Safetygram #20

Nitrous Oxide (N_2O)

General

Nitrous oxide is a colorless, noncorrosive, nontoxic, liquefied compressed gas with a faintly sweet odor and taste. It is packaged in high-pressure cylinders as a liquid under its own vapor pressure of 5,238 kPa @ 21.1ºC (759.7 psia @ 70ºF). Nitrous oxide is nonflammable but is an oxidizer and can support and accelerate combustion. Several different grades of nitrous oxide are available to support different applications. The largest markets for nitrous oxide are in the medical and dental industries as an anesthetic, which uses medical-grade product. Industrial-grade product is used in food processing as a propellant and to a limited extent in auto racing to enhance engine performance. High-purity grades are used in analytical applications and very-high-purity grades are used in the manufacture of semiconductors and other microelectronics devices. Table 1 lists the physical and chemical properties of nitrous oxide.

Manufacture

The primary manufacturing method for the production of nitrous oxide is the thermal decomposition of ammonium nitrate. Other methods of manufacture include the reduction of nitrates and nitrites, thermal decomposition of hydroxylamine, and as a by-product from adipic acid production. Once produced, the nitrous oxide is purified and dried.

Safety Considerations

Health Effects

Acute Effects

Nitrous oxide is a simple asphyxiant and a weak narcotic. Air hunger, dizziness, confusion, headaches, nausea, vomiting, and loss of consciousness or death may occur if nitrous oxide is present in quantities sufficient to dilute the oxygen concentration in air. Overexposure creates an altered (euphoric or excited) mental state. Neurobehavioral impairment is usually evident when nitrous oxide exposure levels are several hundred to several thousand ppm.

Exposure to the liquid can cause frostbite.

Chronic Effects

Long-term exposure to nitrous oxide has been associated with neuropathy. Increased rates of spontaneous abortion (dentist's wives and female dental assistants) and congenital anomalies in offspring (female dental assistants) have been reported. Epidemiological studies have not firmly established a cause-and-effect relationship, but exposure to the gas should be minimized.

Exposure Limits

ACGIH	TLV-TWA	50 ppm
OSHA	PEL (TWA)	25 ppm
NIOSH	IDLH	Not Established

Table 1 Physical and Chemical Properties

Chemical Formula	N_2O
Molecular Weight	44.013
Boiling Point	−88.56ºC (−127.4ºF)
Melting Point	−93.06ºC (−131.5ºF)
Vapor Pressure	5,238 kPa @ 21.1ºC (759.7 psia @ 70ºF)
Specific Gravity (air = 1)	1.53
Gas Density (21.1ºC (70ºF) @1atm)	1.836 kg/m^3 (0.1146 lb/ft^3)
Liquid Density (saturation pressure at 0ºC)	0.913 kg/l (57.0 lb/ft^3)
Specific Volume (21.1ºC (70ºF) @ 1atm)	0.5447 m^3/kg (8.738 ft^3/lb)
Critical Temperature	36.4ºC (97.6ºF)
Critical Pressure	7,254 kPa (1,052.2 psia)

Responsible Care®
Good Chemistry at Work

Warning: The misuse of nitrous oxide can cause death by reducing the level of oxygen below that required to support life. Nitrous oxide abuse can impair an individual's ability to make and implement life-sustaining decisions. For more information on nitrous oxide abuse, contact the Compressed Gas Association at the following website, http://www.cganet.com/N2O/default.htm.

Reactivity

Nitrous oxide in its liquid and gaseous forms is a stable compound. Nitrous oxide is nonflammable but is an oxidizer that can support and accelerate combustion. Ignition of combustibles may be easier to initiate in a nitrous oxide enriched atmosphere. When handling oxidizers, it is important to understand fire chemistry and be aware of the unique mechanisms for ignition that can be encountered. The speed of combustion will be increased and the heat of the fire will be greater than if the combustion was in air. Nitrous oxide decomposes exothermally under high temperature (649ºC, 1200ºF) without the presence of a catalyst, and the decomposition can be self-sustaining. Within specific temperature and pressure conditions, an explosive decomposition reaction can occur. Nitrous oxide is capable of auto-decomposition, but under most conditions an ignition source is required to initiate the reaction. Experimentally, ignition energies as low as 0.14 joules have initiated decomposition. Some ignition sources that may be encountered in the workplace are static discharge, sparks from metal-to-metal contact, adiabatic heat of compression, and external heat sources (such as welding on nitrous oxide lines). Incorporating a heat sink to remove the heat can prevent propagation of a decomposition reaction. Vessel geometries and impurities can influence the chance of an explosive decomposition. Testing has shown that the decomposition reaction is limited to the vapor phase.

Potential for Fire

Let's look at the basic fire triangle. All three legs of the triangle must be present to produce a fire—a fuel, an oxidizer, and an ignition source. If asked to name some fuels, materials like wood, coal, oil, and gas would be mentioned. But would anyone list materials like aluminum, steel, stainless steel? What is the primary reason we can light a piece of wood with a match but not a steel rod? The ignition temperature of the wood is much lower than that of the steel rod and the heat from the match is sufficient for ignition. The presence of an oxidizer influences fire chemistry: as the oxidizer concentration increases, the autoignition temperature decreases. Autoignition temperature is the lowest temperature required to ignite a material in the absence of a flame or spark. So materials that cannot be ignited in normal air may burn readily in an oxidizer atmosphere. With this in mind, it is easy to see that in an oxidizer system we have two legs of the fire triangle present—the oxidizer and the system's materials of construction, which are the fuel. All that is required for an ignition is an energy source.

Now let's consider ignition sources. Typical sources of ignition are fire, open flames, sparks, cigarettes, etc. But that is in the world of normal air, not oxidizers. In oxidizer systems gas velocity, friction, adiabatic heat, or contamination are also potential ignition sources.

In the case of gas velocity, it is not the flow of gas that can cause ignition, but a particle that has been propelled by the gas and impacts the system with sufficient force to ignite. The heat generated may be sufficient to start a fire, depending on the material impacted. Friction from a component malfunctioning or operating poorly can generate heat. Friction between two materials generates fine particles, which may ignite from the heat generated.

Adiabatic heat of compression is a unique form of the heat of compression. Simple heat of compression causes the temperature of a system to rise. An example would be a tire pump. The barrel or compression chamber builds heat as the pump compresses air. This process occurs relatively slowly and the system takes on the heat. Adiabatic heat is caused by the rapid pressurization of a system where the gas absorbs the energy and the gas temperature rises. The compression is so rapid the heat is not transferred to the system. The heating occurs at the point of compression or the point where the flow of gas is stopped, such as at a valve or regulator seat. Depending on the material in use where the hot gas impinges, the heat may be sufficient to ignite the material.

All of these energy sources can be enhanced by the presence of a contaminant. Contaminants are typically easier to ignite than the components of the system. If they react with the oxidizer, they may generate sufficient heat to propagate a reaction to the system.

Pressure

Nitrous oxide is shipped as both a liquefied gas and a refrigerated liquid. The cylinders contain both liquid and vapor phases. In the case of the liquefied compressed gas, the vapor pressure will be directly affected by temperature. The higher or lower the temperature, the higher or lower the pressure. In the case of the refrigerated liquid, it will be transported in a cryogenic liquid cylinder. The pressure in this type of container is determined by the amount of liquid that converts to a gas and collects in the headspace. When the pressure reaches the set point of the pressure relief valve, it will vent until the pressure drops below the set point and the pressure relief valve closes. These cylinders typically operate within a pressure range of 700 to 2,400 kPa (100 to 350 psig). The amount of product contained in either of these types of cylinders cannot be determined by a pressure reading. Cylinder content can only be determined by product weight. The liquid phase of a gas must never be trapped within a system without a relief device being present. If no relief is provided and the system becomes liquid full, the liquid can begin to generate hydrostatic pressures as the liquid warms that can quickly cause catastrophic failure of the system. Cylinders and systems containing pressure hold a large amount of stored energy and must be handled with care to prevent damage that may cause an uncontrolled release of this pressure. Such releases can result in injury or death. For more information on the proper handling of liquefied compressed gases, refer to Air Products' Safetygram-30, "Handling Liquefied Compressed Gas." To understand how cryogenic liquid cylinders operate, consult Air Products' Safetygram-27, "Cryogenic Liquid Containers."

Containers

Nitrous oxide is shipped and stored as a liquefied compressed gas or as a refrigerated liquid. Containers are designed and manufactured according to the applicable codes for the region in which they will be transported. These codes are established by organizations that include the Department of Transportation in the United States and the ADR in the European Union. The codes will cite the specific specifications required for the pressures and temperatures involved. These specifications will include the material of construction, method of manufacture, testing, products permitted for filling and other details.

Cylinders

A typical cylinder is a hollow tube with a closed base that permits the cylinder to stand upright. The opposite end is tapered to a small opening that is threaded to accommodate the installation of a valve. A threaded neck ring is attached to the threaded end to allow a protective cylinder valve cap to be installed. Carbon steel and aluminum are the primary materials of construction for nitrous oxide cylinders.

Nitrous oxide is also available in large skid-mounted cylinders (referred to as "Y" cylinders) that contain 272 kg (600 pounds) of product. The "Y" cylinder valve is equipped with a dip tube that, depending on orientation, will allow either gas or liquid withdrawal. When the valve outlet faces up, vapor can be withdrawn. When the valve outlet is oriented down, liquid is available. (See Figure 1.) For more information on the safe handling of cylinders, see Air Products' Safetygram-10, "Handling, Storage, and Use of Compressed Gas Cylinders."

Cryogenic Liquid Containers

Cryogenic liquid containers, also referred to as liquid cylinders, are double walled, vacuum vessels with multilayer insulation in the vacuum space. They are designed for the reliable and economic transportation of liquefied gases at cryogenic temperatures, typically colder than -90ºC (–130ºF). The primary advantage of a cryogenic liquid cylinder is that it contains a large volume of product at a relatively low pressure. Nitrous oxide cryogenic liquid cylinders are equipped with relief valves set at 2,400 kPa (350 psig). Air Products' Safetygram-27, "Cryogenic Liquid Containers," provides information on the operation of cryogenic liquid cylinders and details proper techniques for handling. Cryogenic liquid cylinders are very heavy and require special handling equipment.

Valves, Connections, and Pressure Relief Devices

Valves

Nitrous oxide containers are supplied with a variety of valves dependant upon the grade and application of the product. Industrial and medical grades are typically equipped with pressure-seal or backseating valves. This includes cryogenic liquid cylinders containing nitrous oxide. Electronic grades of product are usually equipped with a metal diaphragm valve of which several types are used. Air Products uses three different styles of diaphragm valves in nitrous oxide service. They are the spring-loaded diaphragm, tied diaphragm and pneumatic tied diaphragm. Each cylinder valve has its own specific operating requirements. These include the correct way to open and close the valve. Please see Air Products' Safetygram-23, "Cylinder Valves," for identifying features, detailed operating instructions, strengths and weaknesses, and cutaway drawings. If you are not sure which valve is on your container, contact your supplier for verification.

Connections

Table 2 shows the specific connections used for various applications in several regions of the world.

Gas cylinder valve connections fall into three basic categories. The bullet nose, also called bull nose, connections depend on the metal-to-metal seal of a male nipple that is pulled into a female socket. The second type utilizes a gasket between the interface of the nipple and the valve connection face. The yoke fitting is a variation of the gasket, fitting that utilizes a yoke to tighten the connection instead of connection threads. These are most commonly found on small medical cylinders. The third connection is the ultrahigh-integrity connections. These are also call Diameter Index Safety System or DISS connections. These connections also use a gasket, but it is an annealed nickel gasket that is pinched between two highly polished toroidal beads, one on the valve and one on the nipple. These connections offer superior leak integrity when compared to the other connections and are used in applications that demand the highest levels of purity. For a more detailed explanation of how cylinder valve connections work, recommended closing torques, and cutaway diagrams, refer to Air Products' Safetygram-31, "Cylinder Valve Connections."

Pressure Relief Devices

Regulations in some regions of the world do not allow the use of pressure relief devices on high-pressure cylinders containing liquefied compressed nitrous oxide. In other regions, such as, North America, pressure relief devices are required by the regulations. When a pressure relief device is required on a high-pressure cylinder containing nitrous oxide, a frangible disk rated at not more than 5/3 the working pressure of the cylinder is required.

Cryogenic liquid containers use a pressure relief valve. This is a spring-loaded device with a set pressure of 2,400 kPa (350 psig). When the head pressure accumulates to a pressure that exceeds this setting, the spring is compressed, allowing the excess pressure to vent. When the pressure drops low enough, the valve resets and stops the venting. Venting of cryogenic liquid containers, is normal. See Air Products' Safetygram-27, "Cryogenic Liquid Containers," for information on the operation of cryogenic liquid cylinders and their components.

Storage and Handling

Always store and handle cylinders containing compressed and liquified gases in accordance with international or local regulations, such as ISO 11625, "Gas Cylinders–Safe Handleing." For more information, refer to Air Products' Safetygram-10, "Handling, Storage, and Use of Compressed Gas Cylinders." Personnel must know and understand the properties, proper uses, and safety precautions for the specific product before using the product or associated equipment.

Storage

Cylinders should be secured in an upright position and stored in a well-ventilated area protected from the weather. The storage area should be secure with limited access. Additional security may need to be provided for storage areas since nitrous oxide is subject to theft for illegal use. See Compressed Gas Association Guideline, "Nitrous Oxide Sales and Security Recommended Guidelines," for further information. Storage area temperatures should not exceed 52ºC (125ºF) and should be free from combustible materials and free from ignition sources. Storage should be away from heavily traveled areas and emergency exits. Avoid areas where salt or other corrosive materials are present. Valve protection caps and valve outlet seals must remain on unconnected cylinders. When returning a cylinder

Figure 1

H_2O Y Cylinder

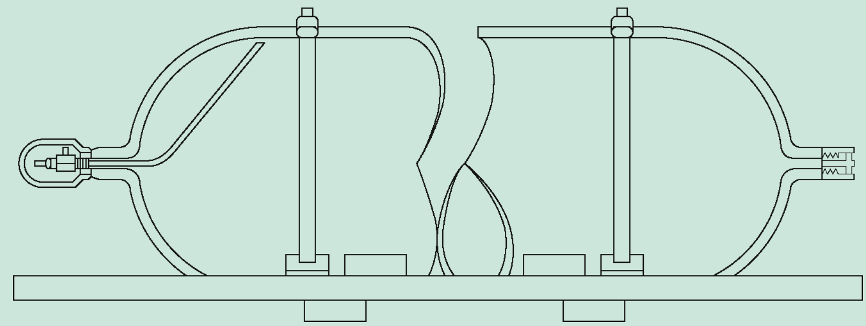

Table 2

Type of Connection	France NF-E 29-650	Germany DIN 477	Japan JIS-B-8246	United Kingdom BS 341	United States CGA-V-1
Threaded	G	8		13	326
Yoke			5		910
Ultrahigh Integrity					712

to storage, the valve outlet seal must be installed leak-tight. Separate full and empty cylinders. Avoid excess inventory and storage time. Visually inspect stored cylinders on a routine basis, at least weekly, for any indication of leakage or other problems. Use a first-in, first-out, inventory system and keep up-to-date inventory records. The use of “FULL,” “IN USE,” and “EMPTY” tags is highly recommended. Storage areas must be posted with the proper signage, such as, “No Smoking,” “No Open Flames,” or NFPA 704 ratings.

Handling and Use

High-Pressure Gas Cylinders

Use only in well-ventilated areas. Use a suitable handcart designed for cylinder movement. Do not drag, roll, or slide cylinders. Never attempt to lift a cylinder by its cap. Secure cylinders at all times during storage. Transport and use an adjustable strap wrench to remove overly tight cylinder caps. Never insert anything into the cap holes to assist in cap removal.

Rapid withdrawal of product (vapor phase) from a cylinder will cause the temperature of the remaining liquid to drop. This may cause sweating or frosting on the outside of the cylinder at the liquid level. The cold temperature of the liquid will decrease the vapor pressure in the cylinder. This may reduce product withdrawal below the requirements of the process or may reverse the flow and allow other process products to backflow into the cylinder. This is an extremely dangerous situation and must be prevented. Extreme care must also be used in compensating for temperature and flow drops. For more detailed information on the use of liquefied compressed gases, refer to Air Products' Safetygram–30 “Handling Liquefied Compressed Gas.” In cases where cylinders are manifolded, users must be aware of the dangers of product migration. For more information about product migration, refer to Air Products' Safetygram-38 “Product Migration of Liquefied Compressed Gases in Manifolded Systems.” Ensure that the cylinder valve is properly closed, valve outlet seal has been reinstalled leak-tight, and valve protection cap is installed before returning to storage, moving, or shipping the cylinder.

Cryogenic Liquid Cylinders

Use only in well-ventilated areas. These containers are not intended for long storage. Storage should be in a well-ventilated area, preferably outside because of the potential for normal venting. When moving cryogenic liquid cylinders, use a cart specifically designed for these containers. Do not drag, roll, or slide cylinders. Use a pressure-reducing regulator or separate control valve to discharge gas from the cylinder. Never apply flame or local heat to any part of a cylinder. Do not allow any part of the cylinder to exceed 52ºC (125ºF). High temperature may cause damage to the cylinder or activation of the pressure relief device if present. If user experiences any difficulty operating the cylinder valve, discontinue use and contact the supplier. Gas phase product is provided by the evaporation of liquid via a vaporizer located between the inner and outer shells of the container. These vaporizers have a limited flow capacity, and care must be taken not to withdraw product at a rate that would overwhelm the vaporizer and allow very cold vapor or liquid to enter the end user's system. Air Products' Safetygram-27, “Cryogenic Liquid Containers,” provides details on the handling and use of these containers.

Disposal

Return unused product to the supplier. Disposal of nitrous oxide must be done in an environmentally acceptable manner in compliance with all applicable national and local codes.

System Design and Maintenance

Systems must be designed with the special considerations required for the safe handling of oxidizers. Oxidizer systems require special cleaning to prevent contact with any incompatible material or any contamination that could provide ignition mechanisms. There are several documents available to help design systems and equipment for the safe handling of oxidizers. They include but are not limited to Compressed Gas Association Pamphlet G-4.4, “Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems,” and the ASTM International Standard G 88, “Designing Systems for Oxygen Service.” The European Industrial Gas Association and the International Standards Organizations also publish related documents including IGC Doc 13/02/E, “Oxygen Pipeline Systems.”

Designing and building these systems requires an intimate knowledge of oxidizers and how they react with the materials they contact. Basic design considerations include but are not limited to control and avoidance of unnecessarily high temperatures and pressures; cleanliness; elimination of particles; minimization of heat of compression; avoidance of friction and galling; minimization of resonance with direct flow paths; use of hardware that has a proven history in oxidizer service; minimizing available fuel and oxidizer through materials selection and system volume; anticipation of indirect oxidizer exposure from system failures; and design of systems to manage fires using techniques, such as fire stops and automatic extinguisher systems. The first step in constructing any system for handling oxidizers should be to consult your supplier.

Personal Protective Equipment (minimum requirements)

General Cylinder Handling

Safety glasses with side shields, leather gloves, and safety shoes.

System Operations

Safety glasses with side shields, leather gloves, and safety shoes. If exposure to liquid phase is possible or when handling the refrigerated liquid, add a long-sleeved shirt and face shield.

Emergency Operations

Same requirements as system operations with the addition of supplied air. If an airline mask is used, an escape pack must also be worn.

First Aid

Skin and Eye Contact

Frostbite (contact with liquid)—Remove contaminated clothing; warm with lukewarm water; blot dry (DO NOT RUB); cover with a clean, sterile dressing; and seek medical attention.

Inhalation

Move exposed personnel to uncontaminated area. If victim is not breathing, perform artificial respiration. If breathing is difficult, give oxygen. Seek medical assistance.

Fire Fighting

Nitrous oxide is not flammable but is an oxidizer, which means it can support and enhance combustion. Violent decomposition can also occur in case of fire. Cylinders exposed to fire may have their pressure relief devices activate, if present, and the cylinders themselves may fail, especially aluminum cylinders. From a safe distance, cool the cylinders with a water spray. Use an extinguishing medium appropriate for the surrounding fire.

Transportation Information

Shipping Name

Nitrous Oxide, 2.2, UN1070, Nonflammable Gas

Hazard Class

2.2

Identification Number

UN1070

Shipping Labels

Nonflammable Gas (primary), Oxidizer

Placard

Nonflammable Gas

AIR PRODUCTS

Emergency Response System

- Call: +1-800-523-9374
  (Continental U.S. and Puerto Rico)
- Call: +1-610-481-7711 (other locations)
- 24 hours a day, 7 days a week
- For assistance involving Air Products and Chemicals, Inc. products

Product Safety Information

- For MSDS
  www.airproducts.com/msds/search.asp
- For Safetygrams
  www.airproducts.com/responsibility/ehs/productsafety/productsafetyinformation/safetygrams.htm
- For Product Safety Information
  www.airproducts.com/responsibility/ehs/productsafety/productsafetyinformation

Technical Information Center

- Call: +1-800-752-1597 (U.S.)
- Call: +1-610-481-8565 (other locations)
- Fax: +1-610-481-8690
- E-mail: gasinfo@apci.com
- Monday–Friday, 8:00 a.m.–5:00 p.m. EST

Information Sources

- Compressed Gas Association (CGA)
  www.cganet.com
- European Industrial Gas Association (EIGA)
  www.eiga.org
- Japanese Industrial Gas Association (JIGA)
  www.jiga.gr.jp/english
- American Chemistry Council
  www.americanchemistry.com

For More Information

Air Products and Chemicals, Inc.
7201 Hamilton Boulevard
Allentown, PA 18195-1501
Tel 610 481-3639
Fax 610 481-8647

tell me more
www.airproducts.com

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