

SF₆ MANAGEMENT AND USAGE PROCEDURE

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PURPOSE AND SCOPE

This document describes the procedures for transport, handling, monitoring, and disposal of sulphur hexafluoride, SF₆, in accordance with:

- IEC 60376:2005 (Specification of technical grade sulphur hexafluoride (SF₆) for use in electrical equipment)
- IEC 60480:2004 (Guidelines for the checking and treatment of sulphur hexafluoride (SF₆) taken from electrical equipment and specification for its re-use)
- [EU 517/2014 \(F-Gas Regulations\)](#)

These apply during installation, commissioning, normal and abnormal operations, and disposal at the end-of-life of high-voltage switchgear and control gear. These procedures are regarded as minimum requirements to ensure the safety of personnel working with SF₆ to meet statutory and regulatory obligations, and to minimize SF₆ emission to the environment.

FOREWORD

Sulphur hexafluoride (SF₆) is an essential gas used within high voltage electrical equipment. The dielectric properties of SF₆ are approximately 2.5 times better than that of air under the same pressure and temperature conditions makes it extremely effective as an arc-interruption and insulating medium. The gas is non-flammable, non-corrosive to metals at ambient temperatures and is non-toxic unless decomposed in electrical arcs. When SF₆ gas is subjected to electrical arcs, the gas molecules may be disrupted, but return to their original form.

It is these qualities that have made its use desirable within the UK Electricity Transmission Market for over thirty years in circuit breakers, gas-insulated substations (GIS), and related equipment in electrical transmission and distribution systems, and has now progressed to be the main dielectric and insulator for new circuit breakers and gas insulated substations.

SF₆ has a high Global Warming Potential (GWP) of 23,900 times greater than CO₂, and every effort must be made to minimise its release to the environment.

National Grid's strategy for handling of SF₆ is influenced by environmental concerns, international standards, and national and international regulations.

In line with the efforts to reduce the release of SF₆, particular attention should be paid to the reclamation of SF₆ used in electrical equipment. This allows for the recycling of SF₆ gas recovered when equipment is maintained, repaired or reaches the end of its service life, which can then be reprocessed to match the equivalent performance of a virgin substance, taking into account its intended use.

European regulation (EU) 517/2014 is the principal regulation governing the use of SF₆ and has been transcribed into UK law. The enforcement agency for this regulation is the Environment Agency. Failure to comply with the requirements set down in this document could lead to penalties being imposed by the EA and/or fines levied on the company by Ofgem.

Much of the requirements in this document are derived from EU 517/2014. Every effort has been made to articulate how National Grid practises will ensure compliance with the regulations.

PART 1 – PROCEDURAL

1 EQUIPMENT CLASSIFICATION, CONSTRUCTION AND SF₆ QUALITY

1.1 Classification

SF₆ gas filled equipment used within an electrical system can be categorised as being either components for switching, such as circuit breakers, disconnectors and earth switches or alternatively for non-switching such as with bus ducting, instrument transformers or cable terminations. The equipment can be either air insulated switchgear, AIS, or gas insulated switchgear, GIS, and sited either in an indoor or outdoor environment.

1.2 Equipment manufacturing

Many factors are considered when purchasing equipment for use on the National Grid system. These include its operational characteristics, maintenance requirements, size, cost, delivery and that it must provide an operational trouble, and leakage-free service life. These are all important factors to analyse during the tender evaluation process.

All SF₆ equipment has gas pressurised within an enclosure, which is made of metal, porcelain or a composite material and is called a 'gas zone'. The number of gas zones within that equipment will vary depending on the equipment's manufacturing design and function, ranging from one, as seen in a typical AIS gas circuit breaker to multiple GIS gas zone equipment.

Equipment can be sealed for life, forming part of the latest generation of low maintenance SF₆ filled equipment, or may be part of a conventional gas zoned system, where its maintenance requirements warrant periodic gas handling. This latter equipment type is that which is used predominantly by National Grid. Sealed for life designs are generally only used at Low and Medium Voltage.

Although TS 2.2 'Switchgear' quotes the National Grid requirement of a maximum permitted leakage rate of SF₆ gas from new switchgear shall be < 0.5% per annum as a tender requirement, many manufacturers now supply to National Grid new generation SF₆ gas filled equipment with typical gas leakage rates well below this value.

1.2.1 Labelling and product and equipment information

Products or equipment that contain, or whose functioning relies upon, SF₆ shall be labelled in accordance to F-Gas regulations *Article 12* indicating:

- a) A reference that the product or equipment containing SF₆ or its function relies upon such gas
- b) For equipment installed from 1st January 2017, the quantity expressed in weight and in CO₂ equivalent of SF₆ contained in the product or equipment, or the quantity of SF₆ for which the equipment is designed, and the global warming potential of SF₆.

The label shall be clearly readable and indelible and shall be placed either:

- c) Adjacent to the service ports for charging or recovering the SF₆; or
- d) On that part of the product or equipment that contains the SF₆

The label shall be in the English language.

Further detail on labelling requirements can be found in TS 2.2 and TS 3.2.14.

Bottles of reclaimed or recycled SF₆ purchased from an approved third party supplier shall be labelled with an indication that the substance has been reclaimed or recycled, information on the batch number and the name and address of the reclamation or recycling facility.

1.2.2 Equipment Construction and Delivery

During construction (prior to equipment commissioning) the following minimum requirements shall be met by the appointed contractor or delivery partner when utilising SF₆:

- For the purposes of pre-commissioning inspection the most up to date standard should be used and referenced in the Contractors Site Quality/ Inspection Test Plan
- For environmental reasons where possible any on site tightness testing should be carried out with dry air or nitrogen. Should this not be possible written permission to use SF₆ should be sought from the National Grid Project Engineer.
- For any asset or associated equipment that will contain SF₆ the appointed contractor shall ensure that an appropriate leak detection system is installed and operational before the equipment is filled with SF₆.
- For all projects that use SF₆, the contractor shall include SF₆ Management as an Environmental Aspect on the Environmental Impacts and Aspects register. The management of SF₆ shall be documented as part of the Contractor Site Quality Plan
- A program of leak checks should be included in the Construction Phase SHES Plan a minimum the frequency shall be monthly. Any suspected leaks shall be reported to the client within 24 hours.
- The contractor shall confirm the method of leak detection and the equipment used for leak detection in the Contractor Site Quality Plan.
- All personnel shall be trained as per the requirements of Section 2.1 of this document.

1.2.3 Responsibilities

For each project it shall be the responsibility of the nominated National Grid Construction Interface Engineer (CIE) to ensure that the requirements of 1.2.1 and 1.2.2 are met by the contractor. The CIE shall maintain a record and obtain documentary evidence that the minimum requirements have been met.

During any stage of the project if the requirements have not been met by the contractor the CIE shall notify the Project Engineer and the Capital Delivery Construction SHE Advisor immediately.

1.2.4 Commissioning of SF₆ equipment and leak detection systems

Prior to hand over the appointed contractor shall seek confirmation from the National Grid commissioning panel that all the quality requirements have been achieved.

SF₆ equipment that does not have a commissioned leak detection system in place shall not be accepted by National Grid.

1.3 Pressurised Enclosures

The SF₆ gas used in electrical equipment is pressurised. As the enclosure is under pressure, the normal safety precautions applicable to pressure vessels must be observed.

In most equipment designs, the enclosures are equipped with one or more of the following:

- a) A pressure relief safety feature
- b) A pressure/density monitoring device
- c) Valves for gas handling and sampling the SF₆ gas
- d) A filter medium which collects moisture and decomposition products.

1.4 Pressurised Storage Vessels

The removal of SF₆ requires the use of a temporary or fixed storage vessel pressure tested to 72bar and fitted with relief valves. These need to be changed or tested every 2 years and are subject to a WSE due every 5 years.

Attention shall be paid to the filling factor of the containers, taking into account their design pressure and the maximum ambient temperature to which they will be subjected.

Mobile storage vessels must not be transported on the Highways whilst containing SF₆ unless specifically designed to do so.

1.5 Pressurised Gas Cylinders

It is the responsibility of the supplier to provide gas in the appropriate containers, according to the local regulations and international transport regulations.

BS EN ISO 7225:2007 (Gas cylinders-Precautionary labels),

BS EN ISO 13769:2009 (Gas cylinders Stamp marking),

BS EN ISO 1089-3:2011 (Transportable gas cylinders-Gas cylinder identification) and

BS EN ISO 1968:2002 (Transportable Gas Cylinders-Periodic inspection and testing of seamless steel gas cylinders),

Gas cylinders shall have:

- a) The symbol “SF₆” and “sulphur hexafluoride” in words.
- b) the mass of sulphur hexafluoride (in kg) stated on each cylinder
- c) The weight of the cylinder empty and without protective valve caps.
- d) The cylinder serial number.
- e) The cylinder registered owner mark.
- f) The cylinder’s service or working pressure.
- g) The date of the cylinder’s initial hydrostatic test.
- h) Any further hydrostatic test dates
- i) valves properly protected

If the cylinder identification cannot be established it should not be accepted from the supplier on delivery.

If the cylinder test date has expired then the cylinder must not be used and be sent back to the supplier.

All new cylinders from the gas supplier shall have a unique identifier on them. The cylinder shall be checked upon delivery to ensure that a label is attached to the neck with the information below

- j) Site
- k) Equipment / gas zone
- l) Cylinder number
- m) Quantity of gas used
- n) Equipment owner
- o) Date
- p) Empty cylinder

1.6 Quality Requirements of SF₆ Gas

The National Grid extreme ambient operating temperature range of SF₆ gas filled equipment, in accordance with NGTS 1, is from between -25°C and +40°C. Once the equipment’s gas zone is filled to the correct gas density, a variation in gas temperature has the effect of altering the equipment’s gas zone pressure. Incorrect filling density, particularly when coupled with any impurities present within the gas, may radically affect the electrical performance of the switchgear insulating system. Care shall be taken to ensure that the equipment is filled to the appropriate density as stated in the specific operation and maintenance manuals.

In order to keep the switchgear manufacturing costs low and the size of the equipment down, high standards of gas quality (technical grade SF₆) and equipment gas zone cleanliness are vital for ensuring a reliable and trouble free operational life. All SF₆ equipment used by National Grid employ a closed gas system and provided that the procedures set out in

Network Engineering work specifications, equipment manufacturers maintenance manuals and the advice within this document are adhered to, long term integrity of the equipment can be achieved.

Content	Specification	Analytical methods (for indication only, not exhaustive).	Precision
Air	2 g/kg [note 1]	Infrared absorption method	35 mg/kg
		Gas-chromatographic method	3-10 mg/kg
		Density method	10 mg/kg
CF ₄	2400 mg/kg [note 2]	Gas-chromatographic Method	9 mg/kg
H ₂ O	25 mg/kg [note 3]	Gravimetric method	0,5 mg/kg[note 5]
		Electrolytic method	2 – 15 mg/kg
		Dew point method	1 °C
Mineral Oil	10 mg/kg	Photometric method	< 2 mg/kg
		Gravimetric method	0,5 mg/kg [note 5]
Total acidity expressed in HF	1 mg/kg [note 4]	Titration	0,2 mg/kg
NOTE 1 - 2 g/kg is equivalent to 1 % vol under ambient conditions (100 kPa and 20 °C [1]). NOTE 2 - 2 400 mg/kg is equivalent to 4 000 µl/l under ambient conditions (100 kPa and 20 °C [1]). NOTE 3 - 25 mg/kg (25 mg/kg) is equivalent to 200 µl/l and to a dew point of –36 °C, measured at ambient conditions (100 kPa and 20 °C [1]). NOTE 4 - 1 mg/kg is equivalent to 7,3 µl/l under ambient conditions (100 kPa and 20 °C [1]). NOTE 5 - Depending on the sample size.			

Maximum acceptable impurity levels (IEC 60480)

The quality of SF₆ contained in bottles or storage vessels shall be measured prior to use where there is any doubt regarding gas provenance.

2 TRAINING, TRANSPORT AND GAS HANDLING

2.1 Training

As per the requirements of Article 10 of Regulation (EU) No 517/2014 all personnel involved in the use or handling of SF₆ shall undertake and achieve appropriate certification. Training and test requirements are further defined in European regulation [EC 305/2008](#) (**Minimum requirements and the conditions for mutual recognition for the certification of personnel recovering certain fluorinated greenhouse gases from high-voltage switchgear**).

All staff involved in the following activities are required to have undergone appropriate accredited training:

- Receiving SF₆
- Leak checks

- Equipment top up
- Gas recovery
- Equipment commissioning
- Equipment repair
- Equipment decommissioning

EC 305/2008 defines the minimum requirements for training. Whilst EC 305/2008 was originally focussed purely on gas recovery EU 517/2014 has expanded the requirements to include the areas above.

As a minimum completion of course “SF₆ Top Up and Testing (EGO43)” is required if carrying out the activities listed above.

No	Minimum knowledge and skills	Test Type	How NGET shall satisfy this requirement
1	Basic knowledge of relevant environmental issues (climate change, Kyoto Protocol, Global Warming Potential), the relevant provisions of Regulation (EC) No 842/2006 and of the relevant Regulations implementing provisions of Regulation (EC) No 842/2006	Theoretical	Completion of “SF ₆ Top up and Testing” course (EG043)
2	Physical, chemical and environmental characteristics of SF ₆	Theoretical	Completion of “SF ₆ Top up and Testing” course (EG043)
3	Use of SF ₆ in electric power equipment (insulation, arc quenching)	Theoretical	Completion of “SF ₆ Top up and Testing” course (EG043)
4	SF ₆ quality, according to the relevant industrial standards (1)	Theoretical	Completion of “SF ₆ Top up and Testing” course (EG043)
5	Understanding of the design of electric power equipment	Theoretical	Completion of “SF ₆ Top up and Testing” course (EG043)
6	Checking the SF ₆ quality	Practical	Completion of “SF ₆ Top up and Testing” course (EG043)
7	Recovery of SF ₆ and SF ₆ mixtures and purification of SF ₆	Practical	SF ₆ Gas Recovery Training Course
8	Storage and transportation of SF ₆	Theoretical	Completion of “SF ₆ Top up and Testing” course (EG043)
9	Operation of SF ₆ recovery equipment	Practical	SF ₆ Gas Recovery Training Course
10	Operation of tight drilling systems, if necessary	Practical	Not required
11	Re-use of SF ₆ and different re-use categories	Theoretical	Completion of “SF ₆ Top up and Testing” course (EG043)
12	Working on open SF ₆ compartments	Practical	Satisfied by NSI10 procedure
13	Neutralising SF ₆ by-products	Theoretical	SF ₆ Gas Recovery Training Course
14	Monitoring of SF ₆ and appropriate data recording obligations under national or Community legislation, or international agreements	Theoretical	Completion of “SF ₆ Top up and Testing” course (EG043)