

 Eskom	Standard	Technology
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Title: **SF6 SAMPLING STANDARD**

Unique Identifier:

240-101383919

Alternative Reference Number: **<n/a>**

Area of Applicability:

Engineering

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STABILISED

COE Acceptance



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Date: 30 August 2021

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1	A specific plant, project or solution	
2	A mature and stable technical area/technology	X
3	Established and accepted practices.	

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SCOT Study Committee Number/Name: **GIS and Mixed Technologies Care Group**

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1. Introduction

Sulfur hexafluoride (SF₆) is widely used in switchgear installations as an insulating and arc-extinguishing (quenching) medium. It is important to ensure that the quality of the gas insulation is kept in good order to maintain the integrity of the insulation. To achieve this it is necessary to perform regular tests against well-defined parameters. This standard specifies the limit for in-service SF₆ gas insulation quality in Eskom's medium and high voltage SF₆ gas insulated switchgear.

2. Supporting clauses

2.1 Scope

The required gas purity and gas sampling interval for SF₆ gas used in Eskom's SF₆ gas insulated switchgear is stated in this standard.

2.1.1 Purpose

The purpose of this standard is to specify the purity and sampling intervals of SF₆ gas in Eskom gas insulated substations in order to ensure that the gas insulation is maintained in good condition. It also provides for uniformity of measurement units between different makes and models of equipment and to avoid confusion with the different units used by the various equipment manufacturers.

2.1.2 Applicability

This standard specifies the required purity for in-service SF₆ gas in Eskom's medium and high voltage switchgear.

2.2 Normative/informative references

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

- [1] ISO 9001, Quality Management Systems.
- [2] NRS 087, Guidelines for the management of SF₆ (Sulfur Hexafluoride) for use in electrical equipment.
- [3] SANS 62271-1 High-voltage switchgear and controlgear Part 1: Common specifications.
- [4] SANS 62271-4 High-voltage switchgear and controlgear Part 4: Handling procedures for sulfur hexafluoride (SF₆) and its mixtures.

2.2.2 Informative

- [5] IEC 60480 Guidelines for the checking and treatment of sulfur hexafluoride (SF₆) taken from electrical equipment and specification for its re-use.
- [6] IEC 60376 Specification of technical grade sulfur hexafluoride (SF₆) for use in electrical equipment.

2.3 Definitions

2.3.1 General

Definition	Description
Sea level atmospheric pressure	1013 hector Pascal

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Definition	Description
SF6 by-products and decomposition products	SF ₆ gas dissociates through an electric arc, heating, spark or discharge forming gaseous by-products and other lower fluorides. The majority of these by-products are highly corrosive and toxic. Solid by-products can usually be identified as a white/grey powder. Contaminated SF ₆ gas usually has a very pungent odour.

2.3.2 Disclosure classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.4 Abbreviations

Abbreviation	Description
AlF3	Aluminium trifluoride
CF4	Carbon tetrafluoride or tetrafluoromethane
Dewpoint	The temperature at which dew begins to form when a gas is cooled.
GIS	Gas insulated (metal-enclosed) substation.
H2S	Hydrogen sulfide
HF	Hydrogen fluoride
MPa	Mega Pascal
OEM	Original equipment manufacturer
ppmv	Parts per million by volume (all ppm values in this document are parts per million by volume)
S2F10	Disulfur decafluoride
SF4	Sulfur tetrafluoride
SF6	Sulfur hexafluoride. Pure SF ₆ gas is a colourless, odourless, non-combustible, non-toxic and inert gas and is chemically stable up to about 500 °C. Specific gravity is 6.14 g/l with a molecular weight of 146. It acts as a simple asphyxiant by displacement of the oxygen in the atmosphere. SF ₆ is approximately 5 times heavier than air and will have a tendency to collect in the lowest parts, e.g. cable trenches, pits, enclosed spaces, etc.
SiF4	Silicon tetrafluoride
SO2	Sulfur dioxide
SO2F2	Sulfuryl fluoride
SOF2	Thionyl fluoride

2.5 Roles and responsibilities

Staff performing gas measurements must be properly trained and familiar with all appropriate procedures and should make use of appropriate and calibrated equipment. All necessary safety and handling procedures must be observed.

SF₆ is a potent greenhouse gas and release of gas to atmosphere during sampling should be avoided if possible. The use of measurement equipment which returns gas to the switchgear when the measurement is complete is recommended.

2.6 Process for monitoring

SF₆ Reporting Forms and any other records associated with the standard should be retained for audit purposes.

2.7 Related/supporting documents

Relevant OEM manuals.

3. Requirements

SF₆ is used in electrical switchgear due to its unique arc quenching ability and its high dielectric strength. Ideally the SF₆ gas in gas insulated switchgear should be absolutely pure. In practice, this is not possible. The presence of very low levels of impurities such as other gases, moisture and acidic by-products can be tolerated with little or no adverse effect. Each manufacturer selects tolerable values according to their own research, design and operating conditions for their equipment. These values should always be adhered to in order to maintain integrity of the equipment, safety of personnel, achieving design life of the equipment and justifying insurance claims in the event of equipment failure.

This standard provides a generic specification for in-service SF₆ gas in Eskom's gas insulated switchgear. This specification is equal to or higher than the strictest known manufacturer's requirement. If any manufacturer's specified requirement for a particular item of equipment is found to be higher than any specified value in this standard, then that value shall be adopted as the acceptable value for that particular item. The intention of this standard is to provide a generic Eskom specification to eliminate confusion between the specifications of different manufacturers.

Staff performing gas measurements should be properly trained and familiar with all appropriate procedures and should make use of appropriate and calibrated equipment. All necessary safety and handling procedures must be observed.

SF₆ is a potent greenhouse gas and release of this gas to atmosphere during sampling should be avoided if possible. The use of measurement equipment that returns gas to the switchgear when the measurement is complete or any other system that retains the sampled gas is recommended.

3.1 SF₆ Gas Purity

SF₆ is used as the insulating medium in gas insulated switchgear due to its high insulation strength and specifically due to its unique arc quenching ability. Pure SF₆ has an insulation strength almost three times that of air and at elevated pressure it is proportionally higher.

The inclusion of small quantities of air in the SF₆ has relatively insignificant effect on the insulation strength of the gas and it is practically impossible to avoid introducing some air during the gas handling process (filling, extracting topping-up etc.). As far as electrical insulation is concerned, absolute purity is not critical but air contains oxygen that is available for oxidation of bare metal surfaces and lubricants as well as reacting with moisture, sulfur, fluorine and other elements under normal switching and particularly under fault conditions to form aggressive compounds, therefore high quantities of air should be avoided. High air content in SF₆ indicates negligence in the handling of what should be pure SF₆.

SF₆ purity is measured in terms of volume percentage. The typical means of purity measurement is with instruments using velocity of sound in SF₆ e.g. DILO Multifunction Analyser or WIKA GA10 Breaker Analyser.

3.2 SF₆ Decomposition By-Products

It is normal for by-products to result from regular switching of a circuit breaker. Filters are installed in circuit breakers to control the build-up of moisture and by-products. The filter however does not entirely remove by-products and the efficiency of the filter may be influenced by temperature and the presence of moisture. When by-products are detected in SF₆ filled switchgear the relative value of the by-products and the switching history should be considered and each case should be evaluated on its own merits. Any detectable quantity of by-products in a non-switching component should receive immediate and urgent attention as no by-products should exist in these compartments. This standard applies to sampling on an operational and maintenance level and does not address advanced laboratory gas analysis and laboratory diagnostics.

Past experience has favoured the use of the Auer/MSA SF₆ Decomposition Products detector tube for general purpose by-product detection and measurements as it is sensitive to most of the common SF₆ by-products with the exception of the non-reactive compounds. HF and SO₂ tubes are also popular for performing by-product measurements. All by-product measurements using detector tubes must be corrected for altitude. New developments in monitoring equipment favour electronic SO₂ meters. Caution must be exercised when using electronic SO₂ meters as certain electronic SO₂ meters are sensitive to SO₂ only whereas others are sensitive to other chemical compounds as well. All by-product measurements should be corrected for altitude if it is not automatically compensated for by the instrument.

Correction due to altitude may be calculated by applying the formula:

$$\text{By-product content (ppmv)} = \text{measured value} \times \frac{1013}{\text{actual atmospheric pressure (hPa)}}$$

3.3 Moisture

Although there are different units for quoting allowable moisture limits, the most important factor in high voltage gas insulation is that condensation of moisture in the gas must never occur. The temperature of the gas must never drop below the dew point of the moisture in the gas at the specific working pressure. A moisture content of 400 ppmv relates to a dewpoint of -29.4 °C at sea level atmospheric pressure but at a gas pressure of 10 bar the moisture will condense at -5 °C. Refer to conversion tables or software to convert meter units to desired units.

Many moisture measuring instruments perform their measurements relative to local atmospheric pressure but imply sea level atmospheric pressure. Unless the instrument automatically compensates for local ambient atmospheric pressure the adjustment will have to be performed manually. It is the responsibility of the instrument user to determine if the instrument is compensated for measurements at atmospheric pressure or not

Correction due to altitude may be calculated by applying the formula:

$$\text{Moisture content (ppmv)} = \text{measured value} \times \frac{1013}{\text{actual atmospheric pressure (hPa)}}$$

If possible, it is best to make use of a cooled mirror dewpoint meter. Cooled mirror dewpoint meters are inherently accurate and are not prone to drift (Atmospheric pressure must still be taken into account unless automatic compensation is provided by the instrument).

Caution must be exercised when using instruments with electronic moisture sensors, particularly older type meters with ceramic sensors as the sensors are prone to degradation from certain contaminants in the SF₆.

3.4 Gas Sampling Interval

The gas sampling interval should be such that it coincides with regular switchgear maintenance requirements but must not be greater than 6 years.

If it be suspected that gas quality has deteriorated due to excessive or abnormal switching duty or regular topping up due to SF₆ gas leakage the need for testing of gas quality should be reviewed and applied as deemed necessary.

4. Gas Specification for in-service SF₆ gas

Gas parameter	Requirement	Note
SF ₆ Gas Purity	98% volume (minimum)	1
Moisture content	400 ppmv (maximum)	2, 3, 4, 5
By-products (switching compartments)	15 ppm (maximum)	6
By-products (non-switching compartments)	0 ppm	7
Notes: 1) Impurities totalling 2% may include air, nitrogen or CF ₄ 2) The maximum moisture content of 400 ppmv applies to all SF ₆ filled switchgear at a maximum gas pressure of 1MPa. 3) At working pressures below 1MPa the moisture content may exceed 400 ppmv provided that the IEC/SANS criteria of -5 °C at working pressure is not exceeded. (Refer IEC/SANS 62271-1) 4) 400 ppmv equates to a dew point of -29 °C at standard atmospheric pressure or a dew point of -5 °C at a pressure of 1MPa 5) For convenience moisture values may be recorded in terms of dew point (°C) 6) Specified value is a guide only. Cause of by-products should always be considered. Follow-up measurements are advised when by-products are detected. Persistent measurements above the specified value require serious attention. 7) Any by-products detected in non-switching compartments should receive immediate and urgent attention. 8) Oil content is not specified as oil measurements are impractical. Strict gas handling procedures must be observed to avoid any possible oil inclusion.		

5. Authorization

This document has been seen and accepted by:

Name and surname	Designation
Bheki Ntshangase	SCOT/SC Chairman
HV Plant Managers	All Grids
GIS and AIS Care Group	GIS and AIS Care Group members
DX Operating Unit Managers	All Operating Unit Managers

6. Revisions

Date	Rev	Compiler	Remarks
May 2016	1	G Drake	Revise and replace expired standard TST41-649. Extensive test additions. New reference number.

7. Development team

The following people were involved in the development of this document:

- GIS and AIS Switchgear Work Groups

8. Acknowledgement

Not applicable.