

Safetygram #28

Nitrogen Trifluoride (NF₃)

General

Nitrogen trifluoride (NF₃) is a colorless, odorless, nonflammable, oxidizing compressed gas. NF₃ offers the advantages of relative ease of use at ambient conditions and the ability to act as a fluorinating agent. Because of these factors, it has gained commercial acceptance in a number of applications. The electronics industry uses it in plasma and thermal cleaning applications for its advantages, such as high etch rates, high selectivity, carbon-free etching, and minimal residual contamination. NF₃ is also used as a fluorine source in high-energy chemical lasers, owing to its ease of use relative to fluorine gas. NF₃ is also used as an intermediate in the production of specialized chemicals. NF₃ is available in a variety of grades and at purity levels in excess of 99.999% due to advanced purification techniques developed by Air Products.

Table 1 lists the physical and chemical properties of NF₃.

Health Effects

NF₃ is not hazardous by skin contact and is a relatively minor irritant to the eyes and mucous membranes. Overexposure to NF₃ via inhalation induces the conversion of hemoglobin to methemoglobin. The formation of methemoglobin reduces the amount of oxygen available to body tissues. This can lead to chemical cyanosis, headache, dizziness, weakness, confusion, and other manifestations associated with a reduced oxygen supply. Hemolytic anemia, enlargement of the spleen, and pathologic changes in the liver, kidneys, and heart muscle may occur as secondary effects of methemoglobinemia. At the cessation of NF₃ exposure, methemoglobin spontaneously reverts to hemoglobin. While methemoglobinemia clears over several hours, hemolytic anemia may take several weeks to resolve.

Table 1

Physical and Chemical Properties

(NF₃ is a colorless, odorless gas. Trace impurities can impart a musty or pungent odor to the gas.)

Melting Point -340.2°F (-206.8°C)	Standard Enthalpy of Formation at 298 K -29.80 kcal/mol (-124.77 kJ/mol)
Boiling Point -200.2°F (-129°C)	Standard Entropy at 298 K 62.2 cal/mol-K (260.5 J/mol-K)
Critical Temperature -38.5°F (-39.3°C)	Gibbs Free Energy of Formation at 298 K -21.4 kcal/mol (-89.6 kJ/mol)
Critical Pressure -44.02 atm (4.46 MPa)	Heat Capacity at 298 K at Constant Pressure 12.79 cal/mol-K (53.54 J/mol-K)
Liquid Density (atm at Boiling Point) 97.13 lb/ft ³ (1554 kg/m ³)	Molecular Weight 71.002
Gas Density (atm, 70°F) x 0.184 lb/ft ³ (2.95 kg/m ³)	Geometry Pyramidal
Heat of Vaporization at Normal Boiling Point 2.77 kcal/mol (11.60 kJ/mol)	N-F Bond Length 1.37 Angstroms
Heat of Fusion 0.095 kcal/mol (0.40 kJ/mol)	N-F Bond Angle 103 Degrees
Specific Gravity (70°F, air=1) 2.503	Mean Bond Energy 66.4 kcal/mol (278.0 kJ/mol)
Specific Volume (70°F, atm) 5.43 ft ³ /lb (0.339 m ³ /kg)	Dipole Moment .234 D
Standard Enthalpy of Formation at 0 K -28.43 kcal/mol (-119.03 kJ/mol)	Solubility (slightly soluble in water) 1.43 x 10 ⁻⁵ mole fraction at 1 atm/22°C



Toxicological Properties

Inhalation LC₅₀ = 6,700 ppm (1 hour) rat.

For all species tested, the immediate effect of acute exposure to high concentrations of NF₃ is extensive methemoglobin formation with subsequent hypoxia. This is often followed by hemolytic anemia that can cause liver, kidney, spleen, and sometimes heart effects. Vomiting has also been observed in dogs and monkeys that have inhaled NF₃. Exposure of rats to 100 ppm NF₃ by inhalation for 7 hours per day, 5 days per week for 19 weeks resulted in mild to moderate pathological changes in the liver and kidneys. No other effects were noted. These chronic exposures failed to produce any measurable changes in the general appearance, appearance of teeth, activity, growth, mortality, blood, serum chemistry, or fluorine content of the teeth and bones of the rats tested.

NF₃ has been found to be weakly mutagenic in bacterial cells and nonmutagenic in animal cells and whole animal test systems.

Exposure Levels

The National Academy of Sciences—National Research Council, Committee of Toxicology, has recommended an Emergency Exposure Limit (EEL) for NF₃ of 22,500 ppm. This is based upon actual measurements which indicate that exposure of up to 30,000 ppm x min did not cause any negative health effects in laboratory animals, while anemia did occur at exposures of 120,000 ppm x min. The EEL is a concentration that is believed not to result in a period of disability or interfere with the performance of tasks. While exposure at these levels may produce injury, the injury would be reversible. The EEL represents a cumulative exposure limit, taking into account both the time of exposure and the concentration at which the exposure occurs. Any combination of time of exposure and concentration that is less than the recommended level of 22,500 ppm x min is acceptable. Table 2 illustrates acceptable exposure times for varying concentrations of NF₃ in air at the EEL of 22,500 ppm x min. The TLV-TWA (10 ppm or 29 mg/m³ [ACGIH, 1997]) for NF₃ was set by the American Conference of Governmental Industrial Hygienists at one-tenth the test level of the previously cited 19-week study under Toxicological Properties.

Fire Potential

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. Nitrogen trifluoride satisfies the oxidizer requirement. 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

Table 2

Acceptable Exposure Times for Varying Concentrations of NF₃ in Air

Time of Exposure (min)	Concentration (ppm)
1	22,500
10	2,250
30	750
60	375

Source: "Recommendation for Revised Emergency Exposure Limits for Spills of NF₃," NAS/NRC Committee on Toxicology, 1974.

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. In the case of oxidizers, as the concentration of the oxidizer increases, the ignition temperature of potential fuels lowers. So materials that cannot be ignited in normal air may burn readily in oxidizer atmospheres. With this in mind, we can see that in an oxidizer system we have two legs of the fire triangle present. The oxidizer is one leg and the materials of construction in the system are the fuels, or second leg. All that is required for an ignition is an energy source.

Now let's consider ignition sources. Typical sources of ignition would be fire, open flames, sparks, cigarettes, etc. But that is in the world of normal air. The autoignition temperature is the lowest temperature required to ignite a material in the absence of a flame or spark. Could gas velocity, friction, adiabatic heat, or contamination provide the ignition source? Yes.

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 malfunctioning or poorly operating component can generate heat. Friction between two materials generates fine particles, which may ignite from the heat generated.

Adiabatic heat is sometimes confused with the heat of compression. The 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. This 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. The reason Air Products limits the fill pressure of nitrogen trifluoride is to minimize the heat that can be generated by this mechanism.

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.

Ignitions typically take place at points in the systems that are more vulnerable to the effects of the above ignition mechanisms. Particle impingement is more likely in an area that changes the direction of flow, such as an elbow. Adiabatic heat is generated in dead ends and created by valves or regulators. If the valve or regulator has a seat made of a nonmetallic material, it may be more prone to ignition because nonmetals typically have lower ignition temperatures than metals. If the ignition of the nonmetal generates enough heat, the ignition may propagate to the metal. This is called the kindling chain, where ignition is promoted from materials of low ignition temperature to materials of higher ignition temperature.

Contamination other than particles can lead to ignition. Other contaminants, such as hydrocarbons, can be easily ignited in oxidizer systems. They can potentially burn with sufficient heat to propagate the ignition to system components. This is another example of the kindling chain.

Reactivity

Reactivity is similar to that of oxygen at room temperature. NF₃ is relatively inert at ambient temperature and pressure conditions and exhibits little, if any, reactivity. However, at higher temperatures (>300°C), NF₃ will dissociate into reactive fluorine species that react with most materials. These reactive species can lead to uncontrolled reactions with polymers and certain metals, liberating heat and causing further dissociation of NF₃. As temperatures increase above 400°C, the reactivity of NF₃ becomes more like that of fluorine. Therefore,

Table 3**Flammability Limits of Various Gases in NF₃**

(Volume %) (70°F (21°C), 14.7 psia (1 bar))

Fuel	in NF ₃		in O ₂		in Air	
	LFL	UFL	LFL	UFL	LFL	UFL
Silane	0.66	95.3	NA	NA	1.37	NA
Hydrogen	5.0	90.6	4.65	93.9	4.0	75.0

Please consult the Technical Information Center at 800-752-1597 for more information on the reactivity of NF₃ with other gases.

Table 4

USA	670 standard	330 limited standard (used by Air Products)	640 DISS
UK	BS 14	DIN 8	
Germany	DIN 8		
France	NF K		

For more information on cylinder valve connections, refer to Air Products Safetygram-31, "Cylinder Valve Outlet Connections."

avoid conditions and/or mechanisms that could lead to the inadvertent heating of NF₃. For example, one such mechanism—adiabatic compression—occurs when high-pressure NF₃ is introduced rapidly into a low-pressure dead-end space. The resulting rise in gas temperature may be sufficient to cause the dissociation of NF₃. NF₃ is often used in concert with other gases, such as silane in the processing of semiconductors. Related information regarding reactivity involves Air Products' flammability testing of NF₃/Silane (SiH₄) mixtures, which yielded consistent results with those reported at the Chemical Technology Research Lab in Tokyo, Japan in 1990. The lower and upper flammability limits (LFL and UFL) for SiH₄ in NF₃ are 0.66% and 95.3%, respectively. In other words, in a binary blend of SiH₄ and NF₃, concentrations of silane greater than or equal to 0.66% and less than or equal to 95.3%, form an explosive mixture. Dilution with nitrogen (N₂) provides a three-component flammability limit of 2.0% SiH₄/2.5% NF₃/95.5% N₂. Although the LFL for SiH₄ increases to 2.0% with the addition of N₂, the large range of flammability still exists. To achieve safe operating conditions in a system using SiH₄ and NF₃, dilution with N₂ is required to remain outside the flammability limits. Table 3 indicates the magnitude of the flammability range of SiH₄ and H₂ blends of NF₃, O₂ and air, respectively.

Environmental Impact

NF₃ can be manufactured, used, and disposed of in a safe and environmentally responsible manner. NF₃ poses a minimal environmental hazard due to its nonreactivity and insolubility in water under normal conditions. Air Products has spon-

sored research at the Massachusetts Institute of Technology to study the reactivity of NF₃ in the atmosphere. Also, Air Products continues to conduct and/or support the analysis of emissions from semiconductor manufacturing production tools. NF₃ has negligible impact on ozone depletion. The photolysis of NF₃ in the stratosphere yields a fluorine radical that reacts fairly rapidly to form hydrogen fluoride (HF). The stability of HF results in an ozone-depleting potential of the fluorine radical that is approximately three orders of magnitude less than that of the chlorine radical. NF₃ has a relatively short atmospheric lifetime (740 years) and dissociates more readily than C₂F₆ and CF₄. HF ultimately diffuses down to the troposphere where it is removed by wet deposition. Due to the low solubility of NF₃ in water (1.43 x 10⁻⁵ mole fraction at 1 atm partial pressure of NF₃ and 22°C) and its nonreactivity with water under normal conditions, the environmental hazards of an NF₃ leak at sea or in coastal waters during shipment are minimal. Any large release of NF₃ would dissipate before significant concentrations of gas could build up in water.

Containers

Nitrogen trifluoride is shipped and stored in high-pressure cylinders, tube trailers or ISO modules, depending on the quantity required by the consumer. These containers are manufactured according to applicable codes and specifications for the temperatures and pressures involved.

Cylinders

A cylinder is a hollow tube with a closed concave 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 tapered end to allow a protective cylinder valve cap to be installed.

Nitrogen trifluoride is also available in large skid-mounted containers (referred to as "Y" cylinders) that contain 430 pounds (195 kilograms) of product. These containers are mounted horizontally and are tapered and threaded at both ends. A valve assembly is installed on one end, and a pressure relief device may be installed on the opposite end.

Tube Trailers and ISO Modules

If large amounts of product are required, nitrogen trifluoride can be purchased in tube trailers or ISO modules. The most common configurations for these units are in four or eight tube bundles of 22-inch (56 centimeter) diameter tubes. These units carry as much as 12,000 pounds (5440 kilograms) of nitrogen trifluoride.

Valves and Connections**Valves**

Containers used in nitrogen trifluoride service are equipped with diaphragm valves. Diaphragm valves come in two basic configurations, spring-loaded and tied diaphragm. Air Products uses the spring-loaded diaphragm valve on its lecture bottles and the tied diaphragm valve on all other containers. The tied diaphragm valve is provided in a manually operated design and a pneumatically operated design for remote operation. For information on the construction and operation of these valves, refer to Air Products Safetygram-23, "Cylinder Valves." Many regulatory agencies and local code officers require these cylinder valves to be equipped with restrictive flow orifices (RFOs). The RFO is a small plug that screws into the valve outlet. It has a hole in the middle that can range in size from 0.006 to 0.16 inches (0.15 to 4 millimeters) in diameter. The purpose of the RFO is to restrict the amount of flow that can come from the cylinder in the event of a system failure. There are recommended sizes for most products, but customers can specify their requirements.

Connections

Valve connections for nitrogen trifluoride may vary from country to country. Table 4 gives some of the connection designations used by the various countries.

Pressure Relief Device

Cylinders containing nitrogen trifluoride in the European Union are not equipped with pressure

relief devices. In North America these containers are equipped with combination pressure relief devices. These devices consist of a frangible disc rated at 5/3 the working pressure of the container. The atmospheric side of the disc is backed with a fusible metal alloy, which melts at one of two nominal temperatures, 165°F or 212°F. These devices require both the temperature condition and pressure condition be satisfied in order to function. These devices are intended to protect the container in a fire situation. For more information on cylinder pressure relief devices, refer to Air Products Safetygram-15, "Cylinder Pressure Relief Devices."

Note: Air Products has been granted an exemption By the United States Department of Transportation (DOT) to eliminate pressure relief devices from both cylinders and tubes in NF₃ service. These devices will gradually be phased out on Air Products' containers.

Storage and Handling

Always store and handle cylinders containing nitrogen trifluoride and other compressed gas cylinders in accordance with Compressed Gas Association Pamphlet P-1, "Safe Handling of Compressed Gases in Containers." For more information, refer to Air Products Safetygram-10, "Handling, Storage, and Use of Compressed Gas Cylinders."

International or local regulations may require additional safeguards for storage or use. 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. Storage area temperatures should not exceed 125°F (52°C) 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 cylinders not connected. When returning a cylinder 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 or Open Flames" and NFPA 704 ratings.

Handling and Use

Use only in well-ventilated areas, preferably in a gas cabinet. 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. 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 125°F (52°C). High temperature may cause damage to the cylinder. If user experiences any difficulty operating the cylinder valve, discontinue use and contact the supplier. Use an adjustable strap wrench to remove overly tight cylinder caps. Never insert anything into the cap holes to assist in cap removal.

Ensure that 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.

Abatement

Return unused product to the supplier. Air Products will assist customers in determining and implementing appropriate methods to control and monitor NF₃ emissions. The method and degree of control and regulatory compliance is the ultimate responsibility of the end user. If your facility implements an abatement policy, please contact your Air Products representative for specific recommendations.

System Design and Maintenance

NF₃ is available in several types of high-pressure containers, including cylinders, Y cylinders, tube trailers, and ISO modules. Leak-checking NF₃ cylinders prior to service is recommended. After placement in a gas cabinet, the cylinder valve should be checked for trace leaks at the valve connection, valve stem, pressure relief device, and cylinder/valve connection. Similar steps should be taken for bulk containers (Y cylinders, tube trailers, and ISO modules). Any of the following techniques should be used:

- An electron-capture type halogen leak detector, thermal conductivity, or an NF₃ point detector can be used.
- An outboard mass spectrophotometer leak detector can be used for a system pressurized with helium or a helium/inert gas mixture.
- GASGUARD[®] systems will perform pressure and vacuum decay testing of the cylinder connection to the gas system as part of the standard control software configuration.

Gasguard Gas Cabinets

NF₃ should be delivered from a system within an exhausted enclosure with proper and continuous ventilation. When using bulk supply of NF₃, such as a Y cylinder, tube trailer, or ISO module, the pigtail-to-valve connection should also be ventilated. Purging of the gas systems with a dry, inert gas, such as nitrogen or argon, is recommended prior to breaking any connection of the gas system. Automation provided by GASGUARD systems ensures thorough and complete purging of the gas delivery system.

Process Lines

Gas distribution lines for NF₃ service should be fabricated from compatible materials (next page) and thoroughly cleaned to remove any oxidizable material. The following steps are crucial for adequate line preparation:

- Clean the line thoroughly with an appropriate cleaning agent and dry with oil-free nitrogen or helium. Shop compressor air should not be used because oil mist will recontaminate the line. Be alert for any dead space where degreasing agents can be trapped.
- Inspect the system for any indications of reaction, leaks, changes in mass flow, or changes in delivery pressure across line filters.
- NF₃ leaks in a process line or equipment may be detected by the two techniques mentioned previously.

Ventilation

NF₃ has no detectable odor, so forced air/exhaust ventilation and ambient air monitoring are recommended where NF₃ is stored or used. Ventilation ducts should be designed for high-flow interference. Standard flow ventilation requirements for gas cabinets adequate for NF₃ include average face velocity of 200 fpm at access ports with 150 fpm as the minimum velocity at any point. Laminar flow is strongly recommended for nonload lock systems.

Monitors

NF₃-specific detectors are highly recommended since NF₃ has no detectable odor. Prolonged breathing of high concentrations of NF₃ should be avoided. The most accurate technique for NF₃ detection is infrared spectral absorption in the 11-micron (900 cm⁻¹) region.

Materials Compatibility

Metals

Systems must be cleaned for oxidizer service. Clean and degrease all metals coming into contact with NF₃ using detergent or suitable cleaning agents that are free of finely divided metal chips and particles. Gaseous NF₃ containing 0.1% or less active fluorides (calculated as HF) was found to be noncorrosive toward several different parent and welded metal specimens. During static exposure of aluminum, stainless steel, Inconel®, Monel®, nickel, titanium, steel, copper, beryllium copper, aluminum bronze, maraging steel, and tungsten, no metal exhibited corrosion penetration rates greater than 0.43 mils per year (mpy). Generally, a corrosion penetration rate of 1 mpy or less is considered acceptable for long-term compatibility. The tests were conducted for 270 days at temperatures ranging from -78°C to 71°C and pressures ranging from 2 x 10⁻⁷ to 2.5 x 10⁻⁶ psi. Carbon steel, stainless steel, nickel and its alloys, and copper are suitable materials of construction for low-pressure service (<70 psig) and temperatures up to 150°C. For pressures up to 1450 psig at ambient temperatures, carbon steel and stainless steel are suitable materials. For high-pressure and higher-temperature service, nickel and certain alloys of nickel and copper are preferred. Most metals will react with NF₃ at temperatures in excess of 300°C. The presence of contaminants in the system can significantly affect the corrosion resistance and compatibility of many metals. For example, both HF and water decrease the corrosion resistance and compatibility of metals exposed to NF₃, and both impurities should be minimized. The presence of fingerprints, halocarbon oils, and machine oils have been shown to significantly reduce the temperature resistance of metals, including stainless steel and nickel.

Nonmetals

All nonmetal components should be thoroughly cleaned and free of oils, grease, and dirt using either detergent or a suitable cleaning agent. Thoroughly clean and dry the components prior to use. Highly fluorinated polymers such as Teflon®, Viton®, Kel-F®, or Neoflon® are materials of choice. Studies have shown that PTFE (Teflon) is the most compatible at temperatures up to 150°C.

Lubricants

Use of perfluorinated lubricants (Krytox® or Fomblin®) for vacuum pumps in NF₃ service is recommended. Hydrocarbon lubricants can react violently with NF₃ and should not be used. NF₃ dissolves some halocarbon greases.

Safety Issues

The following general safeguards are important in handling NF₃.

- Avoid conditions that can result in high temperatures, such as adiabatic compression.
- Do not attempt purification of NF₃ via adsorption. This can result in large energy releases.
- Stainless steel and copper are suitable materials of construction for low-pressure service.
- If elastomers must be used, Teflon and PCTFE materials are acceptable for NF₃ service.
- Ball valves are not recommended for general use in NF₃ service due to the potential for adiabatic compression in closed downstream systems occurring as the result of the rapid opening of this type of valve. Use of ball valves should be restricted to isolation functions only. Any valve that is used in NF₃ service should be opened slowly to prevent adiabatic compression.
- All components should be free of grease, oil, and other contaminants. It is recommended that procedures for cleaning systems for oxygen service as described in CGA Pamphlet G-4.1 be used.
- The operation of high-pressure systems should be done remotely and by personnel wearing appropriate personal protective equipment. Air Products' GASGUARD line of gas delivery systems provides an excellent means to minimize direct operator contact by providing an external control interface.
- Observe the same measures and precautions necessary for the safe handling of any compressed gas.
- NF₃ cylinders must be securely supported while in use to prevent movement and straining of connections. Always protect NF₃ cylinders from mechanical shock or abuse. Never heat NF₃ cylinders with a torch, heat lamp, or water bath. In some delivery systems, NF₃ may be subjected to adiabatic compression. This can occur when a valve between a high-pressure gas source and a low-pressure flow circuit is opened quickly. As gas enters such spaces and rapidly comes to a higher pressure, shock waves may be dissipated on material surfaces in a very short time. When high gas temperatures are expected, systems designed for such service should avoid the use of plastics or polymers in

contact with gas-wetted surfaces. In addition, rapid-opening valves, such as ball valves, should be restricted to use only as isolation valves in NF₃ service.

Purification processes using dry media, such as activated charcoal (carbon) or molecular sieve, may be subject to rapid exotherms (and potential system failures) from sudden exposure of the media to large quantities of NF₃.

Air Products does not recommend purification adsorption of NF₃.

Emergencies

Leaks

If a leak develops in a customer system, close the cylinder valve, vent residual product, and purge the lines with inert gas before attempting repairs. Use appropriate protective equipment. Leaks occurring at the cylinder valve's pressure relief device, diaphragms, or valve to the cylinder connection cannot be repaired. **Attempts to repair these leaks may result in catastrophic failure of the package.**

If such a leak develops or the cylinder valve cannot be closed, immediately contact the Air Products Emergency Response System at these numbers:

- Continental U.S., Canada & Puerto Rico:
800-523-9374
- Other Locations: 610-481-7711

Fire

In North America, NF₃ cylinder valves are equipped with pressure relief devices consisting of a frangible rupture disc backed by a fusible alloy. This allows the cylinder contents to be released, minimizing the potential for a cylinder failure under fire conditions. Where no pressure relief devices are used, the potential for catastrophic failure of a cylinder in a fire is much greater. Although NF₃ is nonflammable, it will vigorously support combustion. Do not use HALON 1301, dry ammonium phosphate, or bicarbonate on NF₃ fires because they produce toxic by-products. Use carbon dioxide (CO₂) extinguishers to extinguish small fires. Use large amounts of water to extinguish fires covering a large area. Although NF₃ is not water-soluble, many of the toxic by-products such as HF are water-soluble. If a container of nitrogen trifluoride is involved in a fire, cool the cylinder with water spray if this can be done safely. If nitrogen trifluoride is feeding the fire, try to shut off the source to aid in extinguishment.

First Aid Treatment

An individual exhibiting symptoms of acute NF_3 poisoning from concentrations in excess of 6,000 ppm should be removed from the contaminated area as quickly as possible. Then trained personnel should start oxygen therapy at once, and a physician should be notified immediately.

Observe these follow-up first-aid measures:

- Continue therapy for up to six hours.
- Individual should rest under close supervision until all possibility of secondary complications can be discounted.
- Be aware of possible anemia and impaired kidney functions.
- Individual should receive follow-up examinations by a physician.

Table 4

Transportation Information

Proper Shipping Name	Nitrogen Trifluoride, Compressed, 2.2, UN2451
Identification Number	UN2451
Hazard Class	2.2, Non-Flammable Compressed Gas
Subsidiary Risk	5.1, Oxidizer
Shipping Labels	Non-Flammable Gas, Oxidizer
Placard	Non-Flammable Gas
Special Shipping Information	Always ensure that cylinder valve is closed, outlet seal is installed gas-tight, and protective cap is in place before shipping. Cylinders must be properly secured for transport.

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/ProductSafetyOverview.htm

For More Information

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

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

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www.airproducts.com