

CGA G-8.3—2019

**SAFE PRACTICES FOR
STORAGE AND HANDLING
OF NITROUS OXIDE**

THIRD EDITION

PREFACE

As part of a program of harmonization of industry standards, the Compressed Gas Association (CGA) has issued CGA G-8.3, *Safe Practices for Storage and Handling of Nitrous Oxide*, jointly produced by members of the International Harmonization Council and originally published by the European Industrial Gases Association (EIGA) as EIGA Doc 176, *Safe Practices for Storage and Handling of Nitrous Oxide*.

This publication is intended as an international harmonized standard for the worldwide use and application of all members of the Asia Industrial Gases Association (AIGA), Compressed Gas Association (CGA), European Industrial Gases Association (EIGA), and Japan Industrial and Medical Gases Association (JIMGA). Each association's technical content is identical, except for regional regulatory requirements and minor changes in formatting and spelling.

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Bulk Distribution Equipment and Standards Committee

NOTE—Technical changes from the previous edition are underlined.

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1 Introduction

Nitrous oxide (N₂O) has been produced and distributed by the industrial gases industry for many years. It is mainly used for medical purposes (anesthesia), food packaging, and electronic industries.

Incidents such as violent decomposition of nitrous oxide and the rupture of nitrous oxide tanks have occurred at production, storage, and distribution facilities. In addition, nitrous oxide gas, in elevated concentrations, can cause health effects in personnel, which shall be prevented.

This publication describes the properties and hazards of nitrous oxide. On this basis, the principles and relevant details of safe storage and distribution of nitrous oxide are considered. Most severe incidents have been caused by insufficient understanding of the properties of nitrous oxide.

Regulatory requirements for medical applications shall also be followed.

2 Scope

This publication 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. The design and installation requirements and recommendations included in this publication apply only to installations begun after the publication date. Some design and installation requirements shall be considered for existing installations where specified in this publication. These requirements shall be completed within 2 years of publication of this standard.

Operational requirements and recommendations should be considered for existing installations. This publication does not cover the manufacturing of nitrous oxide or quality control and analysis procedures. Refer to CGA G-8.4, *Safe Practices for the Production of Nitrous Oxide from Ammonium Nitrate* [1].¹

3 Definitions

For the purposes of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

3.2 Technical definitions

3.2.1 Authorized person

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

¹ References are shown by bracketed numbers and are listed in order of appearance in the reference section.

3.2.2 Bundle (of cylinders)

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

3.2.3 Cryogenic receptacle

Transportable thermally insulated pressure receptacle for refrigerated liquid gas of a capacity of not more than 264 gal (1000 L).

3.2.4 Cylinder

Transportable pressure receptacle of a water capacity not exceeding 40 gal (150 L).

3.2.5 Decomposition

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

3.2.6 Filling degree

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.

3.2.7 Filling ratio

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.

3.2.8 Liquefied gas

Gas that when packaged under pressure for carriage is partially liquid at temperatures above –58 °F (–50 °C).

3.2.9 Maximum allowable working pressure (MAWP)

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.

3.2.10 Minimum design metal temperature (MDMT)

Lowest temperature at which a pressure receptacle is designed to safely operate at maximum allowable working pressure (MAWP).

3.2.11 Net positive suction head (NPSH)

Total head of liquid at the inlet to a pump above the equilibrium pressure head.

3.2.12 Oxypotential

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.

3.2.13 Pressure

psi (bar or kPa) 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).²

3.2.14 Pressure receptacle

Collective term that includes cryogenic receptacles, cylinders, and bundles.

3.2.15 Knowledgeable nitrous oxide technician

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.

² kPa shall indicate gauge pressure unless otherwise noted as (kPa, abs) for absolute pressure or (kPa, differential) for differential pressure. All kPa values are rounded off per CGA P-11, *Guideline for Metric Practice in the Compressed Gas Industry* [2].

3.2.16 Refrigerated liquid gas

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

3.2.17 Stationary tank

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

3.2.18 Tank

Collective term that includes stationary tanks and transport tanks.

3.2.19 Transport tank

Transportable thermally insulated tank for refrigerated liquid gas having a capacity of more than 450 L (118 gal).

4 Properties and hazards

For nitrous oxide identification and properties, see Tables 1, 2, and 3.

Table 1—Identification of nitrous oxide

Chemical formula	N ₂ O
Synonyms	Laughing gas, dinitrogen monoxide
CAS registry number	10024-97-2
EC number	233-032-0
UN number and shipping name	UN 1070, Nitrous oxide ¹⁾ UN 2201, Nitrous oxide, refrigerated liquid
¹⁾ UN 1070, Nitrous oxide is a liquefied gas. According to the United Nations (UN) <i>Model Regulations for the Transport of Dangerous Goods</i> , it is a high pressure liquefied gas, because its critical temperature is between –58 °F and 149 °F (–50 °C and 65 °C) [2].	

4.1 Physical properties and hazards

Table 2—Properties of nitrous oxide

Color, odor, and taste:	Colorless, sweet odor, tasteless	
Characteristics:	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)	1.947 kg/m ³	0.1146 lb/ft ³
15 °C (59 °F) and 14.696 psia (101.325 kPa, abs)	1.88 kg/m 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 [4, 5]

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

4.1.1 Specific hazards

Personnel handling nitrous oxide should 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

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.

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.

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 $^{\circ}\text{F}$ (62 kPa per $^{\circ}\text{C}$). When the volume becomes liquid full, the hydrostatic pressure increases at a rate of 850 psi per $^{\circ}\text{F}$ (10 550 kPa per $^{\circ}\text{C}$). 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

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. In addition, gaseous nitrous oxide under atmospheric conditions is 1.5 times heavier than air and therefore can be found in greater concentrations at lower levels, potentially displacing oxygen in confined spaces and causing an asphyxiation hazard. Nitrous oxide exposure levels should be controlled so that the health and safety risks to personnel are minimized to acceptable levels, i.e., less than the relevant OELs. Nitrous oxide in the gaseous state is colorless and has a sweet odor. Ventilation systems, if required, should be designed to exhaust from the lowest level and allow make-up air to enter at a higher point.

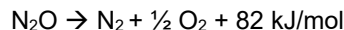
Liquid nitrous oxide forms a mixture of extremely cold liquid and gas when discharged to atmospheric pressure. Nitrous oxide liquid, or cold vapor, that comes into contact with the skin or mouth can cause freezing or severe frostbite. If frostbite occurs, seek medical attention. Do not rub the area.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

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 in U.S. and Canada from 260 psi to 315 psi at temperatures of 0°F to 10°F and in Europe 20 bar to 25 bar at temperatures of -20°C to -13°C .

4.2 Chemical properties and hazards

4.2.1 Oxidizing ability

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. See 4.3.2.



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

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 Table 4.

Table 4—Nitrous oxide

Reference	UN number/Shipping name
UN <i>Recommendations on the Transport of Dangerous Goods: Model Regulations</i> (UN <i>Model Regulations</i>) [3]	UN No.1070/Nitrous oxide UN No.2201/Nitrous oxide, refrigerated liquid
ISO 10156 <i>Gas cylinders – Gases and gas mixtures – Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets</i> [6]	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.	

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.

4.2.1.2 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, see 4.3.3.

4.2.1.4 Flammable gases

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

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

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. For safety precautions with respect to flammable gases, see 5.11.

¹⁾ Directive 96/61/EC, *Integrated Pollution Prevention and Control Directive* [7].

²⁾ Directive 2003/87/EC, *Establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC* [8].

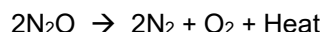
4.2.2 Stability

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.

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.

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 [9].

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



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

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 [9].

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 [9].

4.2.3 Decomposition sources

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

- field decomposition sources:
 - static discharge

- spark (due to metal to metal contact)
- adiabatic heat of compression
- secondary exothermic chemical reaction (due to contamination)
- welding/brazing
- heat generated by a dry running pump
- electric immersion heater
- internal impact
- external source of heat; and
- laboratory decomposition sources:
 - electric spark
 - exploding wire
 - glowing wire
 - blasting cap
 - heat of compression.

4.2.3.1 Temperature and pressure

Nitrous oxide decomposition will not propagate at relatively low temperatures and pressures, see 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:

- nothing happens;
- decomposition is initiated, but the reaction is quenched (below the propagation threshold); and
- decomposition is initiated and the decomposition front propagates through the pipe or vessel (above the propagation threshold).

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 [9].

4.2.3.2 Vessel and pipe geometry

In order for a 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 Figure 1.

4.2.3.3 Propagation threshold

The potential for an explosive decomposition to take place is more closely coupled to the quenching characteristics (temperature, pressure, container geometry) of the nitrous oxide system than with the initial decomposition energy [10].

The propagation threshold shown in Figure 1 should be considered as an approximation, but can give the user some indication, if they are handling nitrous oxide 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.