

IEEE Guide for Sulphur Hexafluoride (SF₆) Gas Handling for High-Voltage (over 1000 Vac) Equipment

IEEE Power & Energy Society

Sponsored by the
Substations Committee
and
Switchgear Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
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IEEE Std C37.122.3™-2011

9 January 2012

IEEE Guide for Sulphur Hexafluoride (SF₆) Gas Handling for High-Voltage (over 1000 Vac) Equipment

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Substations Committee
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IEEE Power & Energy Society

Approved 2 November 2011

IEEE-SA Standards Board

Approved 14 January 2013

American National Standards Institute

Grateful acknowledgment is made to CIGRE for the permission to use the following source material:

CIGRE Brochure No. 276, Guide for preparation of customized "Practical SF₆ handling instructions," August 2005 edition.

Abstract: Significant aspects of handling SF₆ gas used in electric power equipment such as gas recovery, reclamation, recycling in order to keep the gas permanently in a closed cycle and avoiding any deliberate release in environment are described. The purpose of this guide is to provide state-of-the-art technologies and procedures to minimize SF₆ gas emission to a minimum functional level for the electric power equipment to preserve the environment. This guide will include all the aspects for consideration during commissioning and recommissioning, topping up, refilling, checking the gas quality at site, sampling and shipment for off-site gas analysis, and recovering and reclaiming during normal operation and at the end of the life of power equipment while dismantling. This guide also presents the state-of-the-art tools and measuring devices including the necessary personnel protective equipment. The basis for the preparation of this guide is CIGRE Brochure No. 276, Guide for preparation of customized "Practical SF₆ handling instructions," August 2005 edition, developed by the Study Committee B3, Task Force B3.02.01.

Keywords: IEEE C37.122.3, SF₆ analysis, SF₆ handling, SF₆ reclaiming, SF₆ recovery, SF₆ safety, SF₆ transportation

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

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PDF: ISBN 978-0-7381-6821-0 STD97172
Print: ISBN 978-0-7381-6822-7 STDPD97172

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Introduction

This introduction is not part of IEEE Std C37.122.3-2011, IEEE Guide for Sulphur Hexafluoride (SF₆) Gas Handling for High-Voltage (over 1000 Vac) Equipment.

The purpose of this document is to provide practical recommendations for a customized “Practical SF₆ Handling Instruction Guide” that applies to all equipment and can become a standardized document containing standard information and procedures covering the following:

- Commissioning or recommissioning
- Topping-up
- Refilling
- Checking gas quality on-site
- Sampling and shipment for off-site gas analysis
- Recovery and reclaiming
- Recovery and reclaiming at the end of life when the electric power equipment is dismantled

The guide is organized in individual modules that can be bound together to form a customized “Practical SF₆ Handling Instructions” manual. Such a standard manual describes the SF₆ handling procedure according to the state-of-the-art technique. It is recommended that this guide be strictly followed in order to achieve operational, safety-at-work, and environmental benefits such as the following:

- Safer operation of the equipment
- Optimization of resources and tools required
- Minimization of out-of-service time for equipment
- Standard training of personnel handling SF₆
- Reduction of the amount of gas released during handling operations down to the functional physical limit
- Avoidance of any deliberate release, e.g., flushing to the atmosphere
- Reduction of SF₆ losses and emissions during commissioning, service, and operation to a minimum

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1. Overview

1.1 Scope

This guide describes significant aspects of handling SF₆ gas used in electric power equipment, such as gas recovery, reclamation, and recycling, in order to keep the gas permanently in a closed cycle and to avoid any deliberate release into the environment.

1.2 Purpose

To provide state-of-the-art technologies and procedures to minimize SF₆ gas emission to a minimum functional level for the electric power equipment to preserve the environment. This guide will include all the aspects for consideration during commissioning and recommissioning, topping up, refilling, checking the gas quality at site, sampling and shipment for off-site gas analysis, and recovering and reclaiming during normal operation and at the end of the life of power equipment while dismantling. This guide also presents the state-of-the-art tools and measuring devices including the necessary personnel protective equipment. The basis for the preparation of this guide is CIGRE Brochure No. 276, Guide for preparation of customized “Practical SF₆ handling instructions,” August 2005 edition, developed by the Study Committee B3, Task Force B3.02.01.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ASTM D2472-00, Standard Specification for Sulfur Hexafluoride.¹

IEC 60376, Specification of technical grade sulfur hexafluoride (SF₆) for use in electrical equipment.²

IEC 60480, Guidelines for the checking and treatment of sulfur hexafluoride (SF₆) taken from electrical equipment and specification for its reuse.

IEC 62271-1, High-voltage switchgear and controlgear—Part 1: Common specifications.

IEC/TR 62271-303, High-voltage switchgear and controlgear—Part 303: Use and handling of sulphur hexafluoride (SF₆).

ISO 14040, Environmental management—Life cycle assessment—Principles and framework.³

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary: Glossary of Terms & Definitions* [B10] should be referenced for terms not defined in this clause.^{4, 5}

energized: Qualifies a conductive part of the electrical equipment that has an electric potential difference with respect to a relevant reference. The reference potential is usually earth or an equipotential frame.

evacuation: The transfer of air or nitrogen (N₂) from the electric power equipment to the atmosphere or the transfer of SF₆ from the electric power equipment to gas-handling equipment.

pressure: Force divided by area.

NOTE—In this document, pressures are given in terms of absolute units.⁶

reclaimer: Device for purification and storage of used SF₆ for the purpose of reuse. This device is also known as a *gas cart*.

SF₆ recovery: SF₆ transfer from the electric power equipment into a reclaimer or a storage container.

¹ ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (<http://www.astm.org/>).

² IEC publications are available from the Central Office of the International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, CH-1211, Geneva 20, Switzerland (<http://www.iec.ch/>). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

³ ISO publications are available from the ISO Central Secretariat, 1, ch. de la Voie-Creuse, Case Postale 56, CH-1211, Geneva 20, Switzerland (<http://www.iso.org/>). IEC publications are available from the Central Office of the International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, CH-1211, Geneva 20, Switzerland (<http://www.iec.ch/>).

⁴ The *IEEE Standards Dictionary: Glossary of Terms & Definitions* is available at <http://shop.ieee.org/>.

⁵ The numbers in brackets correspond to those of the bibliography in Annex C.

⁶ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

tight drilling system: When connection to SF₆ compartment via available openings (e.g., filling points, pressure gauge) is not provided, then a tight drilling system should be used. This generally consists of a drill fitted with a hollow bit connected to hoses with appropriate gasket systems to avoid leakage during and after drilling.

4. General background modules

4.1 General

This clause provides general background information about SF₆, related equipment, environmental considerations, and safety, organized as modules.

4.2 Gas characteristics

The following subclauses describe the main properties and characteristics of SF₆ gas.

4.2.1 General

Sulfur hexafluoride (SF₆) is a synthetic gas formed by six atoms of fluorine gathered around a centrally situated atom of sulfur. The chemical formula is SF₆ and the molecular weight is 146.05 g/mol.

The chemical bond between fluorine and sulfur is known as one of the most stable existing atomic bonds. Six of these bonds grant the molecule very high chemical and thermal stability. In addition, the compatibility of SF₆ with material used in electric constructions is similar to that of nitrogen (N₂), up to temperatures of about 180 °C (356 °F).

Since the early 1960s, SF₆ has been successfully used by the electric industry in power equipment for the high-voltage (HV) transmission and medium-voltage (MV) distribution of electricity (e.g., gas-insulated substations, ring main units, circuit breakers, transformers, and cables).

For electrical equipment, SF₆ offers excellent electric insulation and switching properties. Today's high performance of HV switchgear in voltage level and current switching capability cannot be reached with any other gas.

Other gases under consideration for application in HV switchgear have shown better insulating performance or switching performance, but not both. Most of these gases do not offer long-term stability. Additionally, they are often toxic or cost prohibitive.

Other non-electrical industrial applications of SF₆ include metallurgy, electronics, scientific equipment, ocular surgery, and military applications.

The maximum tolerable moisture level for the gas in the equipment is specified by IEC 62271-1.⁷ Purity requirements for SF₆ as it comes from the supplier are specified by ASTM D2472-00 and IEC 60376. Purity requirements for reuse of reclaimed SF₆ are specified by IEC 60480.

⁷ Information on references can be found in Clause 2.

4.2.2 Physical

Pure SF₆ is odorless, tasteless, non-toxic, non-corrosive, non-flammable, and chemically inert at ambient temperature. It does not support combustion.

Although the gas is non-toxic, it does not support life, as it is not oxygen. Equipment containing SF₆ should not be entered without adequate ventilation and personal protection equipment.

The solubility of SF₆ in water (7000 ppmv) is four times lower than that of air.

4.2.3 Thermodynamic

At normal room temperatures and pressures [20 °C and 100 kPa (68 °F and 14.5 psi)], SF₆ is about five times heavier than air.⁸ Its density is 6.139 g/L (0.382 lb/ft³).

As the gas is heavier than air, areas below ground level, poorly-ventilated areas, or unventilated areas (e.g., cable ducts, trenches, inspection pits, and drainage systems), may remain full of SF₆. Personnel should be aware of the danger of asphyxiation in such places.

As the critical temperature and pressure of SF₆ are 45.54 °C and 3.759 MPa (113.97 °F and 545.197 psi) respectively, it can be liquefied by compression and is usually transported as a liquid in cylinders or containers.

Given that the gas is delivered in the form of compressed liquid, if large quantities of the gas are released rapidly, the temperature of both the gas and the container will fall quickly. Frost and ice may form on metal parts. If this occurs, gas filling should be immediately stopped until ice and frost are gone. Filling of SF₆ should always be performed slowly. Personnel should be aware of the danger of freeze burns when touching iced and/or frozen metal parts.

The heat capacity of one mole of SF₆ is around three times greater than air.

4.2.4 Electric

SF₆ is strongly electronegative (i.e., it tends to attract free electrons). It has a unique combination of physical properties, including high dielectric strength (about three times that of air), high thermal interruption capabilities (about 10 times that of air), and high heat transfer performance (about twice that of air).

4.2.5 Environmental

SF₆ does not harm the ecosystem; biological accumulation in the food chain does not occur. It is an inert gas with very low solubility in water and therefore presents no danger to surface water, ground water, or the soil.

SF₆ has no impact on the stratospheric ozone layer—its *ozone depletion potential* (ODP) is 0. However, SF₆ is a potent greenhouse gas with a *global warming potential* (GWP) of 23 900. It is also a persistent greenhouse gas with an *atmospheric life time* (ALT) of 650 to 3200 years. The difference in the figures is a consequence of the adoption of different calculation models.

⁸ In this document, pressures are given in terms of absolute units.

The GWP of SF₆ alone is not adequate to measure the environmental impact of electric power equipment based on SF₆ technology. The environmental impact of any specific application should be evaluated and/or compared using the *life-cycle assessment* (LCA) approach, as regulated by ISO 14040.

SF₆ has to be used in a closed cycle. When gas removal from containment is needed, a proper handling procedure should be implemented to avoid any deliberate release into the atmosphere.

The yearly SF₆ emission rate from the overall electric industry represents 0.1% of the yearly emission rate of man-made global warming gases. As just one example, emissions from European manufacturers and users contribute only by 0.008%.

4.3 Characteristics of electric power equipment

The tightness of certain older installed gas-insulated power equipment, especially for HV systems, could be a significant issue for environmental impact. Nevertheless, it has to be kept in mind that handling SF₆ during installation, on-site testing, and maintenance activities may contribute significantly to the overall emissions.

State-of-the-art electric power equipment is designed and manufactured for tightness so that it is compatible with environmental protection guidelines. This implies the following:

- Very-low leakage rates due to the quality of the encapsulation, including its material, the machining process, the design of gaskets, the sealing material itself, and the factory testing procedures
- Very-low handling losses due to smaller gas compartments, reduced maintenance frequency, more sophisticated tools and instruments to handle and to check the gas quality, and specific training of designated personnel

In addition to these items noted, procedures for installation, service, maintenance, repair, and proper disposal should be described by the manufacturer in as detailed a manner as possible. Specially trained personnel should carry out the practical work.

4.3.1 Controlled pressure systems (obsolete)

In controlled pressure systems, a volume is automatically replenished from an external or internal gas source. The volume may consist of several permanently connected gas-filled compartments.

Controlled pressure systems are no longer used in new equipment, because of their high leakage rate. It is recommended that controlled pressure systems in old equipment be replaced by closed-pressure systems, because of the unacceptable leakage rate.

4.3.2 Closed-pressure systems

In closed-pressure systems, a volume is replenished only periodically by manual connection to an external gas source. High-voltage (above 72.5 kV) SF₆ single-pressure circuit breakers are examples of closed-pressure systems.

It is recommended that:

- The leakage rate be kept lower than 0.5% per annum (p.a.) per gas compartment.
- When SF₆ conditions are checked, that gas be recaptured from analysis equipment.
- Appropriate record-keeping procedures are used.

4.3.3 Sealed-pressure system

Sealed-pressure systems have gas volumes that are completely sealed. It is not expected that any gas or vacuum processing will be performed over the expected operating life. Sealed-pressure systems are completely assembled and tested in the factory.

Much state-of-the-art MV electric power equipment uses a sealed-pressure system. These systems are commercially designated “sealed for life,” as they require no on-site gas handling for their entire life duration, typically 40 years. End-of-life disposal is performed under the responsibility of the user and is supported by the manufacturer. Third parties, such as service companies, may also carry out end-of-life disposal.

During the product life of these systems, SF₆ is handled in a controlled environment only twice: for gas filling at the beginning and for gas recovery at the end. Given the limited handling, handling losses can be considered to be of the same order of magnitude as leakage losses. Today a typical leakage rate is lower than 0.1% p.a. per gas compartment.

4.3.4 Description of the installed system

Among all characteristics defined by the current IEC Standards in force and given in the instruction manual from the manufacturer, those most relevant to SF₆ handling are highlighted in Table 1. They are, at least, as shown in Table 1.

Table 1—Equipment characteristics related to SF₆ handling

Equipment characteristic	Closed-pressure systems	Sealed-pressure systems
SF ₆ mass per compartment/substation	X	X
Volume per compartment/substation	X	X
Rated SF ₆ filling pressure at 20 °C (68 °F)	X	X
Leakage rate in % p.a. per gas compartment	X	X
Designation of different compartments (e.g., breaker, disconnector, and bus bar)	X	X
Number of separate compartments	X	X
Location of safety overpressure control means	X	X
System used to observe the pressure in each containment	X	When relevant
Precautions when handling SF ₆ containments	X	—
Record-keeping	X	When relevant
Typical time between two consecutive maintenance operations in years	X	—
Typical time between two consecutive SF ₆ measurements in years	Required	—
Location of SF ₆ valves	X	When relevant
Location of gas tight spacers	X	When relevant
Pressure levels and number of alarms/indicators	X	When relevant

4.3.5 Description of the monitoring system for controlled and closed-pressure systems

In order to operate safely, switchgear needs a minimum gas pressure/density. In the case of controlled or closed-pressure systems, visual indications and/or acoustic alarms are set as a function of that threshold. If the gas pressure/density reaches its minimum threshold, standard operations can no longer be maintained and, according to specific users' requirements, appropriate counter measures (e.g., alarm, automatic lockout, or switching features) come into effect.

Common gas-monitoring systems provide an alarm or indication when 5% to 10% of the gas has been released. The system has been designed to operate safely under these conditions and still keeps a safety margin. In the case of compartments containing a small amount of gas, the impact on the environment is very small. On the contrary, in the case of large compartments, such as long bus-bar ducts, the amount of gas released before reaching the threshold is significant for the environment.

Therefore, it is recommended that the gas pressure/density of each compartment is monitored, whenever technically reasonable, to enable early detection of small leaks.

State-of-the-art monitoring systems continuously monitor gas pressure/density allowing for early detection of small leaks.

In addition to the above, appropriate corrective measures to locate and eliminate the leak should be immediately arranged.

4.4 Environmentally compatible SF₆ policy

SF₆ should be handled in a closed cycle to avoid any deliberate release to the environment. Among all the voluntary initiatives, gas recovery and recycling have the highest priority.

Voluntary agreements involving manufacturers and users have been signed in some countries with the aim of controlling and reducing emissions of SF₆ from electric power equipment. In general, it is mentioned in such agreements that for the development, manufacturing, installation, operation, maintenance, and end-of-life disposal of SF₆ electric power equipment, state-of-the-art technologies, procedures, and training should be applied to minimize SF₆ emissions.

The following voluntary actions are typically performed by users of SF₆:

- Systematically reusing, reprocessing, and disposing of SF₆ in a closed cycle process
- Monitoring of SF₆-filled gas compartments to ensure that leaks are detected and eliminated at an early stage (controlled and closed-pressure systems)
- Reusing SF₆ recovered from electric power equipment directly on-site, as much as possible
- Keeping non-reusable SF₆ in a closed cycle for further processing off-site
- Regularly training personnel handling SF₆, so that SF₆ is only handled by properly qualified personnel
- Recording SF₆ consumption and inventories
- Providing the authorities SF₆-relevant statistical data as a basis for regional/national SF₆ monitoring

The following voluntary actions are typically performed by equipment manufacturers and SF₆ producers:

- Producing and guaranteeing that electric power equipment will have a leakage rate lower than 0.5% p.a. for each compartment (controlled and closed-pressure systems)
- Providing electric power equipment that has a leakage rate lower than 0.1% p.a. for each compartment (sealed-pressure systems)
- Accepting returns of non-reusable SF₆ for reprocessing or reduction to environmentally compatible end products
- Keeping statistics of the SF₆ quantities produced and sold
- Providing the authorities SF₆-relevant statistical data as a basis for regional/national SF₆ monitoring

If SF₆ handling is performed as described above, LCA studies demonstrate that SF₆ technology applied to electric power equipment minimizes the impact on the environment.

4.5 Toxicity

Pure SF₆ is not toxic (see 4.2.2).

Toxic gaseous and/or solid decomposition products may arise during the operation of gas-insulated electric equipment. They are fully described in IEC/TR 62271-303.

Design rules and operational procedures are implemented to handle both the gas and the equipment according to safety rules, in order to eliminate any potential harmful effects.

4.6 Gas categories

SF₆ contains contaminants. These originate from the industrial manufacturing process as well as from use of the gas in electric power equipment. Depending on the nature and the amount of the contaminants, the following gas categories have been defined:

- Gas from gas suppliers (meeting the specification for either purchased gas or technical grade gas)
- Non-arced gas
- Normally arced gas
- Heavily arced gas
- Gas suited for the complete range of use pressures
- Gas suited for the low range of use pressures
- Gas not suited for reuse

The following subclauses provide additional details.

4.6.1 Gas from gas suppliers

Gas obtained from the gas supplier should meet specifications for either purchased gas (as defined in ASTM D2472-00) or technical grade gas (as defined in IEC 60376). The concept of technical grade gas was established to provide SF₆ that is pure enough for the electric industry.

The maximum acceptable impurity levels for purchased gas and technical grade gas are given in Table 2 and Table 3, respectively.

Table 2—Maximum acceptable impurity levels for purchased gas (ASTM D2472-00)

Impurity	Specification
Air (expressed as N ₂)	0.5 g/kg
Carbon tetrafluoride (CF ₄)	0.5 g/kg
H ₂ O (expressed in dew point)	−62 °C (−79.6 °F) ^a
Hydrolysable fluorides (expressed in the concentration of hydrofluoric acid)	0.3 mg/kg

^a −62 °C (−79.6 °F) is equivalent to a water content of 8.0 ppmv at 101 k Pa (14.696 psi).

Table 3—Maximum acceptable impurity levels for technical grade gas (IEC 60376)

Impurity	Specification
Air	2 g/kg ^a
CF ₄	2400 mg/kg ^b
H ₂ O	25 mg/kg ^c
Mineral oil	10 mg/kg
Total acidity expressed in hydrogen fluoride (HF)	1 mg/kg ^d

^a 2 g/kg is equivalent to 1% v under ambient conditions [100 kPa and 20 °C (14.5 psi and 68 °F)].

^b 2400 mg/kg is equivalent to 4000 µl/l (microliters per liter) under ambient conditions [100 kPa and 20 °C (14.5 psi and 68 °F)].

^c 25 mg/kg is equivalent to 200 µl/l and to a dew point of −36 °C (−32.8 °F), measured at ambient conditions [100 kPa and 20 °C (14.5 psi and 68 °F)].

^d 1 mg/kg is equivalent to 7.3 µl/l under ambient conditions [100 kPa and 20 °C (14.5 psi and 68 °F)].

Due to the maximum impurity levels that can be present in SF₆, the SF₆ amount in a container (measured in the liquid phase) should be higher than 99.7% for technical grade gas or 99.8% for purchased gas.

4.6.2 Non-arced gas

If the volume concentration of the indicator gases SO₂ + SOF₂ (sulfur dioxide plus thionyl fluoride) is lower than 100 ppmv, then the gas is non-arced.

Non-arced gas is to be expected at the following:

- Insulation testing in the factory
- Insulation testing on-site during erection/commissioning
- Routine maintenance of insulation compartments
- Repair of insulation compartments after malfunction without arcing
- Retrofitting of insulation compartments
- Decommissioning of insulation compartments in which arcing has not occurred
- Any kind of compartment after filling but prior to energizing

The major contaminants in non-arced gas may be air (mainly introduced by handling) and moisture (mainly desorbed from inner surfaces). Small quantities of reactive gaseous decomposition products (approximately 100 ppmv) may also be present when strong partial discharges have occurred in the gas.

4.6.3 Normally arced gas

Normally arced gas is gas that has been recovered from switchgear compartments after normal switching operations. In practice, if the volume concentration of the indicator gases SO₂ + SOF₂ is between 100 ppmv and 1%, then the gas is normally arced.

Normally arced gas is to be expected at the following:

- Maintenance and repair of switching devices after normal (load or fault) operation
- Interruption testing during switchgear development
- Decommissioning of switchgear

Normally arced gas may contain, in addition to air and moisture, the following:

- The inert gas CF₄, generated by arc erosion of polymers
- Corrosive gaseous decomposition products (approximately 100 ppmv to 200 ppmv) as residues
- Solid decomposition products, mainly metal fluorides and tungsten oxifluorides, usually referred to as *switching dust*

4.6.4 Heavily arced gas

Heavily arced gas is gas that has been recovered from equipment in which failure arcing has occurred. In practice, if the volume concentration of the indicator gases SO₂ + SOF₂ is greater than 1%, then the gas is heavily arced.

Heavily arced gas is to be expected from the following:

- Circuit breakers after interruption failure
- Insulation compartments after internal arcing failure
- Any kind of arcing failure

In this case, high levels of solid and gaseous contaminants should be expected. The gaseous contaminants may reach levels of several percentage points of the volume, of which a substantial fraction can be highly reactive, toxic, and/or corrosive.

4.6.5 Suited for the complete range of use pressures

Gas that is suited for the complete range of use pressures is used SF₆ gas that is stored in cylinders, tagged with the “orange collar,” compliant with a standard for used gas (such as IEC 60480), and that can be reused in any electric power equipment without any limitations.

The maximum acceptable impurity levels are given in Table 4.

Table 4—Maximum acceptable impurity levels for reuse of SF₆ at all use pressures (IEC 60480)

Impurity	Specification
Air and/or CF ₄	3% volume ^a
H ₂ O	25 ppmw ^b (see NOTE 1)
Mineral oil	10 ppmw (see NOTE 2)
Total reactive gaseous decomposition products	50 µl/l total or 12 µl/l for (SO ₂ + SOF ₂) or 25 µl/l HF
NOTE 1—Converted to ppmv these levels should also apply to mixtures until a suitable standard becomes available.	
NOTE 2—If gas-handling equipment (e.g., pump or compressor) containing oil is used, it may be necessary to measure the oil content of the SF ₆ . If all equipment in contact with the SF ₆ is oil-free, then it is not necessary to measure oil content.	

^a In case of SF₆ mixtures, the equipment manufacturer should specify the levels for these gases.

^b 25 mg/kg (25 ppmw) is equivalent to 200 ppmv (200 µl/l) and to a dew point of −36 °C (−32.8 °F), measured at 100 kPa and 20 °C (14.5 psi and 68 °F).

4.6.6 Suited for the low range of use pressures

Gas that is suited for the low range of use pressures is used SF₆ gas that is stored in cylinders, tagged with the “orange collar,” compliant with a standard for used gas (such as IEC 60480), and that can be reused in any electric power equipment having an SF₆ rated filling pressure not exceeding a certain limit [e.g., 200 kPa (29 psi)].

The maximum acceptable impurity levels are given in Table 5.

Table 5—Maximum acceptable impurity levels for reuse of SF₆ at low range of use pressures (IEC 60480)

Impurity	Specification
Air and/or CF ₄	3% volume ^a
H ₂ O	95 ppmw ^b (see NOTE 1)
Mineral oil	10 ppmw (see NOTE 2)
Total reactive gaseous decomposition products	50 µl/l total or 12 µl/l for (SO ₂ + SOF ₂) or 25 µl/l HF
NOTE 1—Converted to ppmv these levels should also apply to mixtures until a suitable standard becomes available.	
NOTE 2—If gas-handling equipment (e.g., pump or compressor) containing oil is used, it may be necessary to measure the oil content of the SF ₆ . If all equipment in contact with the SF ₆ is oil-free, then it is not necessary to measure oil content.	

^a In case of SF₆ mixtures, the equipment manufacturer should specify the levels for these gases.

^b 95 mg/kg (95 ppmw) is equivalent to 750 ppmv (750 µl/l) and to a dew point of −23 °C (−9.4 °F), measured at 100 kPa and 20 °C (14.5 psi and 68 °F).

4.6.7 Not suited for reuse

Gas that is not suited for reuse is used SF₆ gas that does not comply with a standard for used gas, such as IEC 60480. This gas requires further treatment, usually off-site. If further treatment is unsuccessful, the gas will require final disposal.