, strength, quality, or purity of the nitrous oxide, and that they furnish adequate protection against its deterioration or contamination.

10.3 Nitrous oxide (USP)

Nitrous oxide (USP) is classified as a drug and shall be labeled in accordance with the appropriate food and drug regulations as described in BZS 1: Part 8,

Belize Standard Specification for Labelling Part 8: Labelling and Marking of Medical Gas Cylinders.

10.4 Valves on nitrous oxide containers

The valve outlet connection should conform to recognized standards such as CGA V-1, Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections [16]. It is acknowledged that connections other than those found in CGA V-1 can exist. If a user chooses such a connection, extreme care must be taken to ensure that such connections do not cross connect with existing connections in CGA V-1 and that they have been properly engineered for the intended gas service and pressure.

11 SUPPLEMENTAL SPECIFICATION DATA

11.1 Moisture conversion data

Water/dew point is expressed in ppm (v/v) or degrees Fahrenheit at 1 atmosphere pressure absolute (101 kPa, abs). To convert to other units, use Annex 1 - Table 9.

11.2 Assay conversion data

Pressure differential between the sample cylinder and a standard container charged with nitrous oxide of 99.9% or higher purity at approximately the same filling density and at the same temperature. It is recommended that both cylinders be the same size. The absence of carbon dioxide shall be determined to ensure the product is nitrous oxide (see Annex 1 - Table 10).

12 EQUIPMENT AND PROCEDURES

12.1 Principles

a) The equipment used to handle nitrous oxide shall be designed, constructed, and tested to withstand the maximum pressures and temperatures at which it is to be operated and also to minimize the release of nitrous oxide.

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

c) General rules described apply to nitrous oxide systems where the pressure is less than 1051 psi at 97.5 °F (71.5 bar at 36.45 °C). For higher pressures (i.e., in the supercritical state of nitrous oxide), rules defined for pure oxygen concerning material compatibility and equipment selection should be considered for nitrous oxide as well. The oxygen rules are also applicable to nitrous oxide and oxygen mixtures irrespective of the partial pressure or percentage of nitrous oxide.

12.2 Compatibility of materials with nitrous oxide

Nitrous oxide is classified as an oxidizer because it forms oxygen when it decomposes, hence the rules for selecting materials in nitrous oxide are often based on the rules for oxygen compatibility. Due to the possibility of reaction of materials with nitrous oxide and considering its oxidizing properties, metals and nonmetals shall be selected as follows.

12.2.1 Metals

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 aluminum alloys are suitable for use with nitrous oxide. Aluminum and its alloys shall not be used in wetted parts of nitrous oxide pumps.

12.2.2 Nonmetals

Examples of nonmetallic materials exhibiting the best compatibility with gases having a high oxypotential:

a) Plastic products such as polytetrafluoroethylene (PTFE), polychlorotrifluoroethylene (PCTFE), fluorinated ethylene propylene (FEP), polyether ether ketone (PEEKTM), and ethylene propylene diene monomer (EPDM) are acceptable. Others such as polyvinylchloride (PVC), polyvinylidene fluoride, polyamide (Nylon 66®), Vespel® SP21, and polypropylene may be used taking into consideration the external fire risk;
b) Certain grades of elastomers such as Viton® or Neoprene® are known to swell in pressurized nitrous oxide and nonswelling grades are preferred when swelling can be an issue;

c) Nonmetallic materials to be used in high pressure (pressure greater than 435 psi [30 bar]) nitrous oxide/oxygen mixture applications shall conform to specific requirements considering toxicity risks; and

d) Lubricants in contact with nitrous oxide shall be compatible.

12.3 Valves

a) Commonly used materials for high pressure nitrous oxide valves, such as cylinder valves, are brass, copper alloys, and carbon steel. Acceptable nonmetallic materials are the plastics (PTFE, PCTFE, polyamides, and the elastomer silicon rubber).

b) Valves for refrigerated liquefied nitrous oxide shall meet the requirements regarding design, testing, and marking for the intended service. Metallic and nonmetallic materials for such valves shall have passed a test for oxygen compatibility. 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. [2]

12.4 Filters

a) Filters or strainers, used to trap particles, shall be designed considering the potential oxidizing properties of nitrous oxide. Mesh filters or strainers made from high nickel alloys such as Monel®, Inconel®, nickel 200 alloys or high copper alloys (such as brass) are preferred due to increased resistance to oxidizer fires.

b) Stainless steel wire mesh filters have been successfully used in nitrous oxide service without report of incidents of combustion. No glue or similar combustible material shall come in contact with nitrous oxide at pressure greater than 145 psi (10 bar).

c) Filters or strainers shall not be modified to make a flame arrestor by putting steel wool or similar packing into them. Steel wool is combustible in air, and it could contribute towards propagating the decomposition of nitrous oxide rather than quenching it. This requirement also applies to existing facilities and equipment.

d) Liquid nitrous oxide should be filtered as fine as possible. The hole size of the filter is a compromise between allowable pressure drop, space available, and acceptable thermal mass of the filter body.

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

12.5 Cleaning of installation

a) Any equipment and installation designed for storage and transfer of nitrous oxide service shall be clean for oxygen service. With the exception that the maximum quantities of foreign matter (oil, grease, organic materials) in the installation shall not exceed 500 mg/m2 (50 mg/ft2). Visible particles, fibers, or drops of water shall not be accepted.

NOTE: Nitrous oxide is approximately 44% as effective in promoting ignition as pure oxygen. For this reason, the maximum quantity level of 500 mg/m2 (50 mg/ft2) is appropriate.

b) Where it is necessary to change the product service of equipment from any gas to nitrous oxide, the same rules apply for cleaning. Pressure receptacles that are to be changed to nitrous oxide service, shall be cleaned using an appropriate procedure.

c) The surfaces that come in contact with nitrous oxide shall be free of all combustible particles, and oil and grease that could have been introduced into the system during its construction, fabrication, or maintenance.

d) The equipment shall be clean, as for oxygen service, and if cleaning is needed, detergents or suitable cleaning agents that are free from nonmetallic and metallic particles should be used.

12.6 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.

12.7 Avoiding high temperatures

12.7.1 High temperatures shall be avoided to reduce the likelihood of an explosive decomposition of nitrous oxide. Annex 2 - Figure 1 gives the temperature at which decomposition can propagate depending on pipe diameter and pressure. These correlations are based on limited experimental data and consequently, safety margins shall be considered.

12.7.2 Electric heating devices in direct contact with nitrous oxide are prohibited. This requirement also applies to existing facilities/equipment. Only indirect electric heaters with temperature safety controls to prevent exceeding 300 °F (150 °C) are allowed. Water bath heaters, low pressure steam, or other temperature self- limiting devices are recommended:

a) 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. This requirement also applies to existing facilities and equipment. Pumps shall not be allowed to operate with no flow or loss of prime. A number of serious incidents have been attributed to overheated equipment.

b) Liquid transfer pumps should be installed with a flooded suction line and a recycle line return connection to the bottom of the tank to help quench a decomposition reaction during startup;

c) Process hazard analysis (PHA) should focus on prevention of initiation of a decomposition reaction as well as minimizing the possibility of propagation (see Annex 2 - Figure 1);

d) Historically, strainers have been included in some pump systems with the aim of quenching potential propagation but should not be considered a sufficient safeguard;

WARNING: 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.

e) Medical installations could require purging with medically certified gases during any hot work to prevent the formation of oxides;

f) Hot work should not be performed within 3 ft (1 m) of a section of piping that still contains nitrous oxide.

g) 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;

h) Heat from an open flame or a hot air gun shall not be applied to any part of a nitrous oxide installation for 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;

i) Thermal mass flowmeters 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 flowmeters to measure any emissions to atmosphere through vents;

j) Nitrous oxide installations shall be grounded, to dissipate any electrostatic charges; and

k) Strainers or filters shall be located to avoid migration of particles within specific devices (for example, compressor, pump).

12.7.3 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.

12.8 Restriction of flow velocity

a) Nitrous oxide flow can 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.

Therefore, the nitrous oxide velocity should be limited to avoid this temperature being achieved.

b) When designing or modifying an installation, a conservative guide would be to use the velocity limits that are defined for oxygen

12.9 Operating procedures

a) As with any operation associated with a hazardous substance, written operating procedures shall be prepared. Personnel shall be trained in these procedures.

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

c) Included in these procedures shall be a statement to indicate that no part of the installation shall be heated higher than the normal operating temperature, see Annex 2 - Figure 2.

12.10 Maintenance procedures

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

b) Modifications to a nitrous oxide installation or nonroutine maintenance work shall not be made without a risk assessment, which may result in a management of change and requirement for a work permit.

c) Consideration shall be given to ensuring that 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.

d) Pressure equipment shall be depressurized 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.

12.11 Isolation from flammable gases

a) To ensure that there is no hazard of inadvertent mixing of nitrous oxide with flammable gases or liquids, nitrous oxide equipment and pressure receptacles shall be dedicated to nitrous oxide service. Change of service of other equipment shall require a procedure using ISO 11621 or CGA C-10.

b) 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.

c) Mixing nitrous oxide with self-igniting gases such as silane shall be prevented under all circumstances, since immediate ignition and explosion can occur. Some processes that use nitrous oxide and self-igniting gases, such as silane, in separate steps shall be protected with effective backflow preventive devices to prevent backflow of gas.

12.12 Use of carbon dioxide equipment

a) 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. The procedure shall meet the relevant requirements of this publication or any other applicable standard or regulation.

b) Care shall be taken with regard to design, material, insulation, cleanliness, lubricants, seals, and avoiding high temperatures.

WARNING: 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.

13 SUPPLY EQUIPMENT

13.1 Cylinders

a) It is recommended to dedicate a stock of cylinders to nitrous oxide service. Any change of service to or from nitrous oxide shall be made in accordance with approved procedures considering CGA C-10.

b) Suitable materials for nitrous oxide cylinders are carbon steel, chrome molybdenum steel, aluminum alloys, and stainless steel, Cylinders made of nonmetallic materials, for example, full composite (type 4), shall not be used.

c) 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 and valve materials shall meet the requirements as described.

d) Dip tubes made of nonmetallic materials shall not be used because of the risk of static electricity buildup.

e) Where metallic dip tubes are used, electrical continuity shall be ensured for all parts of the cylinder and its accessories. Ensure there is no risk of separation of the dip tube from the valve occurs 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 so electrical continuity is ensured.

f) Cylinders should be filled by weight to ensure accurate fill level.

g) To avoid accidental overpressure in the cylinder by overfilling, some regional regulations require valves to 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 or company specifications (for example, 5/3rds of working pressure, but shall not exceed 1.15 times the test pressure of the gas cylinder including all tolerances.

h) Under no circumstances shall disks with fusible metal backing devices be used because they do not protect against cylinder overfilling.

13.2 Bundles

a) 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.

b) Bundles are fitted with a main isolation valve. If cylinders are equipped with isolation valves, each cylinder in the bundle shall be equipped with a bursting disk and shall be filled individually.

c) Each cylinder shall have a relief device.

d) Where nonclosable fittings are used on each cylinder in the bundle, only one bursting disk 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.

e) The bundle shall be designed, manufactured, and tested according to any applicable regulatory requirements and where appropriate a design code, for example ISO 10961, Gas cylinders—Cylinder bundles—Design, manufacture, testing and inspection.

f) Connections within the manifold should preferably be welded or soldered.

13.3 Transport tanks

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

b) Requirements to build such transport tanks are specified for vacuum-insulated transport tanks. This also applies for cryogenic liquid cylinders up to 450 L (118 gal).

14 PRODUCT TRANSFER

14.1 Cylinders and bundles

14.1.1 Cylinder and bundle filling stations shall be designed and built to withstand the pressure loads and the external loads during service to allow safe filling.

14.1.2 Nitrous oxide cylinder and bundle filling stations consist of the following main elements:

a) Vacuum- or nonvacuum-insulated stationary tank, working pressure approximately 290 psi (20 bar) or noninsulated high pressure tank, working pressure approximately 1160 psi (80 bar);

b) Reciprocating pump, working pressure up to 1450 psi (100 bar). The pump should be equipped with protection against dry running, for example, by means of a thermocouple to monitor the temperature on the discharge side. Where the lubricant could be in contact with nitrous oxide, only oxygen compatible lubrication shall be used;

c) Pump bypass, if the pump is running continuously;

d) If not equipped with a bypass line, the pump shall be automatically switched off when the cylinders are full;

e) Partially or fully insulated pipe from the pump to the filing point;

f) Filling scales with the required accuracy for large and small cylinders;

g) Cylinder or bundle emptying manifold with vacuum pump; and

h) Flexible filling hoses, which should be equipped with safety cable or equivalent system to prevent whipping if broken under pressure.

14.1.2 The following additional requirements shall be met:

a) Installation shall be designed and operated in accordance with safety regulations for oxidizing and medical gases;

b) Written operating procedures, which describe all steps of the filling process (prefill check and reconditioning of the cylinders, tare weight check, control of filling weight) shall be provided.

c) Filling of nonempty cylinders (top filling) and filling by pressure without scale shall not be permitted; and

d) Cylinders shall be filled to the permissible filling ratio. The filling ratio is dependent on the test pressure of the cylinder, see Table 10,

or by local regulations. The filling ratio is 70.3% for a 2000 psi rated cylinder, 73.2% for a 2265 psi rated cylinder, and 74.5% for a 2400 psi rated cylinder.

14.1.3 All parts of a filling installation shall be bonded and earthed to ensure electrical continuity. The electrical potentials between the cylinder or bundle and the ground should be equalized during filling. If necessary, the cylinder or bundle should be bonded directly to ground.

14.2 Transport tanks

14.2.1 Refrigerated liquid nitrous oxide is normally transferred from a stationary tank at the production plant into the transport tank and then transported to the user.

14.2.2 A ground-mounted pump adjacent to the stationary tank is commonly used to fill the transport tank. The suction pipe shall be designed according to pump manufacturer's instructions. The on-board pumping system of the transport tank should not be used as the pump suction is not designed for this type of transfer.

14.2.3 An inherently safer design employing an elevated stationary tank to fill the transport tank via gravity using the two-hose filling procedure eliminates the risk from loss of prime when pumping nitrous oxide into an empty trailer (vapor space). This should be considered for new tank installations.

14.2.4 In addition, the transport tank filling area:

a) Filling connection area should be covered with noncombustible material (such as concrete or natural stones). Wood is not acceptable;

b) Transport tanks should be equipotential bonded to the stationary tank during product transfer; and

c) Connections, seals, and transfer hoses shall be kept clean by using caps, plugs, etc.

14.2.5 Transport tanks should be filled by the two-hose filling procedure to minimize pressure differential and the hazard of decomposition. Filling shall be made through the bottom fill line and the gas phase shall be directed back to the stationary tank. Filling through the top equalizing line or any other line to the top is not recommended to avoid heat input into the gas phase by a hot running pump.

14.2.6 During filling, the pump discharge pressure shall be monitored to ensure that the pump operates within the specified performance conditions. The pressure and the level indicator (if any) of the transport tank shall be monitored to avoid overfilling. At completion of filling the full trycock

shall be opened to verify that the filling quantity is correct. If designed for the function, the vapor return may serve as the full trycock.

14.2.7 The principles of safe filling of transport tanks can also be applied for cryogenic receptacles.

14.3 Filling degree

The maximum filling degree shall be 95%. Annex 2 - Figure 4 indicates the pressure effect of overfilling a tank caused by the expansion of liquid.

15 EFFECTS OF NITROUS OXIDE ON THE HUMAN BODY

15.1 Nitrous oxide's painkilling and numbing qualities begin to take effect when the gas is inhaled at concentrations of 10%. At increasingly higher concentrations, a sense of well-being, or "high," is experienced. A person experiencing a nitrous oxide high can:

a) have slurred speech;
b) have difficulty in maintaining his or her balance or walking;
c) be slow to respond to questions;
d) be immune to any stimulus such as pain, loud noises, and speech; or
e) lapse into unconsciousness.

15.2 Nitrous oxide that is inhaled over a long period of time can lead to a vitamin B12 deficiency. When the level of vitamin B12 in the body is reduced, the red blood cell count is lowered, anemia results, and nerves degenerate. A vitamin B12 deficiency causes a person to:

a) have painful sensations in the arms or legs;
b) have an unsteady walk or gait;
c) become unbalanced and tend to fall over;
d) feel or appear to be irritable; and
e) suffer intellectual deterioration.

16 EMERGENCY RESPONSE

16.1 Procedures for large leaks or spills of nitrous oxide

a) Isolate the leak without putting personnel at risk. If possible, orient leaking containers so the gas escapes rather than the liquid.

b) Isolate the area affected by the spill or leak for at least 75 ft to 150 ft (25 m to 50 m) in all directions, keep unauthorized persons away, and stay upwind.

c) A large spill (e.g., unrestricted open pipe flow) may require a greater distance due to the increased volume of the discharge.

d) Reasonable measures shall be taken to prevent the leaking gas or liquid from reaching low lying areas and try to prevent entry into drains, sewers, basements, or confined spaces.

e) 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.

f) Emergency responders shall avoid water contact with the pressure relief valves to avoid freezing the pressure relief valves closed.

g) Do not touch or walk through spilled liquid.

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

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

16.2 Procedures at fire situations

16.2.1 Plant personnel should be restricted to fight only minor fires, if trained and equipped for such occurrences. Emergency responders should fight large fires.

16.2.2 Evacuation of the plant is recommended if there is a fire in the nitrous oxide area.

16.2.2.1 Fires involving combustible materials with nitrous oxide

a) 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.

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

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

16.2.2.1 Fire in the area of nitrous oxide tanks

a) 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, which can occur despite pressure relief equipment. Fragments of metal can be ejected through the air.

b) Transport tanks and pressure receptacles should be removed from the immediate fire area, if this can be achieved without risk to personnel.

c) If this is not possible, the concerned equipment should be immediately cooled with water jets directed from a safe position, for example, from behind heavy machinery or a solid wall. Avoid water contact with pressure relief valves to avoid freezing the pressure relief valves closed.

d) If the 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 a 2600 ft (800 m) perimeter. See Emergency Response Guidebook.

e) In the event of a fire in the area containing cylinders or bundles of nitrous oxide, EIGA SI 02, Handling of gas cylinders during and after exposure to heat or fire should be followed:

f) Instructions for first response actions to be taken in event of a fire

   i. Warn personnel.

   ii. If present when the fire or heat events starts AND it is safe to do so, close any open cylinder valves and move nearby cylinders away before the fire spreads.

   iii. Evacuate the area.

   iv. Raise the alarm, call the emergency services and the gas supplier.

   v. If possible, identify if any of the cylinders involved are of composite or aluminium alloy construction or have a pressure relief device (PRD). In this situation do not allow anyone to return to the area, and await arrival of the emergency services.

vi. Keep other people out of the area. If safe and practical, barricade the area and place warning notices.

vii. Only if a trained on-site emergency team is equipped and available should they immediately start the cooling of affected cylinders in accordance with written emergency procedures. Possible emergency team actions could include deluging cylinders with water from a safe location, for example from behind heavy machinery or a solid wall. Care shall be taken not to knock cylinders over when cooling.

viii. Make a note (record) of the time that the fire or heating started, and if possible, the content, number and location of gas cylinders directly involved.

ix. Give this information to the emergency services on arrival.

16.3 Procedures at a traffic incident involving a transport tank

16.3.1 The actions required in the event of a traffic incident involving nitrous oxide transport tanks depend on the circumstances.

16.3.2 The following is given as guidance only regarding the type of action that could be required from drivers.

16.3.3 Where practicable, company guidance should be obtained before any major action is taken and co-operation with the police and other emergency services shall be given at all times.

16.3.4 In the event of breakdown:

a) If a stop is required on the roadside due to a breakdown, look for a parking area as far away as possible from built-up areas;

b) Stop the engine and switch on hazard warning lights. Put on your high visibility clothing. Place warning signs on the road;

c) If the position of the vehicle is likely to cause a serious traffic hazard or obstruction, notify the police or traffic authorities; and

d) Report to the company for instructions regarding further actions required, such as arrangements for assistance with repairs, changes of tractor, or transferring the product from the transport tank to another vehicle.

16.3.4 In the event of an incident

a) If involved in an incident, stay calm and give first aid, if possible;

b) Stop the engine and switch on hazard warning lights. Put on your high visibility clothing. Place warning signs on the road;

c) Avoid open flames. Do not smoke;

d) Notify the police and, if necessary, other emergency services such as fire or medical;

e) Keep bystanders at a distance and report to the company; and

f) Frequently check transport tank pressure and, if necessary, vent nitrous oxide gas to the atmosphere to reduce the pressure to less than the maximum allowable pressure. Find a safe place for venting and take precautions to prevent fire hazards

16.3.4 In the event of leak or spill

a) 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;

b) If there seems to be no damage to the 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;

c) If leakage appears to be increasing, stop in a suitable place away from built-up areas, and proceed as follows for major leaks;

d) In the event of major leaks where a release can come in contact with the tractor engine, pull to the side of the road, immediately shutoff the engine, and exit the vehicle keeping all personnel away until the emergency services arrive; and

e) Notify the police and, if necessary, other emergency services and inform them about the nature of the leak. Report the situation to the company. 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 1640 ft (500 m).

16.3.5 In the event of transport tank overturning

If a transport tank overturns, or is lying on its side, it may not be possible to vent gas from either the liquid valve or the gas valve. Follow the

company's emergency response plan and notify the police, and if necessary, other emergency services and inform them about the nature of the incident.

16.3.6 In the event of fire

a) If the transport tank is involved in a fire, notify the police and emergency services and report the situation to the company;

b) The company should assist emergency responders by providing information about the hazards and properties of nitrous oxide; and

c) Be aware of explosive decomposition hazards.

16.4 Personal protective equipment

The following personal protective equipment (PPE) is recommended for emergency responders:

a) Firefighters protective clothing is only required for fire situations; it is not effective in spill situations;

b) Use self-contained breathing apparatus (SCBA) or supplied air respiratory protection while extinguishing fires, as fire in the presence of nitrous oxide can generate asphyxiating, irritating, and/or toxic gases;

c) In the event of minor leakage, wear head protection, safety goggles, gloves, and safety shoes. Ensure that the area is ventilated to reduce the concentration of nitrous oxide; and

d) In the event of major leakage, wear thermal protective clothing, face shields, cryogenic gloves, safety shoes, and SCBA or supplied air respiratory protection.

16.5 First aid

16.5.1 In the event of inhalation of nitrous oxide

a) Move the victim to fresh air and call emergency medical services;

b) Administer oxygen if the victim is experiencing difficulty with breathing; and

c) Perform artificial respiration if the victim is not breathing.

16.5.2 In the event of contact with liquid nitrous oxide

a) Remove and isolate contaminated clothing and shoes;

b) Clothing frozen to the skin should be thawed before being removed. Do not rub the area. Immerse in warm water (100 °F to 105 °F [38 °C to 41 °C]). Keep the victim warm and calm and seek medical attention; and

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

16.5.3 Ingestion of liquid nitrous oxide

Ingestion is not considered a potential route of exposure for liquid nitrous oxide.

18 RECOMMENDATIONS FOR NITROUS OXIDE SECURITY TO PREVENT THEFT AND ABUSE

18.1 Abusive use of nitrous oxide

Bulk manufacturers, container fillers, wholesalers, and distributors, carriers, and customers should be concern over the abusive use of nitrous oxide, which has resulted in deaths and injuries.

18.2 Individual Operations

Policies and procedures specific to individual operations should be developed and implemented using the available information and guidelines.

18.3 Prevention of Nitrous Oxide Theft

To prevent nitrous oxide theft, the following guidelines for nitrous oxide security are recommended. These guidelines are intended to help implement principles of product stewardship and to identify sufficiently responsible control measures that will minimize the theft of nitrous oxide and deter its abuse throughout the supply chain.

18.3.1 Bulk manufacturers

Bulk manufacturers are anyone who produces nitrous oxide and then purifies, compresses, and liquefies this product for storage, shipment, and sale to a second party. It is recommended that bulk manufacturers:

a) Establish a written sales policy that identifies legitimate applications for nitrous oxide, that may include, but is not limited to medical, industrial, and food-based uses;

b) Restrict sale of bulk nitrous oxide to those secondary parties who can substantiate the legitimate use of nitrous oxide, as enumerated above;

c) Provide secondary parties with a current SDS, a Nitrous Oxide Fact Sheet, and any additional instructions for proper use and safe handling practices;

d) Alert employees and secondary parties to the dangers of nitrous oxide abuse;

e) Have a policy to investigate any tampering or vandalism of their bulk storage container;

f) Report incidents involving thefts, misuse, or inventory discrepancies to law enforcement. Provide support in prosecuting any suspects who are caught.

g) Additional security guidance can be found in the following publication - CGA P-52, Security Standard for Qualifying Customers Purchasing Compressed Gases, which provides guidance to the compressed gas industry for qualifying potential customers who purchase products that are considered at risk for illegal use.

18.3.2 Container fillers, wholesalers, and distributors

Container fillers are facilities that transfer nitrous oxide from a bulk storage vessel to cylinders. Wholesalers and distributors are facilities who store nitrous oxide cylinders for sale to secondary parties and customers for legitimate medical, industrial, and food uses. It is recommended that container fillers, wholesalers, or distributors:

a) Establish a written sales policy that identifies legitimate applications for nitrous oxide, that may include but is not limited to medical, industrial and food-based uses;

b) Restrict sale of nitrous oxide to those who can substantiate the legitimate use of nitrous oxide, as enumerated above;

c) Establish a written policy that clearly defines conditions for cash sales of nitrous oxide (e.g., all cash sales shall be accompanied by a driver's license and a certified document that identifies the company or medical practice that will use the product);

d) Sell denatured (e.g., rendered unfit for human consumption) nitrous oxide for enhancing performance of internal combustion engines, so as to deter abuse;

e) Screen existing nitrous oxide accounts to assure that all are legitimate users of nitrous oxide and for unexpected changes in ordering patterns, cylinder balances, or other indications of increased consumption beyond their normal order pattern;

f) Provide secondary parties with a current SDS, a Nitrous Oxide Fact Sheet, and any additional instructions for proper use and safe handling practices;

g) Take physical security steps to prevent the theft of all containers of pure nitrous oxide, denatured product, and mixtures containing nitrous oxide. Do not leave a delivery vehicle unattended without limiting access to nitrous oxide cylinders. “Empty” containers can have residual product that also requires physical security;

NOTE: The objective of physical security is to deter, detect, and delay a malicious act. Physical security can include fences, walls, and other barriers that deter and delay someone from reaching the product. Alarms on storage areas can detect unauthorized entry.

h) Keep cylinders in a secure area when on company premises;

i) Allow only authorized persons in container storage areas by using locks, room enclosures, fencing and/or surveillance;

j) Implement the appropriate secondary security requirements outlined in CGA P-50, Standard for site security;

k) Keep an inventory of both full and empty cylinders, check the inventory on a regulator basis, reconcile the inventory with records to evaluate security measures, and investigate any discrepancies;

l) Report incidents involving thefts, misuse, or inventory discrepancies to law enforcement and the supplier if you are a distributor or wholesaler. Provide support in prosecuting any suspects who are caught;

m) Alert employees and customers to the dangers of nitrous oxide abuse and train them on the special security measures they should take to prevent its theft.

18.4 Carriers

Commercial carriers are anyone who transports nitrous oxide by road, rail, sea, or air. It is recommended that commercial carriers:

a) Take physical security steps to prevent the theft of all containers of pure nitrous oxide, denatured product, and mixtures containing nitrous oxide. Do not leave a delivery vehicle unattended without limiting access to nitrous oxide cylinders;

NOTE: The objective of physical security is to deter, detect, and delay a malicious act. Physical security can include fences, walls, and

other barriers that deter and delay someone from reaching the product. Alarms on storage areas can detect unauthorized entry.

b) Keep cylinders in a secure area when on company premises;

c) Allow only authorized persons in container storage areas by using locks, room enclosures, fencing and/or surveillance;

d) Keep an inventory of product within their possession via bill of lading;

e) Report incidents involving thefts, misuse, or inventory discrepancies to law enforcement and the shipper. Provide support in prosecuting any suspects who are caught;

f) Alert employees to the dangers of nitrous oxide abuse and train them on the special security measures they should take to prevent its theft.

18.5 Sales

a) A written sales policy that identifies legitimate applications for nitrous oxide should be established and followed.

b) Provide reasonable assurance that sales are to legitimate users who understand the proper use and safe handling of nitrous oxide.

c) The written policy shall clearly define conditions for cash sales of nitrous oxide (e.g., all cash sales shall be accompanied by a driver's license and a certified document that identifies the company or medical practice that will use the product).

d) Legitimate users are anyone who can substantiate a medical, industrial, food, or other legitimate use for nitrous oxide.

e) Unexpected changes in ordering patterns, cylinder balances or other indications of increased consumption may be indication of illegitimate use at a previously approved customer location.

f) To deter abuse, only sell denatured (rendered unfit for human consumption) product for enhancing performance of internal combustion engines. Package denatured product using connection CGA 660.

Annex 1 – Table References for Nitrous Oxide

Table 1: Identification of nitrous oxide

Chemical formula	N_2O
Synonyms	Laughing gas, dinitogen monoxide
CAS registry number	10024-97-2
EC number	233-032-0
UN number and shipping name	UN 1070, Nitrous oxide [1)] UN, Nitrous oxide, refrigerated liquid
[1)] UN 1070, Nitrous oxide is a liquefied gas. According to the United Nations (UN) Model Regulations for the Transport of Dangerous Goods, it is a high pressure liquefied gas, because its critical temperature is between -58 ºF and 149 ºF (-50 oC and 65 oC)	

Table 2: Properties of nitrous oxide

Color, odor, and taste: tastelessCharacteristics:	Colorless, sweet odor, Non-flammable Supports combustion Oxidizing gas Anaesthetic Non-corrosive Does not form an acid in water	
	SI units	U.S. units
Molecular weight	44.01	
Density of gas at reference conditions 21.1 °C (70 °F) and 101.325 kPa, abs (14.696 psia) 15 °C (59 °F) and 14.696 psia (101.325 kPa, abs)	1.947 kg/m^3 1.88 kg/m^3	0.1146 lb/ft^3 0.1172 lb/ft^3
Density of gas, at –0 °C (32 °F) and 14.696 psia, (101.325 kPa, abs)	1.977 kg/m^3	0. 123 lb/ft^3
Specific gravity of gas compared to air	1.53	
Density of liquid, at 1 atmosphere pressure (101.325 kPa)	1227 kg/m^3	76.6 lb/ft^3
Critical temperature	36.5 °C	97.7 °F
Critical pressure	71.45 bar	1039 psi
Boiling point at 1 atmosphere pressure (1.013 bar)	–88.3 °C	–127 °F
Melting point of solid at 1 atmosphere (1.013 bar)	–90.8 °C	–131.5 °F
Heat of fusion at melting point	148.9 kJ/kg	64 Btu/lb
Heat of vaporization at normal boiling point	376.3 kJ/kg	161.8 Btu/lb
Triple point pressure	8.78 bar, abs	12.7 psia
Triple point temperature	–90.8 °C	–131.5 °F
Heat capacity, C_p, of gas at 59 °F (15 °C) and 1 atm (101.325 kPa)	0.866 kJ/kg °C	0.207 Btu/lb °F
Heat capacity, C_v, of gas at 59 °F (15 °C) and 1 atm (101.325 kPa)	0.665 kJ/kg °C	0.159 Btu/lb °F
Solubility in water at 25 °C (77 °F) at atmospheric pressure	0.59 v/v	

Table 3: Properties of saturated liquid nitrous oxide

Temperature °F	Temperature °C	Vapour pressure psia	Vapour pressure bar, abs	Liquid density lb/gal	Liquid density kg/L
–131.5	–90.82	12.73	0.878		
–127.2	–88.47	14.69	1.013	10.20	1.2228
–110	–78.89	26	1.793	10.36	1.241
–90	–67.78	46	3.172	10.02	1.201
–70	–56.67	73.98	5.102	9.69	1.161
–50	–45.56	111.97	7.722	9.26	1.110
–30	–34.44	166.95	11.514	8.95	1.073
–10	–23.33	239.93	16.547	8.65	1.036
10	–12.22	334.9	23.097	8.18	0.980
32	0	453.7	31.290	7.54	0.904
50	10	589.85	40.679	6.99	0.838
59	15	654.24	45.120	6.83	0.818
70	21.11	759.8	52.400	6.22	0.745
97.5	36.41	1050.5	72.450	3.86	0.452

Table 4: Nitrous oxide

Reference	UN number/Shipping name
UN *Recommendations on the Transport of Dangerous Goods: Model Regulations* (UN *Model Regulations*)	UN No.1070/Nitrous oxide UN No.2201/Nitrous oxide, refrigerated liquid
ISO 10156 *Gas cylinders – Gases and gas mixtures – Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets*	Oxypotential 0.6
NOTE: Due to the oxypotential of nitrous oxide, a fire hazard can be created if the gas comes in contact with flammable gases or combustible substances in presence of an ignition source.	

Table 5: Explosion limits for some typical flammable gases with nitrous oxide at atmospheric conditions

	Lower explosive limit, mole %			Upper explosive limit, mole %		
	in air [1)]	in oxygen [2)]	in nitrous oxide [1)]	in air [1)]	in oxygen [2)]	in nitrous oxide
Methane	4.4	5.15	1.5	16.5	60.5	49.5
Propane	1.7	2.3	0.7	10.9	52.0	27
Hydrogen	4.1	4.0	2.9	77	94.0	82.5
Ammonia	15.4	15	4.4	33.6	79	65

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

[1)] Directive 96/61/EC, *Integrated Pollution Prevention and Control Directive*.

[2)] Directive 2003/87/EC, *Establishing a scheme for greenhouse gas emission allowance trading within the Community* and amending Council Directive 96/61/EC.

Table 6: Directory of limiting characteristics

QVLs			
Limiting characteristics [1)]	Maxima for gaseous and liquid nitrous oxide		
	A [2)]	B	C
Nitrous oxide (liquid)—Min % (v/v)	99	99	99.9974
Ammonia	25		5
Carbon dioxide	300		2
Carbon monoxide	10		1
Halogens (as chlorine)	1		
Hydrocarbons (C1-C5) (liquid)			1
Nitric oxide	1		1
Nitrogen			10
Nitrogen dioxide (liquid)	1		1
Oxygen		10 000	2
Water Dew point °F °C	200 [3] –33 –36		3 –92 –69
Identity	Yes		

NOTES:

1 Units in ppm (v/v) unless otherwise shown

2 A blank indicates no maximum limiting characteristic.

[1)] Below the critical temperature, nitrous oxide exists in two phases. Unless otherwise specified, the sample shall be obtained from the vapor phase of the container or as agreed to by the supplier and the customer.

[2)] For USP quality verification, the percent nitrous oxide shall be defined as the difference between 100% and the percent air.

[3)] The specification for water in the USP/FCC is 150 mg/m^3, which is equivalent to 200 ppm.

Table 7: Typical uses

QVL	Typical uses
A	Medical (USP), Food (FCC)
B	General commercial uses
C	Semiconductor
NOTE: Typical uses defined in this table are not all-inclusive.	

Table 8: Valves on nitrous oxide containers

Valve type	CGA connection
Threaded	326
Yoke	910
Refrigerated liquid withdrawal and fill connection	624
Liquid cylinder vent connection	624
Ultra-high integrity	712

Table 9: Moisture conversion data

Dew point °F	Dew point °C	Moisture content ppm (v/v)	Moisture content mg/L
–130	–90.0	0.1	0.00008
–120	–84.4	0.25	0.00020
–110	–78.9	0.63	0.00051
–105	–76.1	1.00	0.00080
–104	–75.6	1.08	0.00087
–103	–75.0	1.18	0.00095
–102	–74.4	1.29	0.00104
–101	–73.9	1.40	0.00113
–100	–73.3	1.53	0.00123
–99	–72.8	1.66	0.00133
–98	–72.2	1.81	0.00146
–97	–71.7	1.96	0.00158
–96	–71.1	2.15	0.00173
–95	–70.6	2.35	0.00189
–94	–70.0	2.54	0.00204
–93	–69.4	2.76	0.00222
–92	–68.9	3.00	0.00241
–91	–68.3	3.28	0.00264
–90	–67.8	3.53	0.00284
–89	–67.2	3.84	0.00309
–88	–66.7	4.15	0.00334
–87	–66.1	4.50	0.00362
–86	–65.6	4.78	0.00384
–85	–65.0	5.3	0.00426
–84	–64.4	5.7	0.00458
–83	–63.9	6.2	0.00498
–82	–63.3	6.6	0.00531
–81	–62.8	7.2	0.00579
–80	–62.2	7.8	0.00627
–79	–61.7	8.4	0.00675
–78	–61.1	9.1	0.00732
–77	–60.6	9.8	0.00788
–76	–60.0	10.5	0.00844
–75	–59.4	11.4	0.00917
–74	–58.9	12.3	0.00989
–73	–58.3	13.3	0.01069
–72	–57.8	14.3	0.01150
–71	–52.2	15.4	0.01238
–70	–56.7	16.6	0.01335
–69	–56.1	17.9	0.01439
–68	–55.6	19.2	0.01544
–67	–55.0	20.6	0.01656
–66	–54.4	22.1	0.01777
–65	–53.9	23.6	0.01897
–64	–53.3	25.6	0.02058
–63	–52.8	27.5	0.02211
–62	–52.2	29.4	0.02364
–61	–51.7	31.7	0.02549
–60	–51.1	34.0	0.02734
–59	–50.6	36.5	0.02935
–58	–50.0	39.0	0.03136
–57	–49.4	41.8	0.03361

–56	–48.9	44.6	0.03586
–55	–48.3	48.0	0.03859
–54	–47.8	51	0.04100
–53	–47.2	55	0.04220
–52	–46.7	59	0.04744
–51	–46.1	62	0.04985
–50	–45.6	67	0.05387
–49	–45.0	72	0.05789
–48	–44.4	76	0.06110
–47	–43.9	82	0.06593
–46	–43.3	87	0.06994
–45	–42.8	92	0.07397
–44	–42.2	98	0.07879
–43	–41.7	105	0.08442
–42	–41.1	113	0.09085
–41	–40.6	119	0.09568
–40	–40.0	128	0.10291
–39	–39.4	136	0.10934
–38	–38.9	144	0.11578
–37	–38.3	153	0.12301
–36	–37.8	164	0.13186
–35	–37.2	174	0.13990
–34	–36.7	185	0.14874
–33	–36.1	196	0.15758
–32	–35.6	210	0.16884
–31	–35.0	222	0.17849
–30	–34.4	235	0.18894
–29	–33.9	250	0.20100
–28	–33.3	265	0.21306
–27	–32.8	283	0.22753
–26	–32.2	300	0.24120
–25	–31.7	317	0.25487
–24	–31.1	338	0.27175
–23	–30.6	358	0.28783
–22	–30.0	378	0.30391
–21	–29.4	400	0.32160
–20	–28.9	422	0.33929
–19	–28.3	448	0.36019
–18	–27.8	475	0.38190
–17	–27.2	500	0.40200
–16	–26.7	530	0.42612
–15	–26.1	560	0.45024
–14	–25.6	590	0.47436
–13	–25.0	630	0.50652
–12	–24.4	660	0.53064
–11	–23.9	700	0.56280
–10	–23.3	740	0.59496
–9	–22.8	780	0.62712
–8	–22.2	820	0.65928
–7	–21.7	870	0.69948
–6	–21.1	920	0.73968
–5	–20.6	970	0.77988
–4	–20.0	1020	0.82008
0	–17.8	1270	1.02108

Table 10: Assay Conversion Data

Pressure higher than control cylinder		Nitrous oxide assay of liquid phase
psi	kPa	%
0	0	99.9+
5	34.5	99.9
10	69.0	99.8
15	103	99.7
20	138	99.6
25	172	99.5
30	207	99.4
35	241	99.3
40	276	99.2
45	310	99.1
50	345	99.0

Table 11: Maximum filling ratio of nitrous oxide cylinders

Minimum cylinder test pressure, bar	Maximum filling ratio
180	0.68
225	0.74
250	0.75 [1)]

[1)] This means, for example, that a cylinder with a 10 L capacity and test pressure of 250 bar (3625 psi) may be filled with 7.5 kg of nitrous oxide.

Annex 2: Nitrous Oxide Figures

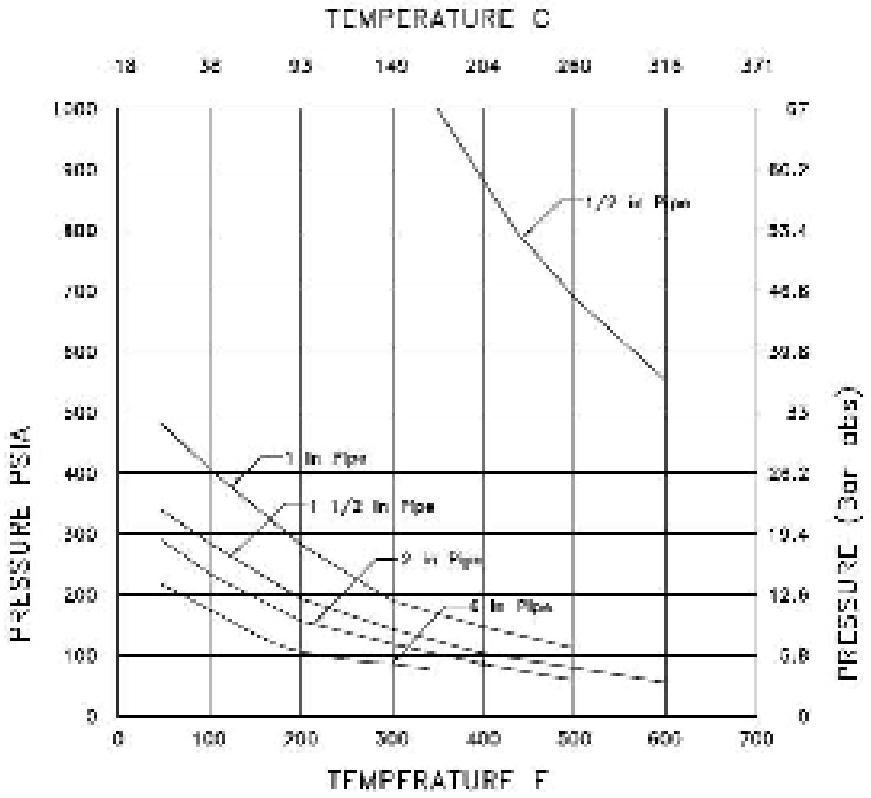
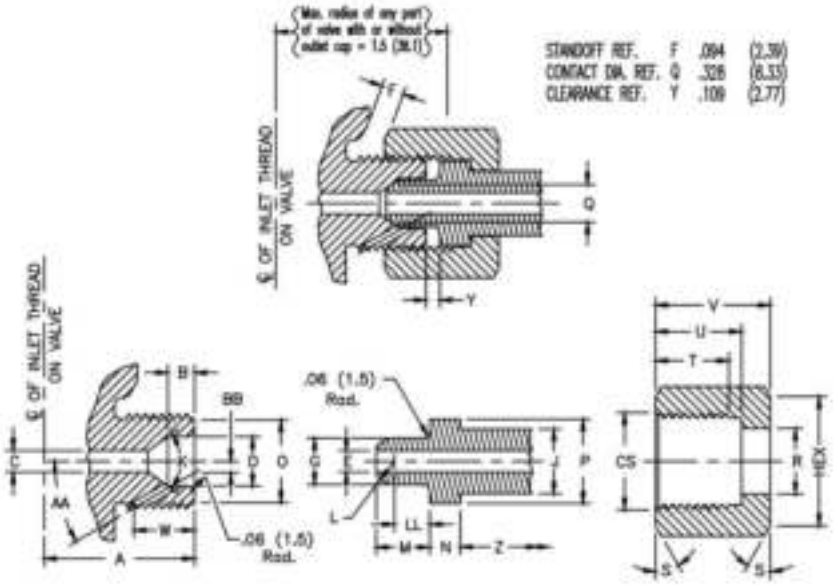


Figure 1: Propagation threshold for nitrous oxide

CONNECTION NO. 326

.825-14NGO-RH-EXT (Small Round Nipple)

STANDARD CYLINDER VALVE OUTLET CONNECTION FOR
PRESSURES UP TO 3000 psi (20 680 kPa) FOR
Nitrous oxide (R744a)



VALVE OUTLET				NIPPLE ②				HEXAGON NUT			
THREAD	.825–14NGO-RH-EXT			DRILL DIA.	E	.125 ±.015	(3.18 ±0.38)	THREAD	.830-14NGO-RH-INT		
MAJOR DIA.		.8258-.8200	(20.965-20.828)	NOSE DIA.	G	.405	(10.29)	MINOR DIA.		.7527-.7604	(19.119-19.314)
PITCH DIA.		.7786-.7750	(19.776-19.685)	SHANK DIA.	J	.582-.557	(14.27-14.15)	PITCH DIA.		.7836-.7872	(19.904-19.994)
MINOR DIA.		.7374 Max.	(18.729) Max.	NOSE RADIUS	L	.295-.299	(5.21-5.88)	MAJOR DIA.		.8380 Min.	(21.892) Min.
LENGTH	A	1.312 Max.	(33.32) Max.	NOSE LENGTH	M	.469	(11.81)	HEX		1-1/8	(28.6)
BORE DEPTH	B	.234 ±.015	(5.94 ±0.38)	SHOULDER LENGTH	N	.280-.281	(6.76-7.14)	HOLE DIA.	R	.567-.572	(14.40-14.53)
DRILL DIA.	C	.187 ±.360	(4.75 ±1.52)	SHOULDER DIA.	P	.730	(18.67)	CHAMFER DIA.	S	38° x 1.125	(28.58)
BORE DIA.	D	.430	(10.92)	SHANK LENGTH	Z	.38 Min.	(9.1) Min.	FULL THREAD	T	.562 Min.	(14.27) Min.
ANGLE	K	70°		L LOCATION	LL	.295-.312	(7.24-7.92)	BORE DEPTH	U	.758 ±.015	(19.85 ±0.38)
CHAMFER DIA.	O	45° x .719	(18.29)					LENGTH	V	.937 Min.	(23.80) Min.
FULL THREAD	W	.531 Min.	(13.49) Min.					C'SINK DIA.	CS	90° x.844	(21.44)
BLEED HOLE① DIA.		.093	(2.36)								
HOLE① ANGLE	AA	30°									
OFFSET	BB	.099	(2.51)								

All dimensions are in inches (millimeters)

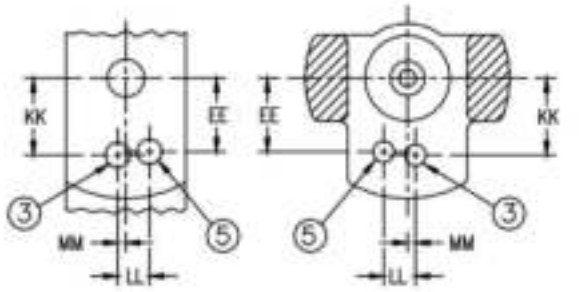
① At least one bleed hole .093 (2.36) diameter located as shown, directed downward, outboard of point of nose contact and inboard of threaded end of engaged nut.
② Nipple may be made from 11/16 (17.5) hex material.

Figure 2: CGA 326 connection

CONNECTION NO. 910

PIN-INDEXED YOKE, PINS 3-5

STANDARD MEDICAL CYLINDER VALVE YOKE CONNECTION FOR
PRESSURES UP TO 3000 psi (20 680 kPa) FOR
Nitrous oxide



DIMEN-SIONS	INCHES	MM
EE	.535 ±.003	13.6 ±.07
KK	.559 ±.003	14.2 ±.07
LL	.233 ±.003	5.9 ±.07
MM	.059 ±.005	1.5 ±.15

Figure 3: CGA Connection No. 910

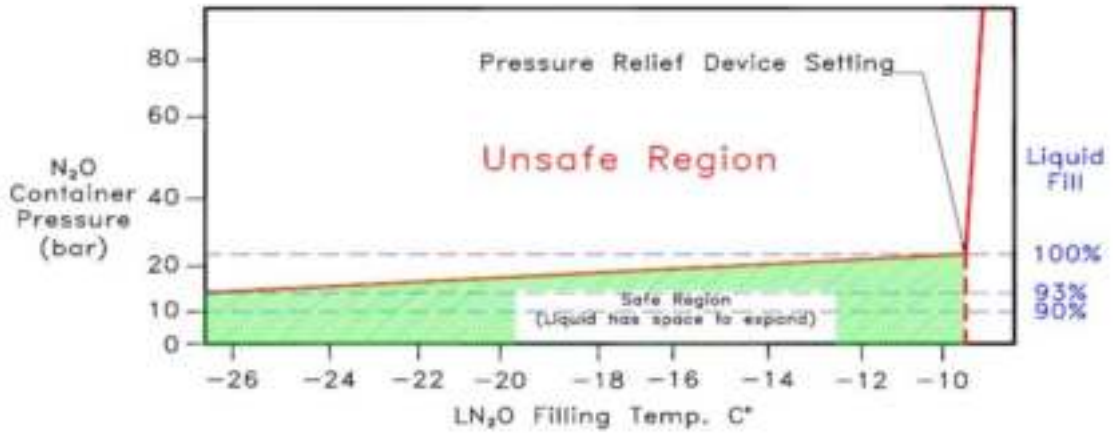


Figure 4: Safe filling volumes for 319 psi (22 bar) nitrous oxide storage tanks

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