CODE OF PRACTICE
NITROGEN TRIFLUORIDE

AIGA 029/10

GLOBALLY HARMONISED DOCUMENT

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This document is adopted from the European Industrial Gases Association document IGC Doc 092/10 ‘Code of Practice – Nitrogen Trifluoride’. Acknowledgement and thanks are hereby given to EIGA for permission granted for the use of their document.

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1 Introduction

Nitrogen trifluoride is an oxidizing compressed gas that has gained acceptance in a number of applications as a fluorinating agent.

It is this property that makes it valuable as a non-reactive source of Fluorine for etching and cleaning applications. The active Fluorine is released only if sufficient energy is applied. Once initiated, the reaction is self propagating and presents a hazard for a material that is incompatible with Fluorine. (e.g. Flammable Gas, Metals).

Nitrogen trifluoride, can be safely handled if equipment is properly designed and appropriate handling precautions are taken.
This document has been prepared in 2003 by the European Industrial Gas Association, with the assistance of the Compressed Gas Association & the Japanese Industrial Gas Association.
The first 5-yearly revision in 2009 incorporated updates of the references to the other codes of practices that have been revised in the meantime. It has been further revised in 2009 to incorporate a few editorial modifications proposed by CGA during the 5 year review of their document G-14.

NOTE — This document shall be used in conjunction with IGC doc. 30/07 "Disposal of Gases – Code of practice", AIGA 004/04 "Handling Gas Container Emergencies", AIGA 021/05 "Oxygen Pipeline systems"

2 Scope and Purpose

Because of its widespread use and its potential for mishandling, this Code of Practice has been written and is intended for the Suppliers, Distributors and Users of nitrogen trifluoride and its handling equipment. It sets out to provide a good understanding of the potential hazards involved in handling nitrogen trifluoride and the approach to be taken to minimise the risk of incidents.
The manufacture, purification and analysis of nitrogen trifluoride are beyond the scope of this document, although the general guidance given is also relevant to these processes.
Within the Annexes of this document are list of references, the EIGA Safety Data Sheet and audit check-lists.

3 Definitions

Auto-ignition temperature: The temperature at which a substance will spontaneously ignite in a specified oxidant at a given pressure.

Bundle: A group of *cylinders* which are manifolded together with a common valve connection for filling and use. *Bundles* are securely mounted in a frame for transport, storage and use and typically contain from four to thirty cylinders.

Cylinder: For the purposes of this document, a cylinder is defined as a transportable container of up to 150 litres water capacity that can be filled with gas under pressure.

Cylinder recovery vessel: Commonly known in the gas industry as "cylinder coffin". A pressure vessel which is designed to safely contain a cylinder and its content for transportation and storage, until it can be safely emptied. A *cylinder recovery vessel* is often fitted with a gauge to indicate internal pressure and with valves to enable purging.

Decomposition temperature of NF_3: The temperature at which NF_3 begins to decompose into other more reactive species such as fluorine.

Filling ratio: Sometimes known as *filling degree* or *filling factor.* The amount of a gas that can safely be filled into a cylinder without over-pressurisation of the cylinder under all anticipated ambient conditions. The filling degree (f) (prescribed in ADR, the European Road Transport Regulations) is expressed as the ratio: (M/C),
Where: M = mass of gas filled (Kg)
C = cylinder water capacity (Litres)

Gas cabinet: A locally ventilated enclosure designed to contain a gas supply cylinder and, where appropriate, an associated purge gas supply cylinder. The term *gas cabinet* also includes the gas supply handling equipment such as purge manifolds and process gas pressure reducing regulators and control systems. The *gas cabinet* can be quite complex in design, often being equipped with automatic microprocessor control.

NF_3: Chemical formula for nitrogen trifluoride.

Oxipotential: The oxidizing power of a gas compared to that of oxygen, given as a dimensionless number, where oxygen = 1 (ref: BAM STP1395 on oxidizing ability of gases)

Passivation: For the purposes of this document, *passivation* is a procedure that is applied where there is a possibility of a reaction between a reactive gas and the container or system into which it is going to be introduced. *Passivation* ensures that any residual contaminants will react in a controlled manner and will create an inert fluoride layer. *Passivation* is usually carried out using a mixture containing a reactive gas diluted in an inert gas, sometimes then followed by the pure reactive gas.

Pressure: In this publication, “bar” shall indicate gauge pressure unless otherwise noted – i.e. “bar, abs.” for absolute pressure and “bar, dif” for differential pressure.

Risk assessment: A documented exercise to assess the risks of a specific operation to personnel and the environment. This process usually takes into account safety controls inherent in equipment, operating procedures and personnel protective equipment provided. Sometimes, it may be deemed appropriate to improve operational safety controls after undertaking a *risk assessment*.

Shall: The use of the word “shall” in this document implies a very strong concern or instruction.

Should: The use of the word “should” in this document indicates a recommendation.

Swarf: small strips or particles of metal that can arise from machining operations.

Tube: For the purposes of this document, a *tube* is a large cylinder, with a water capacity of greater that 150 litres. *Tubes* are often manifolded together in a manner similar to that for *bundles* and mounted on a vehicle trailer for transport, storage and use. These are known as *tube trailers* or *ISO tube modules*.

4 Gas properties

4.1 Gas identification

Chemical formula:	NF_3
CAS No.	7783-54-2
EC No.	232-007-1
UN No.	2451

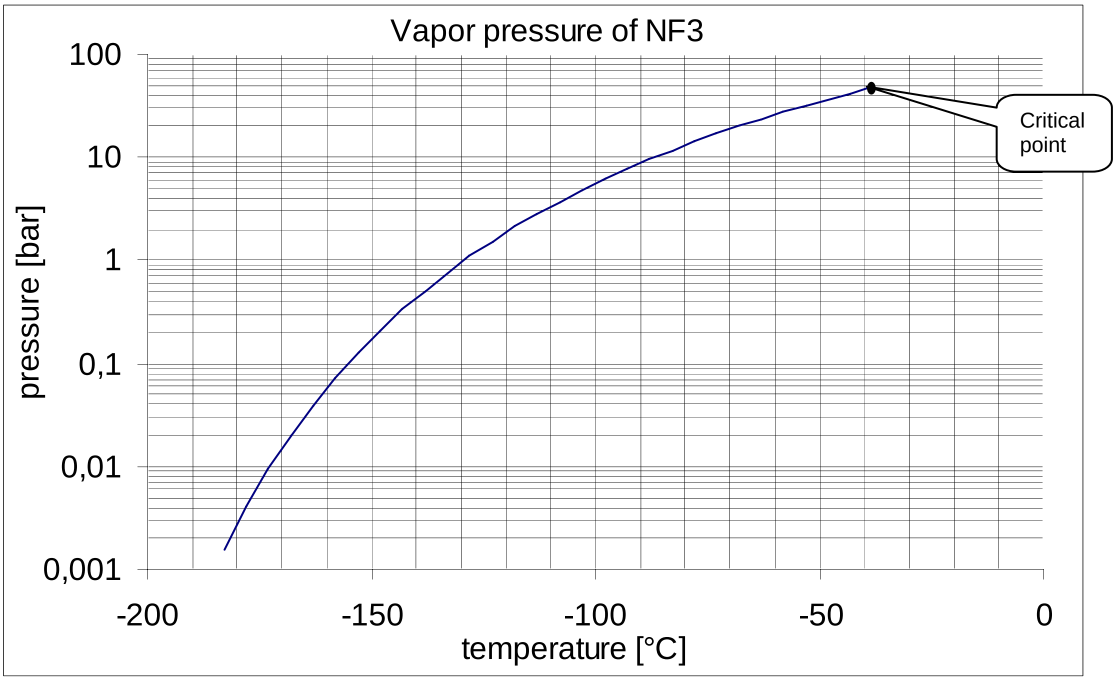
4.2 Physical properties

molar mass:	71	g/mol
melting temperature	-207	°C
latent heat of fusion @ m.p.	1.34	cal/g
boiling temperature	-129	°C
liquid density @ b.p.	1.5	kg/l
latent heat of vapour @ b.p.	39	cal/g
critical temperature	- 39	°C
critical pressure	45	bar
critical density	0.562	kg/l
heat capacity @ 25 °C	0.1794	kcal/(kg*K)
entropy @ 25 °C,1 atm	0.877	kcal/(kg*K)
enthalpy @ 25 °C, 1 atm	-29.8	kcal/mol

Table of conversion factors:

	m^3 gas @ 0ºC, 1 bar a.	l (liquid) @ b.p.	kg
m^3	1	2,064	3,6
l (liquid) @ b.p.	0,484	1	1,531
Kg	0,316	0,653	1

Vapour pressure curve



4.3 Chemical Properties

NF_3 is an odourless, harmful, colourless, non-flammable, oxidizing, gas.
Oxipotential: 1.6 (Ref: BAM STP1395 on oxidizing ability of gases).

Ignition temperatures (ºC) of some metals in NF_3 @ 1 and 7 bar:

	Cu	Fe	Ni
1 bar	550 ºC	817 ºC	1187 ºC
7 bar	475 ºC	612 ºC	967 ºC

NOTE – Harmful is an intermediate category between toxic and non toxic categories according to European directive on dangerous substances.

4.4 Toxicology

TLV	10 ppm
Immediate danger to life & health (IDLH)	1000 ppm
LC_{50} (1h, rat)	6700 ppm
Emergency Exposure Level (EEL):	≥ 22 500 ppm x min

NOTE - Combustion products resulting from the exposure of NF_3 to a flame may be very toxic.

4.5 Environmental Issues

Solubility in water @ 20 °C, 1 bar a	61 mg/l
Lifetime in Atmosphere	740 years
Global Warming Potential: (CO_2 = 1)	10 800

5 Gas major hazards

5.1 Introduction to fire and explosion hazards

Several flash fires have occurred in equipment containing NF_3 at elevated pressure. In all cases a plastic material (i.e.: valve seat, sealing washer) burnt. In some cases, the metallic parts in contact with, and around, the plastic materials also ignited. Due to NF_3 pressure the burning materials were projected in the surrounding area.

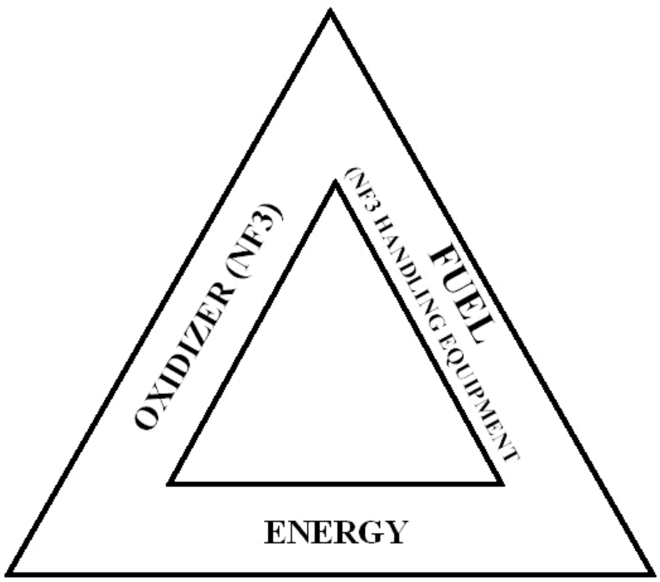


Figure 1: "Triangle of fire"

Figure 1 illustrates that combustion requires the simultaneous occurrence of the following elements:

- the presence of an oxidizer (NF_3)
- a combustible material in contact with the oxidizer
- a source of ignition energy

For each of these elements, several factors influencing the combustion must be considered. They are given in 5.2, 5.3 and 5.4.

5.2 Factors influencing combustion – NF_3 considerations

The following factors influence the combustion of materials:

5.2.1 NF_3 pressure

NF_3 is relatively inert at atmospheric pressure and ambient temperature. The *auto-ignition temperature* of some combustible materials in NF_3 may decrease with increasing NF_3 pressure, making the material more susceptible to ignition. Likewise, operating at high pressures increases the chance for adiabatic compression (see 5.4.4) in the system, which would create high temperature from the heat of compression (see 5.2.2).

5.2.2 NF_3 decomposition temperature

The primary concern with NF_3 and higher temperatures (>300 degrees Centigrade and may depend upon catalyzing effect of certain materials) is the dissociation of NF_3 into reactive fluorine species that will react with most materials. These reactive species can lead to uncontrolled reactions with polymers or certain metals, liberating heat, and causing further dissociation of NF_3. Therefore, precautions must be taken to prevent conditions or mechanisms that could lead to inadvertent heating of NF_3. At higher temperatures, NF_3 loses its inherent chemical stability.
The *auto-ignition temperature* of a material in contact with NF_3 is more easily reached as the temperature of NF_3 increases. NF_3 systems should operate at as low a temperature as is practicable.

5.2.3 NF_3 velocity in pipelines

The NF_3 velocity will create heat by particle impacts (5.4.1) or flow friction (5.4.4) on the material, particularly in areas with tortuous passages and/or small crevices. This creation of heat may initiate a local combustion if the *auto-ignition temperature* of the material in contact with NF3 is reached. The NF_3 velocity must therefore be limited to avoid the risk of this temperature being achieved. The risk of a particle and the resulting energy imparted by the high velocity in an oxidizing environment may lead to an ignition. This highlights the need to properly clean NF3 systems for oxidizing service.
The oxipotential of NF_3 is greater than that of oxygen (1.6, where oxygen = 1), however in the absence of other data, the following velocity limits should be applied (by analogy with the AIGA "Oxygen Pipelines Systems" document No. 022/05, sect 4.4.):

- For pressures above 15 bar, the maximum NF_3 velocity in pipelines is limited so that the product of velocity and pressure does not exceed 450 bar metres/second.
  i.e. $PV \leq 450$ bar m/s
  where:
  V = NF_3 velocity in pipeline (m/s)
  P = the pressure in the pipeline (bar)
- For pressures below 15 bar, the maximum velocity in pipelines is less of a concern, however it is recommended that every effort is made to control this to less than 30 metres/second.

For equipment other than pipelines, recommendations are contained in other sections (such as 7.2.2. "cylinder valves").

5.3 Factors influencing combustion - Material considerations

The most oxidant-compatible materials shall be used with NF_3. In all cases, the materials must be thoroughly cleaned and free from oils, grease, dirt and particles. Even compatible lubricants should be used sparingly.

Materials of concern when in contact with NF_3 are:

- Parts of the NF_3 handling equipment such as some metals, polymers, plastics, lubricants, etc…
- Contamination present in the equipment, such as particles, swarf, dirt, grease, insects, etc….

Factors influencing the combustion of these materials are as follows:

5.3.1 Auto-ignition temperature of materials

The *auto-ignition temperature* is an important factor, which needs to be considered when choosing materials to resist combustion in NF_3. The risk of combustion is higher when the a*uto-ignition temperature* is low since the energy required to reach this temperature is lower.
Methods to determine the *auto-ignition temperatures* of materials in oxygen, as those described in ISO 11114-3, *Transportable gas cylinders—Compatibility of cylinder and valve materials with gas contents—Part 3: Autogeneous ignition test in oxygen atmosphere* may also be used for NF3.

5.3.1.1 Metals

The *auto-ignition temperatures* of three common metals in NF_3 at 1 bar and 7 bar are given in section 4.3. In the accidents mentioned in section 5.1, the accidental combustion of a metal is initiated by the combustion of another material having a lower *auto-ignition temperature* than the metal, such as polymers, plastics, lubricants or contaminants in the NF_3 handling equipment, more commonly known as the "kindling effect".

5.3.1.2 Non metals

Auto ignition tests of plastics and lubricants have been conducted with NF_3 at 70 bar (1000 psi).
Highly fluorinated polymers, such as Teflon® (PTFE), including glass and bronze-filled types, Kalrez®, Kel-F®, and Neoflon® are common plastic materials used for NF_3 applications and exhibit a high resistance to ignition at high temperatures (> 400 ^{o}C). Less fluorinated polymers, such as Halar® and Viton®, demonstrate a tendency to auto-ignite in NF_3 at temperatures less than 400 ^{o}C, with some as low as 240 ^{o}C.

Halocarbon or perfluorinated lubricants, such as Krytox® 240AC and Fomblin®, appear to be the most appropriate for NF_3 service, exhibiting a similar high resistance to ignition at temperatures in excess of 400 ^{o}C. Some halocarbon greases may dissolve in NF_3.

5.3.2 Self propagation of ignition of metals

The self-propagation of metals ignited in NF_3 is also an important factor, which needs to be considered when selecting metal equipment components, in particular when they are in contact with materials having a lower auto-ignition temperature such as plastics. The consequences of the auto-ignition of sensitive materials (i.e. plastics) are aggravated when a metal may self-propagate from ignition under NF_3 pressure. The degree of self-propagation is a function of the NF_3 pressure.

Recent promoted combustion tests of metal rods have shown Monel 400, Nickel 200, and aluminum to exhibit the least potential to self-propagate at pressures in excess of 70 bar (1000 psi). Hastelloy C276 and Hastelloy C22 have demonstrated self-propagation at pressures between 5 and 50 bar, while most of the stainless and carbon steels will self-propagate at pressures lower than 5 bar. However, the value of threshold pressures cannot be used alone to determine a metal's resistance to propagation, since there are several other combustion properties which may impact the selection of a metal for specific NF_3 service conditions.

NOTE: Although aluminum has a relatively high NF_3 threshold pressure, it is not recommended due to its high specific heat of combustion and low melting point (see 5.3.5).

Critical metal components which are in contact with plastic parts of or used in severe NF_3 conditions should be selected in order to minimize self-propagation from ignition under NF_3 pressure. When it is impractical to select the best metal materials, a risk assessment shall be undertaken to determine if any preventive measures are required (e.g., fire resistant barrier with remote access to isolate personnel or the wearing of fire resistant personal protective equipment).

5.3.3 Specific heat of materials

Metals have a significantly higher specific heat than non-metals and therefore absorb significantly more heat with a lower temperature increase. Hence, the preferred materials are metals, which should be used instead of plastics or polymers wherever practicable.

5.3.4 Thermal conductivity of materials

The higher the thermal conductivity of a material, the greater the rate of heat dissipation and the lower the temperature will be at any point of localised heating.
As metals have a higher thermal conductivity than non-metals, metals are the preferred materials.
Copper and its alloys such as brass, nickel and monel have a better thermal conductivity than stainless steel and therefore may be preferred and in particular for critical components such as valve seat supports and filters.
Note: There may be other considerations such as chemical reactivity, heat of combustion etc. (e.g. aluminium and its alloys, which have a good thermal conductivity, are not recommended for other reasons - see 5.3.5.).

5.3.5 Heat of combustion of materials

This is the energy produced by the combustion of a material in contact with NF_3. Should combustion of a plastic, polymer or contaminant within the NF_3 handling equipment occur, the heat produced may be sufficient to initiate the combustion of other materials such as metals.
Materials with a low specific heat of combustion should therefore be chosen wherever practicable.
Fluorocarbon polymers such as PTFE and PCTFE produce less energy than hydrocarbon polymers and consequently are preferred.
Aluminium and its alloys have a very high specific heat of combustion and a lower melting point than some other metals. Therefore they are not recommended for use within NF_3 handling systems (especially small components).

5.3.6 Size and configuration of equipment

For a given mass of material, the risk of ignition increases with the surface area exposed to NF_3. Very careful material selection is therefore necessary for equipment components with a low mass and a high surface area that may be exposed to an ignition in contact with NF_3 (e.g. filters). Contaminants, such as swarf also have a high surface area to mass ratio and must be excluded.
Shape: Rapid changes in direction of flow (such as sharp bends in pipes or obstacles in the flow path) will result in a localised energy increase due to impingement of flowing particles on the surface. These factors should be taken into account when designing NF_3 handling equipment.

5.3.7 Quantity of material

This factor concerns mainly the most combustible materials with high specific heat of combustion (e.g. non-metallic materials such as plastics and polymers), which may initiate the combustion of other materials.
Where non-metallic materials are used, their mass shall be kept to the minimum practicable and they should be in close contact with a metal support. The metal support should contain sufficient material to dissipate any heat that may be generated by the combustion of the non-metallic material.

5.3.8 Cleanliness of equipment

Contaminants within the handling equipment may ignite in contact with NF_3 (e.g. particles, swarf, dirt, grease). Such contaminants shall be removed before the introduction of NF_3. Cleaning is described more extensively in other sections of this document, such as section 6.4.

5.4 Other Factors influencing combustion – energy source

5.4.1 Particle impacts

Solid particles travelling at high velocity in an NF_3 gas stream may initiate the ignition of “sensitive” materials on impact (e.g. plastics and polymers).

5.4.2 Mechanical shocks

Rapid operation of certain flow control equipment may result in the generation of localised heat, which may ignite a "sensitive" material (e.g. plastics and polymers). This should be taken into account in the design and operation of such equipment.

5.4.3 Adiabatic compression

A sudden increase in the pressure of NF_3 will result in a rapid temperature increase. At very high rates of temperature increase, there may be insufficient time for heat exchange to take place with the materials in contact with the hot NF_3. Such high temperature may be sufficient to cause the NF_3 to decompose into more reactive species or initiate the auto-ignition of a non-metallic material.
Adiabatic compression may occur, for example, when a valve is opened and a system is rapidly pressurised with NF_3. Reducing the rate at which such a valve is opened, so as to reduce the rate of pressure increase in the system, will reduce the risk of an ignition.
Using equipment designed to resist the effects of adiabatic compression is also a way to limit the risk of ignition.

5.4.4 Flow friction

Flow friction of NF_3 with the surface of material creates heat through a mechanism of energy distribution, particularly when the gas takes a tortuous passage or contacts crevices in the system. This may result in the ignition of a "sensitive" material (i.e. plastics).

5.4.5 Mechanical friction of equipment moving parts

Localised hot spots may occur from the inadvertent rubbing of two materials (e.g. defective or incorrectly specified equipment). Mechanical equipment shall be carefully selected and maintained to avoid this risk.

6 Gas handling equipment – general considerations

6.1 Design principles

The equipment used to handle NF_3 must be designed, constructed and tested in accordance with the regulatory requirements of the Country in which the equipment is operated. The equipment must be designed to withstand the maximum pressure and temperature at which it is to be operated.
A "hazard and operability" study *(Hazop)* shall be carried on all NF_3 systems.
As NF_3 is an oxidizer, consideration must be given to the following issues when designing systems to handle NF_3:

- materials of construction and compatibility of lubricants and sealing compounds
- minimisation of the effects of adiabatic compression
- gas velocities
- initial cleanliness and passivation
- valve types
- filter materials
- operating procedures
- maintenance procedures
- separation of NF_3 from flammable gases (see also 6.9)
- heat dissipation
- compression

6.2 Materials of construction

Selection of metals and plastics shall be made taking into account the information contained in section 5.3.1 and 5.3.2. As example for filters see 6.6 for cylinder valve parts see 7.2.2.

If a material which is not listed in section 5.3.1 is required to be used in NF_3 service and is thought to be compatible it should be tested to confirm its suitability for use under defined temperature pressure and flow conditions.
Consideration shall also be given to the compatibility of lubricants, seals and sealing compounds which may under normal or failure conditions come into contact with NF_3 (5.3.1.2).

6.3 Gas velocities

The velocity of NF_3 in pipelines shall be in accordance with the recommendations in 5.2.3. For equipment other than pipelines (e.g. for high pressure cylinder valves), specific design shall take into account the guidance given in Section 5 and 7.2.2.

6.4 Cleaning and passivation after installation and maintenance

To ensure that the surfaces that are to come into contact with NF_3 are free from combustible materials and metallic particles that may have been introduced into the system during its construction or fabrication or after maintenance, all equipment must be:

- cleaned, as for oxygen use (using detergents or suitable cleaning agents that are free from fine particles and metal chips). Ref AIGA 012/04 and CGA G4.1.
- dried, using a dry, oil-free inert gas.

In addition, systems handling high pressure NF_3 (pressures above 10 bar) may undergo *passivation*. The purpose of *passivation* is to ensure that any active sites on the surface of gas wetted parts of a system are fully oxidised under controlled conditions before introducing the pure process gas. Typically, the *passivation* process requires the introduction of a dilute fluorine/inert gas mixture into the high pressure NF_3 system in steps of increasing pressure (e.g.10 bar) and holding the pressure for 15 minutes at each stage until the maximum working pressure is reached. The concentration of fluorine in the mix at the first passivation is normally in the range 1% to 3%. The use of this low concentration prevents a rapid temperature rise. If the temperature becomes higher than 40°C, the fluorine mixture should be purged out of the system with an inert gas. During passivation, the moving parts of the system (such as valves, pressure reducers and pumps) should be operated for some time (i.e. open-close-open for valves and pressure reducers and run-stop-run for pumps). This is to ensure that each active surface is passivated.

6.5 Valves

Ball valves are not recommended for general use in NF_3 service due to the potential for adiabatic compression in closed downstream systems occurring as a result of the rapid opening of this type of valve. The use of ball valves should be restricted to isolation functions only and limited to pressures below 7 bar.

Where possible valves are selected such that the velocity through the valves, when fully open, is no greater than the design velocity of the system. The design should be such that the valves can be opened and closed slowly.

Valves that may be subjected to rapid pressure rise should contain the minimum practicable quantity of plastics.

For cylinder valves, see 7.2.2.

6.6 Filters

Care must be taken when selecting filters for use in NF_3 service due its high oxidising potential. Filters made from materials which have a high *auto-ignition temperature* and a high thermal conductivity should be used. Mesh filters and filters made from stainless steel are not recommended, as they are more likely to ignite in NF_3. Sintered metal filters made from nickel are recommended.

6.7 Operating procedures and Personnel

As with any operation associated with a hazardous material, written operating procedures shall be prepared to ensure that operators understand that the equipment shall be operated within its design parameters, so as not to cause a hazard to personnel or damage to the equipment or environment. Included in the procedures shall be a statement to indicate that "any valve that is used in NF_3 service shall be opened slowly".

Consideration shall also be given to the issue and use of personal protective equipment when handling NF_3 and minimizing personnel exposure when NF_3 is being processed under high pressure (e.g. by using remote operation).

6.8 Maintenance procedures

It is essential that equipment in which NF_3 is handled is maintained to a high standard and to ensure that this is conducted in a routine, controlled and safe manner. A maintenance procedure should be written to cover these activities. Particular consideration must be given to ensuring that the cleanliness of the system is maintained and that replacement parts and lubricants are compatible with NF_3. The need for *passivation* of equipment after any maintenance operation (before re-introduction of NF_3) shall be assessed.

6.9 Separation from flammable gases

To ensure that there is no risk of inadvertent mixing of NF_3 with flammable gases or other flammable materials:

- NF_3 handling equipment shall be dedicated to NF_3 service and shall not be used for any other purpose.
- Where it is necessary to use a purge gas (e.g. nitrogen), adequate precautions shall be taken to ensure the purge gas is not contaminated with flammable materials (e.g. from another process) or with NF_3.

6.10 Heat dissipation

Heat dissipation in equipment has to be taken into account, particularly the thermal conductivity of materials according to section 5.3.4. Surface temperatures of materials in contact with NF_3 should be kept to a minimum, e.g. by cooling equipment and/or gas streams.

6.11 Compression

During compression two main factors create heat:

- Adiabatic compression
- Mechanical moving part friction

Heat dissipation and compression ratio are therefore particularly important considerations when compressing NF_3.

7 Gas Cylinder filling

7.1 Filling facility considerations

Local Fire and other applicable Regulations shall be met.

Cylinders, cylinder bundles, tubes, tube modules and filling systems containing NF_3 shall be protected against fire risk. This can be achieved by locating at least 5 metres away from flammable materials or by separation using fire resistant walls.

Storage containers shall be located in well ventilated areas where the temperature of the container cannot exceed the maximum set by local regulations.

Filling operations should be located at well ventilated areas (inside rooms or under outside shelters with adequate natural ventilation, e.g. at least 6 air changes per hour).

NF_3 detectors shall be placed in appropriate areas such as ventilation exhausts, near critical high pressure NF_3 equipment (e.g. compressor, filling areas) to detect a leak as soon as possible. If an NF_3 leak is detected, the NF_3 source(s) valve(s) should close automatically. This should include both the NF_3 supply and the NF_3 cylinders being filled.

When it is impractical to select the best materials according to 5.3.1 and 5.3.2, preventive measures must be taken to protect operators (e.g. : fire resistance barrier with remote access or operator wearing fire retardant clothing, gloves and eye protection. Remote operation of high pressure systems shall be undertaken wherever feasible.

Personnel who operate NF_3 systems shall have a good understanding of the properties and hazards of nitrogen trifluoride (see Section 5.). They should also be trained to take the appropriate action in the event of an emergency (see Section 10.).

Materials that are to be used in nitrogen trifluoride service must be kept clean (free from oil, particles etc.) and therefore stored in a clean environment. Great care must be taken when changing gas wetted components to avoid contamination from oil that may be on the operator's hands (e.g. cylinder valve outlet gasket washers). Consideration should be given to wearing suitable gloves for such operations.

7.2 Gas containers and associated equipment

7.2.1 Cylinders, tubes and bundles

Suitable materials of construction for receptacles containing NF_3 are carbon steel, nickel, and stainless steel. The internal cleanliness of the receptacles is important. It has been found that commercially available gas receptacles can be used. Additional cleaning may be undertaken to remove trace contaminants.

Where it is necessary to change the service of cylinders (which have been in a different product service) into NF_3, adequate cleaning shall be undertaken to ensure it is safe to introduce NF_3. This shall include the removal of any materials likely to react with NF_3. This may include solvent washing, internal shotblasting, vacuum baking etc.
Where bundles and tube modules are used for transporting and storing NF_3, the individual cylinders or tubes in the bundle and module respectively are usually manifolded together, and terminate with one connection point. It is recommended that isolation valves are fitted on each individual receptacle to reduce the amount of product that could be lost in the event of a leak on the down-stream equipment. Bundles and modules are normally fitted with manifold isolation valves to enable the complete gas containment package to be isolated during transport.

It may be difficult to approach or get access to the bundle or module in the event of a leak to enable isolation of the source of NF_3. It is recommended that an actuated outlet valve on the bundle or module manifold should be installed. This valve could be closed remotely by manual intervention or a signal from a gas or fire detector in the event of an incident. Wherever practicable, this valve should be used exclusively for emergency shut down of the system.

Note — Gas containers which comply with the US DOT regulations are equipped with pressure relief devices consisting of a frangible rupture disc backed by a fusible alloy plug. This device allows the vessel contents to be released, preventing catastrophic cylinder failure under fire conditions. The disc is designed to burst at 5/3 of the rated cylinder service pressure (e.g. a cylinder rated at 2265psig requires a burst disc rated at 3775psig). The alloy plug will melt at 74ºC. Both the pressure and temperature conditions must be met before the device will vent.

7.2.2 Note for EIGA : This note was approved to be inserted in the previous AIGA version in 2006Cylinder valves

Cylinder valves for NF_3 service shall be designed taking into account the requirements contained in Section 5. Whilst stainless steel is normally used to house a PTCFE seat in the valve stem, consideration shall be given to the use of plastics with AIT > 475°C (see section 5.3.1.2) in a nickel housing (see section 5.3.1.1).

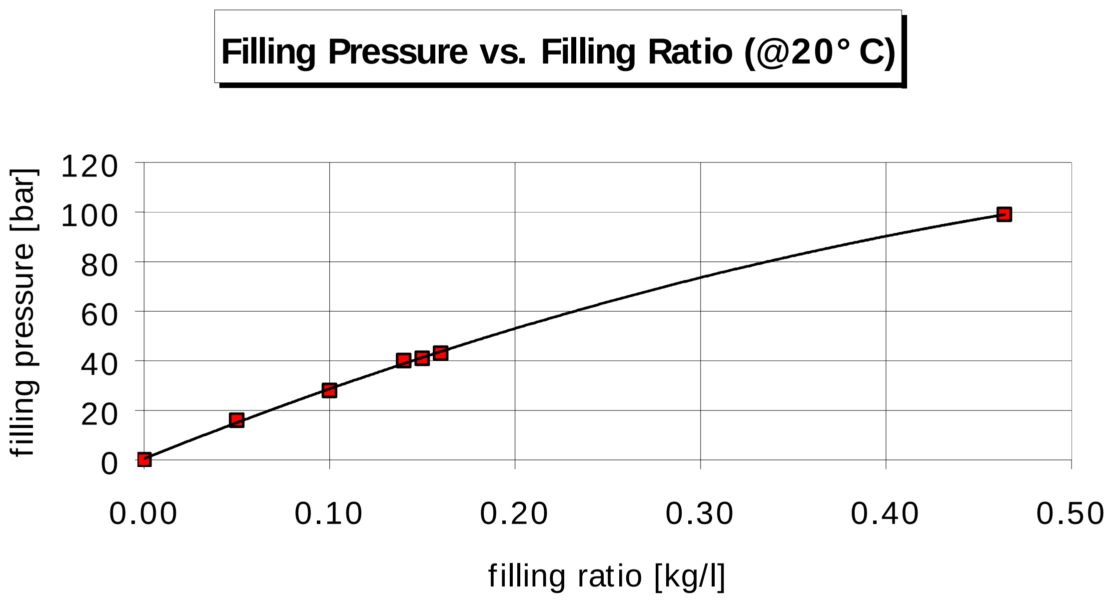
Due to the high NF_3 velocity inside valves which are fitted to cylinders and tubes, they must be designed to withstand the service conditions and must be constructed of materials which are compatible with NF_3 (see Section 6.).

Cylinder valve types should be type tested before being used for NF_3 service. Such tests may include adiabatic testing with oxygen and endurance testing (according to EN 849 “Transportable gas cylinders – Cylinder valves – Specification and type testing” or ISO 10297 “Gas cylinders – cylinder valves – Specification and type testing”. Suitably designed pneumatically actuated valves have been found to be satisfactory in NF_3 service, although these valves must be designed to open slowly to avoid adiabatic compression.

7.2.3 Cylinder filling ratios

NF_3 cylinders are normally filled by weight because pressure measurement cannot be readily relied upon to determine cylinder content over a range of temperatures.

The recommended filling ratio is 0.5 kg/litre (which equates to a filling pressure of about 100 bar at 20°C).



7.3 Cylinder filling equipment

7.3.1 Filling manifold

Pipeline components in contact with NF_3 filling shall be designed in accordance with 5.2.3 and 6.3. Cylinder valves and other equipment creating a higher velocity due to pressure drop shall be designed and constructed according to the requirements contained in Section 5. Particular attention shall be taken with filters and valve seat materials.

When not under NF_3 pressure, manifolds should be under constant inert gas flow-through purge, with vent to a safe location and/or plugged to ensure that any contaminants are excluded.

The design of filling manifold pigtails should ensure that the NF_3 velocities are in accordance with 5.2.3. Under certain conditions, (e.g. a full cylinder being vented) it may not be possible to comply with 5.2.3, however such operations may be safely achieved by operating valves remotely and ensuring the system is clean. Convoluted stainless steel flexible hoses or small diameter (flexible) or stainless steel tube may also be used.

7.3.2 Compressors

Consideration should be given to the location of an NF_3 compressor in a separate enclosure, provided with remote start-up and shut-down capability.
NF_3 compressors shall be specifically designed for NF_3 service. NF_3 hot wetted parts (e.g. valves) should be made of nickel, or monel.
Where it is absolutely necessary to use non-metallic components (e.g. washers and seats), only PTFE or PCTFE shall be used.

The heat generated by the compression of NF_3 should be considered and the compressor design should endeavour to minimise the NF_3 gas temperature. This can be achieved by:

- Limiting the compression ratio and, if necessary undertaking the required compression in several stages, possibly cooling the gas between each stage.
- Choosing materials with high thermal conductivity for components that are in contact with the gas
- Limiting the rate at which the gas is compressed – this may be particularly important where high compression ratios are used, e.g. single stage piston compressors.
- Introducing a high temperature interlock to shut down the system in the event of excessive temperature being reached

7.3.3 Vacuum pumps

Vacuum pumps in contact with NF_3 shall be either dry pumps or using a fluorinated fluid for example, “FOMBLIN®”.

7.3.4 Pressure gauges

Special care should be taken to ensure that pressure gauges are cleaned internally to a standard equivalent to that used in oxygen service before use and installation. Care must be taken to ensure that cleaning materials are also removed (e.g. solvents).

Consideration should be given to the protection of the operator in the event of a pressure gauge failure.

8 Gas supply to point-of-use

8.1 Facility considerations

Areas where nitrogen trifluoride supply containers are stored and used shall be in accordance with local regulations. In the absence of local regulations, a well ventilated area 5 metres away from any fire risk (or separated by a fire resistant barrier), is recommended.

Consideration shall be given to fire fighting and the arrangements to keep supply gas containers cooled in the event of a fire.

Materials that are to be used in nitrogen trifluoride service must be kept clean (free from oil, particles etc.) and therefore stored in a clean environment. Great care must be taken when changing gas wetted components to avoid contamination from oil that may be on the operator's hands (e.g. cylinder valve outlet gasket washers). Consideration should be given to wearing suitable gloves for such operations.

8.2 Gas supply manifolds

Gas supply manifolds shall be located in a well ventilated area. *Gas cabinets* are often used for this purpose.

Provision shall be made to deal with emergencies, such as leaks and reactions within nitrogen trifluoride supply systems (see Section 10).

All parts of the gas supply system that are likely to come into contact with nitrogen trifluoride at pressures above 10 bar should be cleaned and passivated prior to introducing nitrogen trifluoride for the first time (see 6.4.).

Adequate precautions shall be taken to ensure that nitrogen trifluoride does not inadvertently come into contact with any flammable gas or other flammable material. Non return valves shall not be solely relied upon to provide protection from contaminating the NF_3 supply due to backflow of other gases in the system.

A purge gas is often used to purge parts of the nitrogen trifluoride system after supply cylinder change-over or maintenance work. Appropriate precautions shall be taken to ensure that the purge gas supply does not become contaminated with nitrogen trifluoride. It is recommended that a dedicated purge gas source (e.g. a *cylinder* supply) is used. This will avoid the risk of back-feeding (via the purge gas system) into another process gas supply system.

8.3 Operating procedures and personnel

All operations involving nitrogen trifluoride shall be covered by written operating procedures.

A *risk assessment* should be carried out on all operations involving nitrogen trifluoride.

Components and materials that may be used on nitrogen trifluoride supply systems (e.g. during cylinder change-over or equipment maintenance) shall be clearly identified, carefully stored and handled to ensure that they do not become contaminated. It is recommended that cylinder valve outlet connection gaskets are only handled whilst wearing approved gloves. This will avoid the risk of contamination of the gasket by the natural oils found on the skin.

All personnel involved in the handling of nitrogen trifluoride and the operation of nitrogen trifluoride supply systems shall be adequately trained. This training shall include the importance of cleanliness and the need for exclusive use of specified materials and components on nitrogen trifluoride gas handling systems.

Personnel who operate gas supply manifolds or change-over supply cylinders shall have a good understanding of the properties and fire and explosion hazards of nitrogen trifluoride (see Section 5.).

They should also be trained to take the appropriate action in the event of an emergency (see Section 10.).

When it is impracticable to select the best materials according to 5.3.1 and 5.3.2, preventive measures shall be considered to protect operators (e.g. fire resistant barrier or gas cabinet with remote access, or operator wearing fire retardant clothing, gloves and eye protection). Remote operation of high pressure systems shall be undertaken wherever practicable.

9 Gas abatement systems

9.1 Basic principles of abatement

a) $2\ NF_3 + 2\ AlCl_3 \longrightarrow N_2 + 3\ Cl_2 + 2\ AlF_3$ @ 70°C
b) $2\ NF_3 + 3\ H_2 \longrightarrow N_2 + 6\ HF$ (very intensive reaction)
c) $NF_3 + Fe \longrightarrow Fe\ F_2, Fe\ F_3 + N_2$ @ 300-400°C
d) $NF_3 + Si \longrightarrow Si\ F_4 + N_2$ @ > 400°C
e) thermal ionisation and reaction with added partners
f) plasma ionisation and reaction with added partners
g) in combination with PFC recovery systems
h) reclaimation at cylinder filling facilities

The best method of abatement depends on whether it is pure (cylinder filling facilities) or contaminated/diluted (after some process uses).
At a cylinder filling facility, where the NF_3 is not contaminated, recovery is usually practicable.
After use in a process, e.g. in an exhaust system, contamination could be present and a chemical abatement system may be necessary. Such an abatement system could also deal with other PFC's that may be present in the system.

9.2 Abatement - semiconductor process tool exhaust system

There are a number of solid state abatement systems commercially available. These systems are normally designed to fit into the process exhaust.

9.3 Abatement at a cylinder filling facility

Wherever practicable, residual NF_3 shall be reclaimed (for re-qualification or purification and subsequent use). See also IGC document 30/10 "Disposal of gases – Code of practice".

10 Emergency response

It is always important to be prepared for an emergency situation and the information below should be used to as a guide to what actions to take in the event of an emergency and what information should be considered to be included in an emergency procedure. Special training is necessary for emergency response

Refer to the AIGA 04/04 "Handling Gas Container Emergencies".

In the event of a leak involving NF_3 isolate all the sources of NF_3 where possible by closing the valves on the cylinder, bundle or tube module (and any cylinders that may be in the process of being filled).

To help control small fires, use Carbon dioxide (CO2) or water extinguishers. Carbon dioxide may not extinguish a reaction; it will help to cool down the area and limit the reaction. Do not use Halons, dry ammonium phosphate, or bicarbonate on NF_3 fires as they produce toxic by-products. Water may be used for fires covering a large area.

Before attempting to tackle any emergency situation always ensure that personnel are properly trained and adequate and appropriate personal protective equipment is worn.

Appendix 1: References

Note — Physical and chemical data given in this code have been selected by the working group to be the most appropriate. Reference sources are not given.

Nitrogen Trifluoride : its chemistry, toxicity and safe handling, 1976, naval surface weapon centre, White Oak Laboratory, White Oak, and Silver Spring, Maryland 20910, USA.

Gugliemini, C.J., Kadri, S.H., Martrich, R.L., Slusser, J.W., Vora, J., Werley, B.L, and Woytek, A. J., Flammability of metals in Fluorine and Nitrogen Trifluoride, Flammability and sensitivity of Materials in Oxygen enriched atmospheres: Seventh Volume, ASTM STP 1267, Dwigth, D. Janoff, William T. Royals, and Mohan V. Gunaji, Eds, American Society for Testing and Materials, Philadelphia, 1995.

Occupational Health Guideline for Nitrogen Trifuoride, US department of health and human services, 1978.

IGC doc. 30/10 "Disposal of Gases – Code of practice"

AIGA 004/04 "Handling Gas Container Emergencies"

AIGA 021/05 "Oxygen Pipeline systems".

EN/ISO 11114-3 "Transportable gas cylinder – compatibility of cylinder and valve materials with gas contents – part 3 : autogeneous ignition test in oxygen atmosphere.

AIGA 012/04 "Cleaning of equipment for oxygen service – Guidelines".

ASTM D1430-95 Specification for polychlorotrifluoroethylene (PCTFE).

EN 849 "Transportable gas cylinders – cylinder valves – specification and type testing"

ISO 10297 "Gas cylinders – cylinder valves – Specification and type testing".

CGA G.4.1 – Cleaning equipment for oxygen service, 1/1/1996.

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Label 2.2 : Non flammable, non toxic gas.

Label 5.1 : Oxidizing substances.

O : Oxidizing

1 IDENTIFICATION OF THE SUBSTANCE / PREPARATION AND OF THE COMPANY / UNDERTAKING

Trade name : Nitrogen trifluoride
MSDS No : WEB_EIGA091
Chemical formula : NF3
Company identification : Company Name
Company Address
ZIP CODE City Country
Emergency phone nr : Company Tel. Emergency N°

2 COMPOSITION / INFORMATION ON INGREDIENTS

Substance / Preparation : Substance.

Substance name		Contents	CAS No	EC No	Index No	Classification
Nitrogen trifluoride	:	100 %	7783-54-2	232-007-1	-----	O; R8

Contains no other components or impurities which will influence the classification of the product.

3 HAZARDS IDENTIFICATION

Hazards identification : Liquefied gas.
Oxidant. Strongly supports combustion. May react violently with combustible materials.

4 FIRST AID MEASURES

First aid measures
- Inhalation : Delayed adverse effects possible.
Remove victim to uncontaminated area wearing self contained breathing apparatus. Keep victim warm and rested. Call a doctor. Apply artificial respiration if breathing stopped.

5 FIRE-FIGHTING MEASURES

Flammable class : Non flammable.
Specific hazards : Exposure to fire may cause containers to rupture/explode.
Supports combustion.
Hazardous combustion products : If involved in a fire the following toxic and/or corrosive fumes may be produced by thermal decomposition : Hydrogen fluoride. Nitric oxide/nitrogen dioxide.
Extinguishing media
- Suitable extinguishing media : Carbon dioxide. Water.
- Unsuitable extinguishing media : Halons.
Specific methods : If possible, stop flow of product.
Move away from the container and cool with water from a protected position.
Special protective equipment for fire fighters : Use self-contained breathing apparatus and chemically protective clothing.

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6 ACCIDENTAL RELEASE MEASURES

Personal precautions : Evacuate area.
Wear self-contained breathing apparatus when entering area unless atmosphere is proved to be safe.
Ensure adequate air ventilation.
Eliminate ignition sources.

Environmental precautions : Try to stop release.
Prevent from entering sewers, basements and workpits, or any place where its accumulation can be dangerous.

Clean up methods : Ventilate area.

7 HANDLING AND STORAGE

Storage : Segregate from flammable gases and other flammable materials in store.
Keep container below 50°C in a well ventilated place.

Handling : Use no oil or grease.
Open valve slowly to avoid pressure shock.
Suck back of water into the container must be prevented.
Do not allow backfeed into the container.
Use only properly specified equipment which is suitable for this product, its supply pressure and temperature. Contact your gas supplier if in doubt.
Keep away from ignition sources (including static discharges).
Refer to supplier's container handling instructions.

8 EXPOSURE CONTROLS / PERSONAL PROTECTION

Personal protection : Keep self contained breathing apparatus readily available for emergency use.
Do not smoke while handling product.
Ensure adequate ventilation.

Occupational Exposure Limits : Nitrogen trifluoride : TLV© -TWA [ppm] : 10
Nitrogen trifluoride : OEL (UK)-LTEL [ppm] : 10
Nitrogen trifluoride : OEL (UK)-STEL [ppm] : 15
Nitrogen trifluoride : VME - France [ppm] : 10
Nitrogen trifluoride : HTP-värden - 15min - [ppm] : 10
Nitrogen trifluoride : HTP-värden - 15min - [mg/m³] : 29

9 PHYSICAL AND CHEMICAL PROPERTIES

Physical state at 20 °C	: Liquefied gas.
Colour	: Colourless gas.
Odo(u)r	: Mouldy.
Molecular weight	: 71
Melting point [°C]	: -207
Boiling point [°C]	: -129
Critical temperature [°C]	: -39
Vapour pressure, 20°C	: Not applicable.
Relative density, gas (air=1)	: 2.4
Relative density, liquid (water=1)	: 1.5
Solubility in water [mg/l]	: 61
Flammability range [vol% in air]	: Non flammable.
Auto-ignition temperature [°C]	: Not applicable.
Other data	: Gas/vapour heavier than air. May accumulate in confined spaces, particularly at or below ground level.

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10 STABILITY AND REACTIVITY

Stability and reactivity : May react violently with combustible materials.
May react violently with reducing agents.
Violently oxidises organic material.

11 TOXICOLOGICAL INFORMATION

Toxicity information : Damage to red blood cells (haemolytic poison).

12 ECOLOGICAL INFORMATION

Ecological effects information : No known ecological damage caused by this product.
Global warming factor [CO2=1] : 8000

13 DISPOSAL CONSIDERATIONS

General : Do not discharge into any place where its accumulation could be dangerous.
Avoid discharge to atmosphere.
Contact supplier if guidance is required.

14 TRANSPORT INFORMATION

UN No. : 2451
H.I. nr : 25
ADR/RID
- Proper shipping name : NITROGEN TRIFLUORIDE
- ADR Class : 2
- ADR/RID Classification code : 2 O
- Labelling ADR : Label 2.2 : Non flammable, non toxic gas.
Label 5.1 : Oxidizing substances.

Other transport information : Avoid transport on vehicles where the load space is not separated from the driver's compartment.
Ensure vehicle driver is aware of the potential hazards of the load and knows what to do in the event of an accident or an emergency.
Before transporting product containers :
- Ensure that containers are firmly secured.
- Ensure cylinder valve is closed and not leaking.
- Ensure valve outlet cap nut or plug (where provided) is correctly fitted.
- Ensure valve protection device (where provided) is correctly fitted.
- Ensure there is adequate ventilation.
- Compliance with applicable regulations.

15 REGULATORY INFORMATION

EC Classification : Not included in Annex I.
Proposed by the industry.
O; R8

EC Labelling
- Symbol(s) : O : Oxidizing
- R Phrase(s) : R8 : Contact with combustible material may cause fire.
- S Phrase(s) : S9 : Keep container in a well-ventilated place.
S17 : Keep away from combustible material.
S23 : Do not breathe the gas, fumes, vapours, spray.

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16 OTHER INFORMATION

Ensure all national/local regulations are observed.
Users of breathing apparatus must be trained.

This Safety Data Sheet has been established in accordance with the applicable European Directives and applies to all countries that have translated the Directives in their national laws.

Before using this product in any new process or experiment, a thorough material compatibility and safety study should be carried out.
Details given in this document are believed to be correct at the time of going to press. Whilst proper care has been taken in the preparation of this document, no liability for injury or damage resulting from its use can be accepted.

NOTE FOR EIGA MEMBER COMPANIES : This SDS is for information only to the EIGA members. EIGA members are not allowed to transmit them as such to their final customers.

End of document

Company Name
Company Address ZIP CODE City Country

Appendix 3: Audit checklist

It is recommended that facilities handling nitrogen trifluoride undergo periodic audits to assess their compliance with this code and with other recognised safe working practices. The nature and detail of such audits will be determined by the type of work undertaken at the facility, its level of involvement with NF_3, and compliance with local regulations.

The checklists given in the following 3 pages are unlikely to be exhaustive for all NF_3 facility audit applications, however they may provide a helpful starting point. There are separate checklist sections to cover NF_3 cylinder filling and NF_3 supply systems, however the other checklist sections are likely to be applicable to all NF_3 handling facilities. The “Ref” column gives, where appropriate, the section of this document where more information on the checklist item may be found.

No	CHECKLIST ITEM	Ref
1	**NF_3 storage area**	
1.1	Are NF_3 cylinders & other containers safely stored in a well ventilated area, at least 5 metres away from flammable materials (or separated by fire resisting wall)?	7.1; 8.1
1.2	Does the NF_3 storage facility meet local Fire Regulations (where applicable)?	7.1; 8.1
1.3	Is the storage area properly labelled?	----
1.4	Are cylinders in the store properly secured to prevent them falling over and are their valve protection caps properly fitted?	----
2	**NF_3 Filling procedures and equipment**	
2.1	Has the NF_3 filling equipment been designed by competent engineers, who are familiar with the properties of NF_3 and the precautionary measures and material requirements necessary for its safe handling (as set out in this Code)?	whole Code
2.2	Has a "Hazop" been carried out on the system?	6.1
2.3	Has a risk assessment been carried out on the system?	8.3
2.4	*If there is any uncertainty with respect to 2.1, 2.2 or 2.3, it is recommended that detailed and documented reviews of the process equipment drawings, system design and all component specifications are carried out to confirm compliance with this Code.*	Whole Code
2.5	Is the NF_3 cylinder filling system and all its component parts located in well ventilated places away from fire risk?	7.1
2.6	Are there adequate operating procedures for NF_3 cylinder filling equipment? Do these procedures take into account all the recommended operational precautions set out in this code?	6.7; 5.4.4;
2.7	Is the NF_3 cylinder filling equipment dedicated to NF_3 service?	6.9
2.8	Are all flammable gases separated from the NF_3 cylinder filling equipment?	6.9
2.9	Is there an NF_3 compressor – does it comply with the recommendations in this Code?	7.4.2
2.10	Is there a purge gas associated with the NF_3 cylinder filling equipment? If so, is it a dedicated supply? If it is not a dedicated supply (e.g. "house" supply), are there adequate precautions to ensure the purge gas is not contaminated with flammable materials or cannot become contaminated with NF_3.	6.9
2.11	Are all lubricants that could come into contact with NF_3 compatible with NF_3 (e.g. vacuum pump & compressor oils)?	7.4.3
2.12	Are NF_3 cylinders approved for and dedicated to NF_3 service or, if not, are they properly prepared prior to filling to ensure they are not contaminated with any materials that may react with NF_3?	7.2.1
2.13	Have the NF_3 cylinder valves been approved for NF_3 service by a responsible expert (competent) person within the gas company and/or a competent external authority.	7.2.2
2.14	Are cylinder valves properly prepared prior to use to ensure they are not contaminated with any materials that may react with NF_3?	7.2.2
2.15	Are only approved compatible gaskets used for sealing valve outlet connections and do operators take care to ensure they are in good clean condition before use?	6.2
2.16	Are there adequate checks to ensure NF_3 are not overfilled?	7.3
2.17	Are there adequate checks and controls to prevent unauthorised modification of equipment and operating procedures?	----

No	CHECKLIST ITEM	Ref
2.18	Are adequate precautions taken to prevent the contamination of equipment, particularly when it is not in use?	7.4.1
2.19	Are precautions taken to detect and act upon fire or NF_3 leakage (e.g. installation of detectors, automatic valve shut-off etc.)?	7.1

3	**NF_3 Supply and supply equipment (for cylinder filling or use)**	
3.1	Has the equipment been designed and installed in accordance with this code?	Whole Code
3.2	*If there is any uncertainty with respect to 3.1, it is recommended that detailed and documented reviews of the process equipment drawings, system design and all component specifications are carried out to confirm compliance with this Code.*	Whole Code
3.3	Are NF_3 supply cylinders located in a well ventilated place away from fire risk?	8.1; 8.2
3.4	Are there adequate operating procedures for NF_3 supply equipment? Do these procedures take into account all the recommended operational precautions set out in this code?	6.7; 8.3; 5.4.4
3.5	Is the NF_3 supply equipment dedicated to NF_3 service?	6.9
3.6	Are cylinders connected for use properly secured to prevent them falling over?	----
3.7	Are all flammable gases separated from NF_3 supply equipment?	6.9; 8.2
3.8	Is there a purge gas associated with the NF_3 supply equipment? If so, is it a dedicated supply? If it is not a dedicated supply (e.g. “house” supply), are there adequate precautions to ensure the purge gas is not contaminated with flammable materials or cannot become contaminated with NF_3.	6.9; 8.2
3.9	Are all lubricants that could come into contact with NF_3 compatible with NF_3 (e.g. vacuum pump oil)?	7.4.3
3.10	Are only approved compatible gaskets used for sealing valve outlet connections and do operators take care to ensure they are in good clean condition before use?	6.2
3.11	Are there adequate checks and controls to prevent unauthorised modification of equipment and operating procedures?	----
3.12	Are adequate precautions taken to prevent the contamination of equipment, particularly when it is not in use?	7.4.1

4	**NF_3 Abatement and abatement equipment**	
4.1	Has a risk assessment been carried out to confirm that the arrangements for the disposal of waste NF_3 are adequate to ensure the safety of people and to minimise any impact on the environment?	9; 8.1

No	CHECKLIST ITEM	Ref
5	**Maintenance procedures**	
5.1	Are there adequately documented procedures to cover the maintenance of NF_3 handling equipment? Are records kept of work carried out?	6.8
5.2	Is NF_3 equipment maintenance covered by a “permit-to-work” procedure, where appropriate?	----
5.3	Are materials and components that may be used during the maintenance of NF_3 equipment clearly specified/identified?	----
5.4	After maintenance work, is there an adequate cleaning and purging (plus passivation where appropriate) procedure to be implemented before the equipment is returned to NF_3 service?	5.3.7; 6.4
6	**Personnel**	
6.1	Is there a recorded training programme on gas handling for all personnel involved in handling NF_3 and maintaining NF_3 equipment?	----
6.2	Are all personnel involved with NF_3 sufficiently trained to cover their degree of involvement? ***Note:*** *It is recommended that a representative sample of operational personnel are interviewed during the audit to assess their understanding of the properties of NF_3 and the particular care that is necessary to avoid incidents.*	5; 6.7; 7.1; 8.3; 10
6.3	Do personnel who handle NF_3 have access to an NF_3 material safety data sheet?	App.2
6.4	Do personnel who handle NF_3 wear/use appropriate personal protection equipment?	8.3; 7.1
7	**Emergency response**	
7.1	Is there an adequate emergency response procedure in place?	10
7.2	Is there adequate fire fighting and personal protective equipment readily available in the event of an NF_3 ignition?	10
7.3	Is the local Fire Brigade aware of the location of and hazards arising from NF_3 on site?	----
7.4	Is there adequate first aid information available locally?	App.2 Sec 4