NSP/003/010 – Code of Practice for working with SF_6

1. Purpose

The purpose of this document is to bring together all the requirements, guidance and best practice for working with SF_6 and associated electrical equipment into a comprehensive, concise and usable format. If the guidance in this document is followed then it will reduce the impact of SF_6 and associated equipment on health, safety and the environment.

This document supersedes the following documents, all copies of which should be destroyed.

Ref	Version	Date	Title
None			

2. Scope

This Technical Guidance document addresses the procedures for Storage, Handling, Testing and Disposal of Sulphur Hexafluoride Gas (SF_6) associated with electrical switchgear owned and operated by Northern Powergrid (the Company).

2.1 Table of Contents

3. Working with SF_6

General

The normative referenced document, ENA Engineering Recommendation G69 *Guidance on working with Sulphur Hexafluoride* (ENA EREC G69) is indispensable for the application of this document. In general, the provisions of ENA EREC G69 are applied for activities involving SF_6 in this document.

Sulphur Hexafluoride (SF_6) has been used in electrical equipment for more than 40 years. Extensive use continues to be made by the manufacturers of High Voltage (HV) switchgear because of its high dielectric strength (2.5 times that of air under the same conditions), excellent arc quenching capabilities and high chemical stability.

SF_6 is a fluorinated greenhouse gas. As a result, the UK electricity industry in conjunction with other European utilities, SF_6 manufacturers and manufacturers of SF_6 filled electrical equipment have agreed a set of actions with the objective of reducing emissions of the gas into the atmosphere.

3.1.1. Legislation

The following legislation must be adhered to when working with SF_6.

3.1.1.1. The Control of Substances Hazardous to Health Regulations 2002 (COSHH)

The Company is required to control exposure to hazardous substances to prevent ill health. The Regulations protect both employees and others who may be exposed.

3.1.1.2. Environmental Protection Act 1990 and Associated Waste Regulations

The Company is required to classify and dispose of special waste and hazardous waste correctly in accordance with the following waste regulations to reduce risks to health. This applies to used SF_6 and associated by-products.

a) The Special Waste Regulations 1996.
b) The Special Waste (Amendment) Regulations 1996.
c) The Hazardous Waste (England and Wales) Regulations 2005.

3.1.1.3. The Provision and Use of Work Equipment Regulations 1998 (PUWER)

These regulations require risks to people's health and safety, from equipment that they use at work, to be prevented or controlled and include the requirement to regularly inspect work equipment before use. This applies to gas handling and associated equipment.

3.1.1.4. The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009

These regulations apply to the transport, by road or rail, of hazardous substances and articles classified as dangerous goods. They stipulate requirements to protect persons directly involved with transportation of dangerous goods (such as consignors or carriers), or who might become involved (such as members of the emergency services and public). These regulations apply to the transportation of technical grade SF_6 (Section 3.1.2.1) and used SF_6 (Section 3.1.2.3), by road or rail either in transportable pressure cylinders or switchgear.

3.1.1.5. The Fluorinated Greenhouse Gases Regulations 2015

3.1.1.5.1. Containment

There is no mandatory requirement in the Regulation for the Company to:

a) prevent leakage of SF_6 from HV switchgear;
b) check switchgear for SF_6 leaks;

c) repair any leakage of SF_6 from switchgear.

However, in order to reduce the environmental impact and cost associated with topping up, appropriate measures to address any leakage should be arranged as soon as possible. A robust management procedure should be in place to ensure that a proportionate level of action is taken to address such releases.

3.1.1.5.2. Recovery

The Company must ensure that SF_6, or mixtures of SF_6, are properly recovered from HV switchgear before final disposal of the switchgear and, when appropriate, during servicing and maintenance. Deliberate release of SF_6 from HV switchgear to the atmosphere is no longer environmentally acceptable.

In addition, used and technical grade SF_6 contained in refillable containers must also be recovered. Recovery operations must be carried out by appropriately trained and certified personnel.

3.1.1.5.3. Training and Certification Programs

The Regulation includes requirements for certification and training of personnel who recover SF_6 from HV switchgear. The Company requires all individuals who work with or transport SF_6 gas to have successfully completed an approved fluorinated gas (F Gas) training course/assessment and have current certification in accordance with the F Gas regulations. UK certification bodies are listed in the Fluorinated Greenhouse Gases Regulations 2015

There is currently no requirement for re-certification within the Regulation. However, re-certification may be required in future, when the Regulation is revised. Notwithstanding, certification bodies may define an expiry date on their certificates.

To enable uncertified personnel to gain the practical skills required for the examination, the Regulation permits a person to undertake SF_6 gas recovery activities for up to one year, provided they are supervised by certified personnel and they are enrolled on a training course for the purposes of obtaining a certificate.

3.1.1.5.4. Reporting

Ofgem requires the Company to report their holdings and emissions of SF_6 on an annual basis. In accordance with the common framework for reporting, the holding or 'bank' for the Company is the aggregate quantity of SF_6 gas contained within switchgear, gas insulated substations and other gas containers (e.g. gas bottles) at the start of the reporting year. Annual emissions of SF_6 are the sum of emissions that occur during installation, service (including operation and maintenance) and disposal of equipment within the reporting year.

3.1.1.5.5. Labelling

The Regulation requires products and equipment filled with certain fluorinated greenhouse gases to be appropriately labelled. New equipment that contains fluorinated greenhouse gases should be supplied with a clear indelible label that:

a) indicates the equipment contains SF_6;
b) states the mass of gas in each compartment within the switchgear (and a total for the unit), the filling pressure and the volume for each compartment.
c) identifies equipment that is hermetically sealed.

The label shall be placed near the rating plate, or incorporated into the rating plate.

The label should state the total mass of SF_6 standardised at 20 °C. Equipment such as GIS may only be part filled in the manufacturing plant for transport or storage purposes. In this case, the labelling of part filled compartments, including the quantity of gas filled at the manufacturing plant, should be specifically agreed with the manufacturer.

Label Example

ABB XYZ 36kV CB Serial Number: 1234/A/2015	Mass of SF6 (kg)	Chamber Volume (litres)	Filling Pressure (Bar(g) at 20C)	Filling Pressure (psi at 20C)	Pressure system (closed or sealed)
CB Chamber	1.5	150	9.0	123	Sealed
Busbar chamber	3.0	500	2.0	32	Closed
Disconnector Chamber	1.0	300	3.5	45	Closed
Total	5.5				

The manufacturer should supply the label and should also provide a cutaway diagram or GA drawing identifying the gas zones/compartments which includes a copy of the table above. The manufacturer shall also provide both hard and soft copies of the information for placement on site and the company's internal intranets to help Northern Powergrid to understand the equipment, report volumes installed and calculate leaks, etc.

3.1.2. Properties of Sulphur Hexafluoride (SF_6)

Sulphur Hexafluoride is a synthesised gas and is the product of a manufacturing process. In its pure state sulphur Hexafluoride gas has the following properties.

a) Inert.
b) Colourless.
c) Tasteless.
d) Non-flammable.
e) Non-toxic.

In its pure state sulphur Hexafluoride is non–toxic and extremely stable at ambient temperatures. Providing it has not been exposed to electrical breakdown or partial discharge it does not have to be classified as a dangerous substance. Moderate exposure does not present any significant health risks. However, sulphur Hexafluoride in normal conditions is 5 times heavier than air and it will tend to accumulate in low lying areas including: basements, tunnels, cable trenches and on switchroom floors. Because sulphur Hexafluoride will not support life, large volumes in the atmosphere (exceeding 80% by volume) may cause personnel to suffer oxygen deficiency and asphyxiation.

3.1.2.1. Technical Grade SF_6

Technical grade SF_6 is taken to mean gas suitable for use in electrical equipment, which conforms to the requirements of BS EN 60376. Technical grade SF_6 will generally only be encountered in the following situations.

a) Electrical equipment containing SF_6 which has not been put into service.
b) Filled gas cylinders received from the supplier.
c) Partially filled gas cylinders and storage vessels used for the replenishment of electrical equipment.

The maximum acceptable impurity levels for technical grade SF_6 are shown in the Table 1 below.

Table 1 Maximum impurity levels for technical grade SF_6

Impurity	Maximum Acceptable Level
Air	0.2 % w [1]
CF_4	2400 ppmw [2]
H_2O	25 ppmw [3]
Mineral Oil	10 ppmw [4]
Total Acidity expressed as HF	1 ppmw [5]
NOTE 1: 0.2 % w is equivalent to 1 % v under ambient conditions (100 kPa and 20 °C)	
NOTE 2: 2400 ppmw is equivalent to 4000 ppmv under ambient conditions (100 kPa and 20 °C)	
NOTE 3: 25 mg/kg (25 ppmw) is equivalent to 200 ppmv (200 µl/l) and to a dew point of -36 °C measured under ambient conditions (100 kPa and 20 °C)	
NOTE 4: SF_6 should be substantially free from oil. The maximum permitted concentration of oil and the method of measurement are under consideration	
NOTE 5: 1 ppmw is equivalent to 6 ppmv measured under ambient conditions (100 kPa and 20 °C)	

3.1.2.2. Non-Arced SF_6

SF_6 within or recovered from electrical switchgear that has not been 'in service' but has been insulation tested in the factory and/or on site during installation or commissioning may be classified as non-arced SF_6.

Non-arced SF_6 can easily contain air and moisture but may also contain small quantities of reactive gaseous decomposition products if there has been strong partial discharges within the gas during testing and where no adsorbers are provided.

3.1.2.3. Used SF_6

SF_6 within or recovered from 'in service' electrical switchgear, whether used for insulating or arc extinction purposes, is classified as used SF_6.

Used SF_6 may contain toxic and corrosive by-products, which are generated from decomposition of the SF_6. This can occur when the gas is heated by flame to extreme temperatures (above 500 °C) or more commonly when electrical energy in the form of an arc, spark or discharge is released during the following switchgear operations.

a) switching.
b) Internal short circuit.
c) Partial discharge etc.

The by-products are generally small in quantity as the gas recombines, albeit not entirely, following the energy release and consist of the following.

a) Toxic gases – which in the presence of moist air will have a pungent odour similar to rotten eggs.

b) Metal fluorides – in the form of dry white powder or grey deposits when exposed to moisture.

The overall toxicity and health risks to personnel should be estimated using the quantities of thionyl fluoride (SOF2) present in used SF_6. In the presence of moisture, over time, SOF2 decomposes into sulphur dioxide (SO2) and hydrogen fluoride (HF).

3.1.2.4. Environmental Effects

SF_6 when present in the atmosphere contributes to global warming and is regulated to reduce emissions and the potential impact on the environment. Consequently, SF_6 should not be deliberately released into the atmosphere and should be handled carefully in accordance with procedures and in a closed cycle to minimise any leakage into the atmosphere. SF_6 does not harm the ecosystem and is:

a) not carcinogenic;
b) not mutagenic;
c) not nitrifying.

As its solubility in water is very low, SF_6 does not present any danger to surface and ground water or the soil. SF_6 has no known impact on the stratospheric ozone layer.

3.1.3. SF_6 Filled Switchgear

3.1.3.1. Applications and Construction

In switchgear with rated voltages up to and including 36 kV, certain types of equipment use SF_6 for both insulation and arc quenching. Alternatively other types use SF_6 for insulation in combination with vacuum interrupters for arc quenching.

The Company has three types of construction of distribution switchgear incorporating SF_6.

a) Metalclad equipment – which incorporates switching devices including circuit breaker interrupters or load switches, contained within SF_6 gas-filled compartments made from metal. The rest of the equipment is contained within air or solid insulation.
b) Metal clad switchgear - SF_6 insulated cubicle – where switchgear is constructed so that all the switching devices and busbars are contained within a single gas-filled compartment, which is usually made from cast resin. Ring Main Units (RMUs) are frequently of this type of construction.
c) Gas Insulated Switchgear (GIS) – SF_6 is used as the primary insulating medium. This equipment is usually modular and is assembled using individual SF_6 gas compartments, which contain separate equipment such as circuit breakers, disconnectors, busbars etc. This equipment is more commonly used at voltages above 36 kV.

3.1.3.2. Gas-Filled Compartments

Gas-filled compartments normally used in SF_6 switchgear are classified as either:

a) closed pressure systems;
b) sealed pressure systems.

In a closed pressure system there is provision to replenish SF_6, which may have leaked, as well as recovery of the gas to inspect and maintain equipment contained within the enclosure and re-filling on completion.

Sealed pressure systems are completely assembled and tested in the factory. These enclosures are commonly referred to as “sealed for life”, where no further gas or vacuum processing is required and never opened during the expected service life of the equipment.

3.1.3.3. SF_6 Quantities & Pressure

Typically the quantities of SF_6 used in distribution equipment are relatively small and will not generally exceed 20 kilograms.

SF_6 gas in switchgear is at relatively low pressure ranging from 0.1 bar gauge to 9 bar gauge. Distribution switchgear with sealed enclosures typically operates just above atmospheric pressure, which reduces the leakage rate and extends the life of the equipment. SF_6 filled electrical equipment is designed for leakages that do not exceed 10 % of the initial mass of gas over the whole service life. Maximum permissible annual leakage rates are described in section 3.3.5 but because modern manufacturing materials and techniques can now achieve leakage rates of 0.1% per year, service life should not be compromised by SF_6 leakage.

3.1.3.4. Common Features

SF_6 filled switchgear incorporates pressure or density gauges which are fitted to gas-filled compartments. Some designs incorporate contacts for alarms or "lock-out" in the case of circuit breakers to prevent operation.

Equipment with closed pressure systems are equipped with connection points for gas filling and gas testing. Gas-filled compartments are also designed to incorporate desiccant filters to absorb any moisture. In equipment where the gas is used for arc extinction, molecular sieves, activated alumina or charcoal may be fitted to adsorb any gaseous decomposition products.

In general, modern SF_6 switchgear is designed to minimise the risk of injury to operators. Each switchgear type is required to pass an internal arc test, specified in national and international standards. In the case of an internal arc within ground mounted equipment, the resultant pressurised gas will normally be vented in a predetermined way. However, there are some types of SF_6 switchgear, in particular pole mounted and earlier types that do not incorporate bursting discs or overpressure relief devices.

Storage

3.1.4. Purchasing SF_6

SF_6 gas supplied should be of a technical grade and comply with the requirements of BS EN 60376 *Specification of Technical Grade Sulphur Hexafluoride (SF_6) for use in Electrical Equipment*. Consignments should not be accepted without an accompanying certificate of compliance.

Standard sizes of cylinders for SF_6, expressed in litres, range from 3 litres up to 500 litres. These cylinders have a maximum pressure capability of 70 bar, which should not be exceeded under any circumstances.

SF_6 gas should only be supplied in refillable cylinders; the use of non-refillable cylinders is prohibited under the Fluorinated Greenhouse Gases Regulations 2015.

3.1.5. Labelling

Cylinders should be clearly marked at the valve with the following information.

a) SF_6 Hazard Symbol.
b) 'Sulphur Hexafluoride' in words.
c) Bare weight of the cylinder (excluding protective cap).

Additionally the mass of SF_6 (kilograms) is to be stated with each cylinder.

3.1.6. Storage Rules and Dangers

SF_6 gas is supplied in pressurised cylinders, which like any gas cylinder is capable of being damaged or ruptured by incorrect storage and handling. Cylinders should never be left standing without secure protection. Cylinders can

develop accidental leaks and should be stored in a ventilated area where escaped gas cannot accumulate in low lying areas such as trenches and cable basements.

The following rules for storage of SF_6 cylinders apply and should be strictly followed to prevent uncontrolled release, explosion and fire.

a) Valves should be protected by protective caps.
b) The storage area should be a cool, dry, well-ventilated area.
c) Keep away from flammable or explosive material.
d) Protect from direct sunlight.
e) Mounted clear of wet ground.
f) Secured to prevent falling over.
g) Prohibit smoking in the vicinity of the storage area.
h) Cylinders containing technical grade gas or used SF_6 suitable for re-use in electrical equipment should be physically separated from those containing used gas not suitable for re-use in electrical equipment.

Handling

3.1.7. General Requirements for Handling SF_6

The procedures for handling SF_6 depend upon whether the gas is of a technical grade or has been used within electrical equipment where there is a possibility that toxic and corrosive by-products may be present.
SF_6 is handled during the following processes.

a) Filling new switchgear.
b) Replenishing SF_6 in switchgear which has been in service.
c) Maintenance of switchgear.
d) Testing.
e) Emergency release.

In all instances of handling SF_6 it shall be common practice to conduct leakage tests before, during and after works using an SF_6 leakage detector. The Company staff shall only handle SF_6 associated with electrical switchgear when the following criteria are satisfied.

a) Personnel are adequately trained to test and fill equipment and that they are certified to recover SF_6 gas as required by the Fluorinated Greenhouse Gases Regulations 2015 (See section 3.1.1.5.3).
b) Suitable equipment and facilities are provided.
c) Correct procedures are adopted for maintenance, refilling, testing and disposal of SF_6 gas.

Should these criteria not be met, a trained and certified external specialist contractor or manufacturer shall be used that fulfils the above stipulations.

3.1.8. Transporting SF_6

All compressed gases, including SF_6 should only be transported in cylinders or containers that comply with international and UK regulations except for SF_6 contained in switchgear that is pre-filled at the factory (see Clause 3.3.2.1). The transportation of SF_6 by road is subject to the requirements of *The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009*. This applies to the transport of SF_6 subject to exemptions for small loads. The load limits (thresholds) for small loads of SF_6 gas are as follows.

Table 2 Load limits (thresholds for small load of SF_6

SF_6 Gas	Characteristic	Transport Category	Small Load Threshold (Litres or kg)
Technical Grade	Liquefied inert gas	3 (C/E)	1000
Suitable for re-use in electrical equipment	Liquefied inert gas	3 (C/E)	1000
Not suitable for re-use in electrical equipment	Liquefied toxic gas (containing toxic gaseous decomposition products)	3 (C/E)	1000
Not suitable for re-use in electrical equipment	Liquefied toxic gas (containing toxic gaseous decomposition products)	1 (C/D)	50
Not suitable for re-use in electrical equipment	Liquefied toxic gas (containing toxic gaseous decomposition products)	1 (C/D)	50
NOTE 1: The regulations are based on 1 Litre = 1 kg.			
NOTE 2: Small Load Threshold is the same irrespective of whether SF_6 is carried as part of a mixed load.			

The following minimum requirements for transporting small loads of SF_6 apply.

a) Drivers should have been given general training in the carriage of dangerous goods and a record of that training should be kept.
b) At least one 2 kg dry powder fire extinguisher or equivalent should be carried on the vehicle.
c) Cylinders should be stowed properly.

Transportation by road of SF_6 in quantities above the small load threshold should comply with all applicable requirements in the Regulations. As such, this operation will generally be assigned to a carrier, who is familiar with these requirements.

3.1.8.1. Transporting Technical Grade SF_6

Before technical grade SF_6 is transported by road the following factors should be considered.

Avoid transport on vehicles where the load space is not separate from the driver's compartment.

Ensure the vehicles' driver is aware of the potential hazards and knows what to do in the event of an accident or emergency.

During transportation cylinders and containers should be:

a) firmly secured;
b) cylinder valve closed (not leaking);
c) valve outlet (i.e. cap, nut or plug) correctly fitted;
d) adequately ventilated;
e) in accordance with applicable regulations.

The vehicle should be carrying the appropriate 'transport documents' and 'instructions in writing' advising personnel of appropriate procedures in an emergency (see Appendix A).

The following precautions should be taken when loading or unloading cylinders containing SF_6.

a) Cylinders are only to be moved using a gas trolley.
b) Cylinders should not be lifted using the neck or cap. The only exception to this is approved hand trucks, which grip the cylinder cap for lifting onto the hand truck.
c) Where appropriate lifting attachments have not been provided on the container, a suitable cradle or platform should be used.

3.1.8.2. Transporting Used SF_6

Used SF_6 from electrical installations (unlike technical grade SF_6) may contain toxic and corrosive decomposition products. As such it is classified by ADR as a Class 2.3 and a Class 8 substance.

Class 2.3 Class 8

Figure 1 ADR hazard notices for used SF_6

The transportation of dangerous goods is governed by criteria laid out in *The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009*. As such it is preferable for the Company to use a suitably certified transportation contractor to carry out this work.

Used SF_6 should only be stored and transported in specially marked cylinders/containers, which are exclusively used for this purpose. These containers should comply with the requirements for Hydrogen Chloride and used SF_6.

Suitable cylinders are marked with an orange collar whilst larger containers have an orange ring. These are available on loan from suppliers who have facilities for recycling used SF_6 gas and should already be marked with the specified hazard diamonds

3.1.8.3. Transporting SF_6 in Switchgear

It may be necessary to transport switchgear filled with SF_6, under the following circumstances.

a) New switchgear incorporating a sealed pressure system from the manufacturer to the user.
b) New switchgear incorporating a closed pressure system which is filled with SF_6 to prevent damage to internal components or moisture ingress.
c) Switchgear with a faulty sealed pressure system being returned from site to the manufacturer.
d) Switchgear which has reached its “end of life” being returned from site for disposal.

Transport of switchgear filled with SF_6 is permissible providing the compartments are adequate for this purpose, measures have been taken to prevent leakage during transport and the same precautions previously detailed for transporting SF_6 gas in cylinders are followed.

3.1.9. Handling Technical Grade SF_6

3.1.9.1. Applications

There may be a requirement for the Company staff to handle technical grade SF_6 on site following installation of equipment, both for initial filling and any subsequent replenishment or "topping up".

3.1.9.2. Precautions

Technical grade SF_6 is non-toxic and direct exposure with the gas in small quantities is not hazardous. Although no special personal protective equipment needs to be worn when handling technical grade SF_6, personnel should be familiar with its properties (see section 3.1.2.1) before commencing work.

Any leakage will be concentrated at floor level in enclosed constricted substations. In case of significant leakages, special precautions are required to avoid asphyxiation where concentrations of SF_6 volume exceed 1,000 parts per million by volume (ppmv).

Where SF_6 is to be handled outdoors, natural ventilation will generally prevent accumulation of the gas. Therefore special precautions are only required if work is carried out in close proximity to the equipment, at or near ground level, or in confined spaces such as cable trenches.

When handling technical grade SF_6 indoors, adequate ventilation should be provided to ensure the maximum permissible concentration should not exceed 1,000 ppmv. Particular care should be taken to ventilate work areas naturally by opening doors and windows or activating any forced ventilation systems available. In the case where there has been a significant release of gas within a small switchroom, or the concentration of SF_6 could exceed 1000 ppmv during the work, consideration should be given to using portable forced ventilation equipment.

When venting switchrooms the risks to other personnel, third parties and the environment should be assessed and suitable control measures put in place. This should include an understanding of where the gas may end up. Steps should then be taken to ensure oxygen content is sufficient to sustain human life before entering the switchroom. This may include testing the oxygen content with portable instruments.

Appropriate safety notices should be displayed at the entrances to switchrooms where SF_6 gas is handled.
If there is a risk that SF_6 may be released into the switchroom then naked flames, smoking, extreme heat sources and welding without special precautions should not be permitted and safety notices should be displayed to this effect.

3.1.10. Filling Technical Grade SF_6

HV switchgear at rated voltages up to and including 36 kV are generally constructed with sealed pressure systems. This equipment incorporates "sealed-for-life" compartments, which are equipped, pre-filled with SF_6 gas and sealed at the factory. No further handling of the gas should be required.

The majority of sealed pressure systems have a valve suitable for sampling and replenishing the gas, however if the equipment has sustained a major leakage of SF_6 then it should be returned to the manufacturer for further investigation and not refilled on site.

Switchgear classified as having closed pressure systems is designed for SF_6 gas to be removed and replaced for inspection and maintenance. Replenishment or "topping up" of the gas-filled compartment is also possible.

3.1.10.1. Quantities of SF_6

The quantity of SF_6 in switchgear compartments depends on the design and rating of the equipment. This is usually stated on the equipment rating plate for new equipment. Rating plates of older equipment may only make reference to the filling pressure or minimum operating pressure and it will be necessary to contact the manufacturer

to establish the mass of gas (kilograms) in the switchgear. Section 3.1.3.3 gives general guidance regarding expected quantities and pressures relating to HV equipment, however this will vary based upon the manufacturer and model of switchgear. Manufacturer's instructions should be consulted prior to any filling or "topping up" taking place.

3.1.10.2. Requirements and Equipment

When handling SF_6, four fundamental requirements should be met.

a) Personnel working on the equipment are not subjected to unacceptable risk.
b) Losses of SF_6 into the atmosphere should be kept to a minimum.
c) Leakage rate of gas-filled compartments should not exceed that specified by the manufacturer.
d) Quantity of gas in gas-filled compartments should not exceed that specified by the manufacturer.

To comply with these requirements it is essential that personnel have access to written procedures and manufacturers' instructions when filling switchgear with SF_6.

Filling with technical grade SF_6 is usually carried out manually from a pressurised cylinder, the following equipment is required.

a) Vacuum pump.
b) Pressurised cylinder.
c) Gloves.
d) Clean pressure hoses and couplings.
e) Regulator.
f) Over pressure relief device in the low pressure line.

3.1.10.3. Filling Procedure

Filling should be carried out in accordance with the manufacturers' instructions. Generally the procedure is to evacuate the air from the gas-filled compartment and pipework using a vacuum pump before introducing technical grade SF_6 (evacuation method), however some manufacturers may recommend alternative methods.

Manufacturers' instructions for filling typically specify the following.

a) Filling method (Evacuation or Other).
b) Maximum residual pressure (expressed in millibars or kPa) to be obtained during evacuation and the time during which the equipment should be kept under vacuum before introducing SF_6.
c) Filling pressure at a specified temperature (preferably 20 °C) or required density. A correction factor or guidance should be given on performing the compensation to pressure or density if filling at other than the specified temperature.

In the absence of manufacturer's instructions, an evacuation time of at least 30 mins should be observed, with an evacuation pressure less than 20 millibars (2 kPa).

The filling procedure requires the equipment to be assembled correctly in accordance with manufacturer's instructions. This includes connecting a pressure regulator to the cylinder to regulate the gas flow and a calibrated gauge to monitor the filling pressure or density. A pressure relief device on the low pressure side should be fitted. If a density monitor or pressure gauge is not fitted to the equipment then the filling equipment should include this function.

The hoses shall be connected to the filling point. To prevent leakage during connection and disconnection, modern equipment is fitted with either 8 mm or 20 mm diameter couplings which incorporate a non-return valve.

During filling operations a leakage detector should be used around hose connections to detect any SF_6 gas. The correct operation of density monitors or pressure gauges and any associated gas alarms should also be checked as part of this operation. When the required filling pressure or density is reached there should be means to quickly shut off the gas flow.

Following the filling operation, measures should be taken to establish that acceptable levels of gas tightness have been achieved. Manufacturers' instructions will state the checks to be performed, methods and any special equipment required. Typically, this will include using an SF_6 leakage detector to check leaks around gas tight flanges, filling points, gauges etc.

The mass of gas used in kilograms, gas filling pressure and temperature should be recorded together with the date and identification of the gas compartment and kept on file.

3.1.10.4. Checks on SF_6 quality after filling

Checks on the SF_6 gas quality after filling may not be necessary if the SF_6 gas used for filling is:

a) technical grade SF_6 supplied from a gas supplier in a sealed container; or
b) stored in sealed containers fitted with an appropriate label that identifies the contents as used SF_6 suitable for re-use in electrical equipment and meeting the requirements of BS EN 60480.

In all other cases it is important to check the quality of gas in the gas-filled compartment before energisation as any impurities will reduce the insulating properties of the gas.

The maximum acceptable quantities for each impurity should be stated in manufacturers' instructions and should not be more than the maximum impurity levels stated in Section 3.4.

A summary of the quality checks are listed below.

a) Measurement of moisture content (i.e. dew point).
b) Measurement of SF_6 percentage.
c) Measurement of acidity.

It may be necessary to top up gas-filled compartments with small volumes after SF_6 gas quality checks.

3.1.11. Leakage of SF_6 in Switchgear

The maximum permissible relative leakage rates per annum are 0.5 % or 1 % of the total initial mass of SF_6 dependent upon the switchgear specification. These are specified in *IEC 62271-1, IEC 62271-100, IEC 62271-200, IEC 62271-203 and IEC/TR 62271-303*.

Leakage rates may be higher for equipment manufactured before 1985 or that has not been manufactured to IEC standards. Quantities of SF_6 gas lost due to leakage vary according to.

a) equipment type;
b) rated voltage;
c) design operating pressure;
d) Installation practices.

The gas tightness of distribution switchgear incorporating sealed pressure systems is specified in terms of the expected service life. Typically this can be up to 30 years. Lower leakage rates of 1 % of the initial mass of gas per annum can be achieved for modern equipment using standard materials and sealing techniques. Leakage rates are further reduced by designing the filling pressure to be just above atmospheric pressure. As a consequence, leakage

rates for distribution switchgear rated up to 36 kV are lower than higher voltage switchgear containing larger gas volumes at higher pressures.

Due to the large quantity of distribution switchgear owned and operated by the Company, it is not viable to regularly monitor SF_6 gas pressure.

Ground mounted switchgear is normally fitted with pressure indicators that should be checked:

a) prior to operation;
b) during substation inspections.

Pole mounted switchgear may be fitted with pressure transducers to enable pressure to be indicated at the control box, providing this option is available and has been specified by the Company.

Inspection regimes are covered in the Company documents; MNT004 *Policy for the Inspection and Maintenance of Overhead Systems* and MNT005 *Policy for the Inspection and Maintenance of Ground Mounted Plant*.

Primary switchgear is generally fitted with falling and low pressure gas alarms. Where SF_6 is used for arc extinction in this equipment, a low pressure lockout inhibits operation at low gas pressure. These alarms should be displayed at the control room via SCADA.

For periodic inspections and after any filling or topping up has been carried out, portable, handheld SF_6 leak detectors shall be used which can be used to check for leaks (down to 1 ppm) around switchgear gas flanges and gas filling connections.

3.1.11.1. Leakage Rates

To assist in tracking leakage rates, pressure or density readings should be recorded at commissioning, topping up and during periodic inspections. This may not be possible for gauges that have red and green sectors but no markings. It should also be noted that readings from some pressure gauges will need to be corrected because the gauges will not be temperature compensated (section 3.3.5.3).

If the leakage rate is greater than the maximum permissible rate then, the equipment should be taken out of service as soon as practicable. Remedial work should be carried out to rectify the source of the leakage. More commonly gas replenishment may be required because of accumulated gas loss over time. Providing the leakage rate is less than the maximum permissible rate stated in Section 3.3.5, gas may be replenished in accordance with the procedure for filling switchgear with technical grade SF_6.

3.1.11.2. Effects of Low Pressure on Switchgear Capability

The minimum functional pressure (density) for insulation and/or switching is the pressure (density) at which electrical type tests are carried out by the manufacturer and is stated on the switchgear rating plate, where the minimum functional pressure (density) for insulation is represented by the symbol p_{me} (ρ_{me}) and the minimum functional pressure (density) for switching is represented by the symbol p_{mm} (ρ_{mm}).

A loss of gas down to the minimum functional pressure (density) for insulation and/or switching will not reduce the capability or electrical rating of switchgear.

At pressures below the minimum functional pressure (density), the capability of the switchgear cannot be guaranteed. As such the electrical (i.e. insulation and/or switching) ratings assigned by the manufacturer may no longer apply, therefore the switchgear should not be operated live.

3.1.11.3. Pressure or Density Monitoring

Modern SF_6 switchgear rated at 66 kV and above should be equipped with monitoring devices that provide continuous monitoring and local indication of gas density or temperature compensated gas pressure in each compartment. Older designs may be fitted with gas pressure gauges that are not compensated for temperature. Each monitoring device should be equipped with a two stage pressure switch/alarm for low density or pressure. One pressure switch/alarm should correspond to the minimum functional pressure (density) and the other to a pressure above the minimum functional pressure (density) but below the rated filling pressure (density), so as to give early warning of falling pressure. Where the rated filling density or pressure differs between adjacent compartments, a third pressure switch/alarm, “high density or pressure” may be provided to indicate failure of the gas-tight bushing.

Modern ground mounted switchgear rated at 36 kV and below should be equipped with similar monitoring devices, however switchgear with an insulation capability only, may only be provided with a single pressure switch/alarm corresponding to the minimum functional pressure (density).

Pole mounted switchgear rated at 36 kV and below should be equipped with a minimum of a single pressure switch/alarm corresponding to the minimum functional pressure and have an indication of gas pressure and/or pressure switch operation (at minimum functional pressure) in the control cabinet.

Early ground mounted switchgear and pole mounted switchgear rated below 36 kV may only be provided with facilities to measure gas pressure and may not have an alarm monitoring feature.

Where no pressure switches are fitted or no facilities exist for giving remote alarm indications, pressure monitoring should be carried out by pressure monitoring on site and the leakage rate should be verified as being within the expected range.

Gas pressure is affected by variations in ambient temperature, heat from normal load current, fault current and from solar radiation. Gas pressure gauges fitted to older SF_6 switchgear designs may not be of the temperature compensated type and will need to be manually compensated for temperature variations from the nominal value of +20 °C. This should be allowed for when interpreting measurements and alarms. Pressure/temperature compensation charts can usually be found in the operation and maintenance manual for the switchgear.

3.1.12. Guidance when entering sites containing SF_6 filled equipment

Sites containing SF_6 filled equipment should display appropriate notices to advise personnel that SF_6 is present and, where appropriate, any precautions to be taken. General precautions are detailed in Section 3.3.3.2.

Prior to entering these sites personnel should ascertain, wherever possible, that there has been no internal fault with the resultant release of SF_6 and decomposition products. Usually this will not be possible so personnel should be prepared to detect the signs immediately on entry. These include:

a) visual evidence of an internal fault (damage to switchgear enclosures, white powder deposits);
b) pungent odour (similar to rotten eggs) and smell of ozone;
c) irritation of the eyes and respiratory tract.

Providing none of these signs are detected personnel may safely enter the site without the use of specialist personal protecting equipment.

In the event of an internal fault and with the resultant release of SF_6, toxic and corrosive decomposition products may be present.

3.1.13. Facilities

For installations with SF_6 equipment operating at a voltage below 36 kV it is not mandatory to provide dedicated washing and changing facilities.

On larger sites, where the weight of used SF_6 being handled is high, consideration should be given to providing dedicated facilities with hot and cold water supplies.

3.1.14. Handling Used SF_6

SF_6 which has been used in electrical equipment, such as circuit breakers, for both insulation and arc extinction, may contain decomposition products. Special precautions need to be taken when handling used SF_6 to minimise health risks to personnel. By definition, used SF_6 could be encountered during:

a) maintenance of electrical equipment with closed pressure systems, which have been in service, such as circuit breakers, ring main units, pole mounted auto-reclosers etc.);
b) modification and extension to the above equipment;
c) dismantlement of equipment at 'end of life';
d) emergency conditions where SF_6 gas-filled compartments have ruptured due to internal arcing or failure of SF_6 gas seals, resulting in an abnormal release of SF_6 gas.

It is unlikely that personnel will have to carry out any invasive maintenance or modifications on distribution switchgear rated up to 36 kV. In these circumstances the manufacturer or a specialist contractor should be engaged to carry out the work. As a consequence, personnel are only likely to encounter used SF_6 during emergency conditions.

3.1.14.1. Training

Specific training should be given to personnel who are required to handle used SF_6. This should include: operation of gas handling equipment, precautions to minimise health risks from decomposition products and first aid instructions. Specific training requirements are detailed in *The Fluorinated Greenhouse Gases Regulations 2015.*

Should suitably trained personnel not be available, a trained and certified specialist contractor shall be used.

3.1.14.2. Hazards Associated With Used SF_6

The hazards associated with exposure to used SF_6 gas include:

a) skin burns and eye damage through contact with contaminated liquid;
b) poisoning through gas inhalation;
c) irritation to eyes and respiratory tract;
d) suffocation through oxygen displacement in low lying areas such as switchroom floors, cable trenches, cable basements.

Decomposition products may also be present, these take the form of gases and solid deposits which have the following characteristics.

a) Gaseous – Colourless but pungent odour (rotten eggs).
b) Solid – Metal fluoride powders (white powders) which form extremely acidic, grey deposits when exposed to moisture.

3.1.15. Requirements for Handling Used SF_6

General requirements for handling SF_6 can be found in the Company Operational Practice Manual (OPM) Section WB1.5.4.

3.1.15.1. Personal Protective Equipment

Personnel who may encounter SF_6 decomposition products should be equipped with appropriate personal protective equipment (PPE) to minimise the risks of exposure. As a minimum this should include:

a) protective footwear or acid resistant chemical type boots;
b) disposable overboots for protective footwear;
c) disposable industrial grade overalls which are pocket less, hooded, non-permeable and dust-proof with elasticated wrists and ankles;
d) acid resistant gloves (e.g. made from nitrile rubber, neoprene or PVC);
e) chemical type industrial goggles (BS EN 166 Grade 1, Impact Resistance C&D);
f) face mask (BS EN 140) with disposable canister particle filter (BS EN 143) capable of trapping particles greater than or equal to 1 µm, gas filter (BS EN 141) or combined filter of type A2/B2/E2/K2/P3 (BS EN 14387).

3.1.15.2. Hygiene

Strict hygiene requirements should be observed during handling of used SF_6.

a) Maintain a high standard of personal hygiene including washing exposed body parts immediately before and after work.
b) Do not eat, drink, smoke or inhale substances within the work area.
c) Avoid wiping eyes, nose, face and exposed skin other than with clean paper tissues.

3.1.15.3. First Aid

First aid equipment and appropriately trained personnel should be available at the location. In addition to the normal industrial first aid kit, sterile eye-wash equipment containing saline solution should be provided. A summary of the first aid actions are as follows.

a) In case of skin irritation, remove the casualty from the work area, carefully remove contaminated clothing and wash skin with cool running water.
b) In case of eye irritation, remove the casualty from the work area, bathe the eye using sterile eye-wash equipment and copious amounts of saline solution. Continue to irrigate the eye until medical advice is sought.

c) In case of breathing difficulty, remove the casualty from the work area into the open air. Remove any contaminated clothing and cover with a blanket. Keep the casualty still and under observation. Seek emergency medical assistance without delay. If breathing fails artificial respiration should be administered.

3.1.15.4. Equipment

In addition to the PPE and first aid equipment previously mentioned, self-contained gas handling equipment should be used. This enables as much of the gas as possible to be recovered from the gas-filled compartment. Gas handling carts (complying with NSP/007/027) incorporate the necessary vacuum pumps, compressors and filters which remove decomposition products and enable the gas to be re-used in most circumstances. An industrial vacuum cleaner (complying with BS EN 60335-2-69) with high efficiency exhaust filter (capable of trapping particles greater than or equal to 1 µm), disposable bag and disposable lint free cloths are also needed to remove solid decomposition products.

3.1.16. Removing SF_6 From Equipment

When removing used SF_6 gas from the equipment, personnel should follow the precautions and requirements summarised below.

a) Warning notices should be displayed at the entrances of the work areas.
b) Work areas should be adequately ventilated.
c) Personnel should be trained and authorised to handle used SF_6.
d) Suitable PPE should be available to personnel in the event of a leak.
e) First aid equipment should be available.
f) Washing and changing facilities should be available.

Providing gas-filled compartments are not to be opened, personnel do not need to wear PPE that protects against exposure to SF_6decomposition products when handling used SF_6.

Prior to removal, the quality of the SF_6 gas should be tested to determine the level of decomposition products. The test procedure is detailed in Section 3.4. If the measured values are below the maximum impurity levels stated in Section 3.4, then the gas is suitable for re-use without further processing. If the maximum levels for each of the impurities are exceeded then the SF_6 may either be reclaimed at site using suitable gas handling equipment and filters or returned to the SF_6 manufacturer for reclamation.

Generally, once the condition of the used SF_6 gas is known, the gas should be recovered from the compartment by connecting the gas cart or free standing vacuum compressor to the equipment gas filling point. If the gas is classed as non-arced or normally arced SF_6 then it is advisable to connect a pre-filter between the gas-filled compartment and the vacuum compressor. If the gas is classed as heavily arced then it is advisable to connect an additional pre-filter at the inlet of the SF_6 reclaimer. To ensure as much gas is removed as possible, the gas-filled compartment should be taken down to a pressure of less than 20 mbar. The time is dependent upon the quantity of gas to be removed and the efficiency of the vacuum pump.

The recovered gas should be stored in cylinders suitable for SF_6 decomposition products marked 'Used SF_6 suitable for re-use in electrical equipment' or 'Used SF_6 not suitable for re-use'.

3.1.16.1. Opening & Entering Compartments Containing Used SF_6

Sealed pressure systems will not ordinarily need to be opened on site. Should this be required, the equipment manufacturer or a specialist contractor should be used.

For closed pressure systems, following recovery, the compartment should be slowly filled with air or nitrogen to atmospheric pressure to equalise the pressure with that outside. This ensures that the compartment can be opened safely. In particular, if this work is done outdoors the equipment should be covered and protected to prevent

moisture entering the open compartment as this will react with the metal fluoride powders to produce a corrosive grey acid which could damage the equipment. If the gas-filled compartment contained gas classed as heavily arced SF6 then at least 1 hour should be allowed before opening the compartment. This is to allow any remaining solid decomposition products to settle down in the compartment.

Prior to opening any compartments previously pressurised with SF6, a risk assessment should be carried out to determine if any pressure adjustments are necessary in adjacent compartments.

3.1.16.2. Removing Decomposition Products

Any solid decomposition products readily identifiable as white powder should be removed using a suitable vacuum cleaner fitted with a dust filter, which is reserved and marked 'SF_6 Use Only'. Adsorber materials that may be installed in the compartment should be removed at this time.

When all traces of the dust have been removed the compartment and associated components should be first wiped down using dry lint free cloths and then, if necessary, using a solvent based cleaning agent recommended by the manufacturer.

On completion of the work, any safety equipment, tools, clothes and removed components that may be contaminated but suitable for re-use should be immediately treated in a neutralising solution for a minimum time period. The minimum time period is dependent upon the type of neutralising agent, the concentration of the neutralising solution and whether the gas-filled compartment contained normally arced or heavily arced SF6. Further information on neutralising solutions is provided in Section 3.5.3. Following treatment, treated materials should be rinsed with clean water.

Generally, treatment for 1 hour in a sodium carbonate solution, 10 % by weight to water, will be sufficient for materials contaminated with normally arced SF_6.

All disposable equipment and components including, overalls, canisters, filter bags, cloths etc should be deposited in plastic bags, sealed with tape and suitably labelled for disposal as hazardous waste.

3.1.16.3. Treatment of SF_6 Decomposition Products

Any equipment and materials which have been contaminated with used SF6 decomposition products should be treated in the process described in Section 3.5.3.

Commercially available SF_6 disposal kits should be utilised where possible.

3.1.16.4. Refilling a Compartment

Following decontamination, the compartment may be filled with either technical grade SF_6 gas or reclaimed gas which has been adequately filtered by the gas handling equipment to reduce impurity levels below the maximum concentrations stated in Section 3.4.

The same filling procedure as that for technical grade SF_6 gas should be used. Prior to filling the following steps should be taken.

a) Ensure the gas compartment and associated components are thoroughly clean and dry.
b) Replacement adsorber material has been installed in compartments (where there is this provision) according to the manufacturer's instructions.
c) Tools and equipment are fully accounted for so none are inadvertently left inside the compartment.
d) Flanges, o-rings and other gas sealing components have been cleaned and prepared strictly in accordance with the manufacturer's instructions to ensure gas tightness.

e) Covers are replaced correctly to ensure the gas sealing system is not damaged and overpressure device (where there is provision) is correctly orientated.
f) Bolts are tightened using a torque wrench to the prescribed settings.

The gas compartment should be evacuated to remove any air and nitrogen before being filled with SF_6 to the prescribed pressure.

The operator should ensure that a pressure relief device and pressure gauge is fitted to the compartment side of the filling equipment and carefully monitored to reduce the risk of the compartment being over pressurised. Filling equipment should also be fitted with a shut-off valve, which can be operated quickly in this event. The filling pressure is usually stated at an ambient temperature of 20 °C. The ambient temperature referred to here is the temperature of the SF_6 gas in the switchgear compartment and not the surrounding ambient air temperature.

Since the SF_6 gas is contained with a sealed and pressurised cylinder it is almost impossible to measure the temperature of the SF_6 gas directly. If the temperature of the SF_6 gas and the ambient air is not equalised prior to filling, it may be necessary to revisit the compartment after the temperature of the SF_6 has equalised (nominally 24 hours) and check the pressure. In the event the ambient temperature is different to 20 °C, the operator should adjust the filling pressure according to information provided by the manufacturer. The mass of gas used during the filling process should be measured and recorded in accordance with the Company procedures. The mass of gas used can be determined by weighing the bottle prior to and after use or by filling the compartment via a mass flow meter. During the filling operation the gas tightness of the compartment and gas filling equipment should be monitored using an SF_6 leak detector.

3.1.17. Emergency Situations

Emergency situations occur when used SF_6 gas has been unexpectedly released in significant quantities from equipment which has been in service. Although these occasions are unlikely, they may create a particularly hazardous environment for personnel called to deal with these situations. Circumstances which may create emergency situations include:

a) internal arcing leading to an internal pressure rise and consequent operation of the overpressure relief device or rupture of the compartment;
b) mechanical failure of the compartment or gas sealing components;
c) external fire leading to an internal pressure rise with the same consequences as an internal arc;
d) catastrophic failure of the electrical equipment due to explosion or mechanical shock from third parties.

Personnel who need to access affected areas to make assessments or clean-up SF_6 decomposition products should be specifically trained in the hazards and safety measures to be taken. This includes wearing appropriate personal protective equipment (PPE) to minimise the risks of exposure to toxic and corrosive by-products (see Clause 3.3.9.1) and to minimise the possibility of asphyxiation.

3.1.17.1. Detection of Abnormal Leakage of Used SF_6

The attention to an abnormal leakage of SF_6 may be alerted by:

a) operation of an alarm from SF_6 detectors or pressure gauge contacts;
b) visual indication by inspecting a pressure gauge;
c) characteristic odour of SF_6 decomposition product (rotten eggs).

At primary substations low pressure alarms and indications are commonly available via SCADA to indicate when an SF_6 leakage has occurred. However, this is not usually the case for distribution substations where the abnormal release of SF_6 gas may not be known until the operator has entered the site.

Immediately following detection of an abnormal SF_6 leakage the operator should not approach or remain in the vicinity of the equipment. Even in the most severe cases it is unlikely that immediate exposure to SF_6 decontamination would be harmful providing the exposure time does not exceed 30 minutes.

Steps should then be taken to determine whether the levels of SF_6, oxygen and decomposition products in the area are acceptable.

3.1.17.2. Checking Oxygen Levels

Where equipment is located outdoors or contains small volumes of SF_6 gas then lack of oxygen should not pose a hazard. In the unlikely case where large volumes of SF_6 may have been released into small, confined indoor areas then oxygen levels should first be verified using an oxygen detector.

3.1.17.3. Checking Levels of SF_6 Gas Decomposition

Providing oxygen levels are sufficient, the concentration of gaseous decomposition products should be checked. Although this should be done by direct measurement of the toxic components, a more practical approach is to measure the concentration of used SF_6 in the air. If the concentration exceeds 200 ppmv or, more commonly, where there are no means to carry out this test, then a full face respirator should be worn at all times. For concentrations of SF_6 < 200 ppmv, it is unlikely that any toxic components would be present in large enough quantities to be harmful.

3.1.17.4. Outdoor Situations

In the case of outdoor equipment the contaminated gas will disperse quickly and the concentration of gaseous decomposition products will be negligible. However, solid by-products may remain on the ground and in the equipment. Steps should be taken to protect the equipment from moisture to prevent formation of corrosive acids. Wherever practicable, powders should be cleaned up using a vacuum cleaner fitted with a dust filter, which is reserved and marked 'SF_6 Use Only'. Remnants should be treated with an alkaline neutralising solution (see Section 3.5.3).

3.1.17.5. Indoor Situations

Before carrying out any work the area should be thoroughly ventilated (See Clause 3.3.3.2). Time should be allowed for any dust to settle before cleaning the area and equipment with an approved vacuum cleaner. Similar to outdoor equipment, remnants should be treated with an alkaline solution.

3.1.18. Special Considerations for Fire

If a fire reaches any SF_6 gas-filled compartment the gas inside will heat up relatively slowly and the pressure will increase. For larger equipment with closed pressure systems, pressure relief devices, which are normally fitted to the compartments, will operate before the compartment ruptures. Smaller equipment with sealed cast resin enclosures may soften before the internal pressure is high enough to either operate the pressure relief device or rupture the enclosure. In both cases gas release will occur at temperatures below which significant SF_6 decomposition can take place. It is important to note that the toxicity of decomposed SF_6 is likely to be very much lower than other fumes from wiring, insulation and paint materials. As SF_6 is non-flammable there are no special precautions to be taken over and above those usually deployed during a substation fire.

3.1.19. Reclaiming Used SF_6

Used SF6 that contains excessive levels of impurities may be reclaimed at site using suitable gas handling equipment fitted with a variety of filters to remove the different decomposition products.

Where the SF6 is not to be reused or the gas still contains unacceptable levels of impurities then the preferred option is to return it to an SF6 manufacturer who can reclaim the gas.

Testing

The effectiveness of SF_6 gas as an insulation and arc quenching medium depends upon its quality. Impurities in the gas, such as air and moisture, reduce dielectric strength. Although small quantities (which are invariably present even in technical grade SF_6 gas supplied by the manufacturer) have little effect, additional impurities can be introduced from the gas handling process and electrical equipment itself. High levels of these impurities may constitute a hazard to the safe and reliable operation of the switchgear.

Decomposition products, which may be produced in the equipment as a result of arcing, present a health hazard to personnel. Detecting and quantifying the presence of these products is necessary to determine the procedures required to reduce risks to an acceptable level.

The material supplied for use in electrical equipment should consist essentially of sulphur Hexafluoride (SF_6), which occupies at least 99.9 % concentration by mass. Common impurities which can be contained in the gas include: nitrogen, oxygen and carbon tetra fluoride. Other impurities such as water, oil, hydrofluoric acid and toxins may also be present.

Impurities such as water, oxygen and acids in sufficient quantities may give rise to corrosion, condensation or reduced dielectric strength within the gas-filled compartment; all of which are undesirable. Providing quantities of these impurities do not exceed the maximum permitted impurity levels in the table below, then the gas will be satisfactory for use in electrical equipment and no problems will result.

The maximum concentrations of SF_6 decomposition products are shown in Table 3.

All technical grade SF_6 gas supplied by manufacturers should meet this specification. Individual certificates of compliance should be supplied from manufacturers, including a statement that the gas is non-toxic, in lieu of testing.

Table 3 Maximum concentrations SF_6 decomposition products

Contaminant	Main origin	Effect on	Maximum Tolerable Impurity Levels in the Equipment	Maximum Impurity Levels for Reclaimed SF_6 to be Re-used [1]	Practical Impurity Detection Level	Technical Grade [2]
Air	Handling	Switching gas insulation	3 % vol	3 % vol	< 1 % vol	0.05 %
CF_4	Switching arcs					
Humidity	Desorption from surfaces and other polymers	Surface insulation by liquid condensation	800 ppmv at 500 kPa 4010 ppmv at 100 kPa	200 ppmv at > 200 kPa [3] 750 ppmv at < 200 kPa [3]	< 25 ppmv	200 ppmv at 100 kPa
SF_4 WF_6 SOF_4	Arcing, partial discharges	Surface insulation, Toxicity	100 ppmv	50 ppmv [4] (total)	< 10 ppmv (total)	7.3 ppmv [8]
SOF_2 SO_2, HF SO_2F_2	Secondary reactions		2000 ppmv			
CuF_2 WO_3 WO_2F_2 WOF_4 AlF_3	Contact erosion in switchgear, Internal arcing	Toxicity	Non-critical [5]	No value [6]	Detection not practical	
Carbon	Polymer carbonisation	Surface insulation	Low [5]	No Value [6]	Detection not practical	
Metal dust / particles	Mechanical wear	Gas insulation				
Oil	Pumps & Lubrication	Surface insulation	Low [5]	No Value [6]	Detection not practical	10 mg/kg
NOTE 1: Based on BS EN 60480						
NOTE 2: Based on BS EN 60376						
NOTE 3: Only applicable if the gas is reused at a pressure equal to or below specified reference pressure						
NOTE 4: or 12 ppmv $SO_2 + SOF_2$						
NOTE 5: Cannot be quantified						
NOTE 6: No value required, contaminant can be removed by dust filter of 1µm pore size						
NOTE 7: No value given, oil contamination has to be (and can be) avoided						
NOTE 8: Hydrolysable fluorides as HF						

3.1.19.1. Testing of SF_6 Taken From Electrical Equipment

For distribution switchgear rated up to 36 kV with sealed pressure systems, further handling of SF_6 at site is not expected under normal operating conditions. Testing is restricted to checking pressure gauges fitted to the compartments. These should be checked before operation or during substation inspections to ensure no abnormal leakages of SF_6. Distribution switchgear with sealed pressure systems may have facilities to top-up the SF_6. The quality of SF_6 within distribution switchgear should be tested following topping-up operations to verify its suitability for service.

For switchgear with closed pressure systems, verifying SF_6 quality is a maintenance requirement. Testing should be carried out on gas in the equipment prior to recovery, after filling/replenishment and periodically to check the levels of decomposition products.

The following SF_6 gas tests are carried out at site to determine the concentrations of important impurities.

a) Measurement of SF_6 percentage.
b) Measurement of moisture content (i.e. dew point).
c) Measurement of acidity.

Off-site analysis of SF_6 gas quality may be performed by sampling the gas and sending it to a qualified chemical laboratory.

3.1.19.2. Air Content

Air content (i.e. oxygen and nitrogen) should be minimised to maintain the dielectric strength in the gas-filled compartment and avoid production of acidic products.

Contamination may occur as a result of air leakage into the gas filling equipment or left in the compartment as a result of inadequate evacuation of the gas-filled compartment prior to filling. Consequently, this test is of most value immediately after filling the compartment.

Switchgear operates with SF_6 above atmospheric pressure, therefore there is no need to repeat this measurement during normal service.

On site air content is usually determined by measuring the magnetic susceptibility of the sample. This is done using commercially available portable instruments. Alternatively the air content can be determined by measuring the percentage of SF_6; where the air content is the difference between 100 % SF_6 and the percentage of SF_6 measured.

3.1.19.3. Acidity

The acidity of SF_6 gas is the total concentration of reactive gaseous decomposition products present. It is therefore necessary to periodically test the gas to ensure these by-products are kept below maximum permissible levels.

Characteristically, decomposition products comprise of hydrolysable fluorides which react with moisture to produce sulphur dioxide (SO_2) and hydrogen fluoride (HF). Sulphur dioxide even in small quantities is detectable by its acrid smell. Measurement of acidity is more readily obtained using portable instruments, which is the preferred method at site. Portable instruments generally measure SO_2, thionyl fluoride (SOF_2) and/or HF, as these are the most abundant reactive gaseous decomposition products.

3.1.19.4. Dew Point

The dew point is the temperature at which the water vapour in a gas begins to deposit as a liquid or ice, under standardized conditions.

The maximum acceptable moisture content for technical grade or used SF_6 gas is 25 mg/kg, which is equivalent to a dew point temperature of -36 °C. However, moisture may be introduced during filling operations and from imperfectly dry insulation when the equipment is in service, causing the dew point temperature to increase. Consequently, dew point tests are carried out immediately following gas filling or replenishment of gas. Further tests are performed periodically to check deterioration remains within acceptable limits.

Acceptable limits of moisture content for used SF_6 are dependent upon the manufacturer's recommendations and the ambient conditions.

It is essential that SF_6 should not continue to be used when its dew point at the operating pressure of the equipment is greater than the lowest ambient operating temperature.

3.1.19.5. Frequency of Testing

Based on guidelines found within the relevant BS, IEC and CIGRE documents, the test schedule in Table 3 for HV switchgear should be used.

Table 4 SF_6 gas testing schedule for HV SF_6 switchgear

Test Requirement	Tests	Criteria	Frequency
Technical Grade Gas	Moisture CF_4 Air (or O_2 & N_2) Acidity Oil	As per BS EN60376 or Rely on suppliers certificate	Prior to Filling
Recycled Gas	Air and CF_4	<2% Volume	Prior to Filling
	Moisture	Dew Point < Minimum Operating Temperature	
	Gaseous arc decomposition products (via acidity)	< 50 ppmv total or < 12 ppmv SO_2 + SOF_2	
	Solid Contaminants	No value – removed by 1µm pore size filters	
After Refilling or Topping Up	Air	<2% Volume	Immediately after Filling
	Moisture	Dew Point < Minimum Operating Temperature	Immediately after Filling then Daily until acceptable stable level achieved
	Gaseous arc decomposition products (via acidity)	< 50 ppmv total or < 12 ppmv SO_2 + SOF_2 or < 25 ppmv HF	Immediately after Filling
In Service Switchgear up to 36kV	Read Pressure or Density Gauge	Manufacturers Specification	Prior to local operation or during substation inspection
In Service Switchgear above 36kV	Pressure or Density	Manufacturers Specification	Constantly monitored by gauges and SCADA
	Air (Optional)	< 3% Volume	
	Moisture	Dew Point < Minimum Operating Temperature	
	Gaseous arc decomposition products (via acidity)	< 200 ppmv total or < 100 ppmv SO_2 + SOF_2 or < 100 ppmv HF	

3.1.19.6. Method of Testing

To carry out SF_6 gas quality checks described previously, samples of SF_6 gas need to be obtained from either compressed gas cylinders, the gas-filled compartment or by direct connection of portable test instruments.

In the event that the sample cannot be passed directly from the cylinder to the test device or when the test cannot be carried out at site, it is necessary to use an intermediate sampling cylinder. To prevent contamination of the sampled gas, sample cylinders should be thoroughly purged. Intermediate sample cylinders can be supplied on a loan basis from the SF_6 gas manufacturer or testing laboratory if required. Stainless steel cylinders with a volume smaller than 1 litre are recommended. The gas quantity should be not smaller than 6 g.

Cylinders containing gas samples should be accompanied by a label to identify the switchgear, the compartment (the gas was sampled from), the date, the gas compartment pressure and ambient temperature. It is important to note that water is the only contaminant that cannot be determined accurately from a sampling cylinder as the water content of a sample in a cylinder is not representative of the gas compartment because of water adsorption on the surfaces of the cylinder.

Sample cylinders should not be used for substances other than SF_6; after use they should be thoroughly purged from any contamination by heating to 100 °C with their valve open and evacuating with an oil sealed rotary pump. The cylinders are then flushed at least twice with technical grade SF_6 by alternate filling and venting–off, and finally stored for future use, filled with technical grade SF_6 slightly above atmospheric pressure.

Disposal

Disposal of SF_6 gas and decomposition products becomes necessary under the following circumstances.

a) After an emergency situation.
b) When sufficient quantities of used SF_6 have been collected by users who do not have SF_6 reclaim equipment.
c) When electrical switchgear has come to the end of its service life.

SF_6 should be recovered and reclaimed from equipment prior to its disposal or dismantlement. Reclaimed SF_6 can be re-used on site, stored or transported off site for further re-use.

3.1.20. Sealed Pressure Systems

Disposal of equipment with sealed pressure systems (i.e. ‘sealed for life’), small enough to be transported, should be disposed of in the following way.

Recovery and reclamation of the SF_6 and dismantling of the equipment is carried out at a designated dismantling site by an experienced subcontractor such as an equipment manufacturer or specialist subcontractor. It is the responsibility of the Company to advise the history of the SF_6 gas compartment(s) or, if unknown, to arrange analysis of the SF_6 for reactive gaseous by-products. A competent subcontractor who has the necessary experience and trained personnel to carry out the work should be selected. The Company shall undertake reasonable checks to confirm this. This does not preclude SF_6 recovery and dismantling of equipment on site, particularly where movement or transport of equipment as a single unit is difficult.

In the case of larger equipment with sealed pressure systems it may be more appropriate to recover and reclaim the SF_6 at site. This may be because it is considered to be at too high a pressure to allow it to be dismantled and transported in smaller units.

In these circumstances the gas is recovered and reclaimed at site using the process stated in Section 3.3.10. The equipment is both neutralised and dismantled on site or it is made ready for transport to a designated dismantling site. Appropriate equipment, personnel and procedures should be put in place for work on site.

3.1.21. Closed Pressure Systems

Disposal of equipment with closed pressure systems, small enough to be transported, should be disposed of in the following way.
Recovery and reclamation of the SF_6 and dismantling of the equipment is carried out at a designated dismantling site by an experienced subcontractor such as an equipment manufacturer or specialist subcontractor. It is the responsibility of the Company to advise the history of the SF_6 gas compartment(s) or, if unknown, to arrange analysis of the SF_6 for reactive gaseous by-products. A competent subcontractor who has the necessary experience and trained personnel to carry out the work should be selected. The Company shall undertake reasonable checks to confirm this. This does not preclude SF_6 recovery and dismantling of equipment on site, particularly where movement or transport of equipment as a single unit is difficult.

In the case of larger equipment with closed pressure systems it may be more appropriate to recover and reclaim the SF_6 at site. This may be because it is considered to be at too high a pressure to allow it to be dismantled and transported in smaller units.

In these circumstances the gas is recovered and reclaimed at site using the process stated in Section 3.3.10. The equipment is both neutralised and dismantled on site or it is made ready for transport to a designated dismantling site. Appropriate equipment, personnel and procedures should be put in place for work on site.

3.1.22. Neutralisation

Prior to disposal, equipment should be neutralised, which involves washing or immersing these products or materials in an alkaline solution using the following procedure.

a) In a suitable non-porous container (e.g. plastic dustbin), prepare a solution by dissolving the recommended amounts of neutralising agent in water.
b) Stir the solution ensuring all the crystals have been dissolved completely.
c) Wash or immerse the materials in the solution.
d) Stir thoroughly and leave for a minimum time period.
e) Pour the bulk of the solution into the nearest foul water drain or cesspool.
f) Allow running water to flow over the materials in the container for up to 2 hours, stirring occasionally.
g) Empty the water into the nearest foul water drain or cesspool ensuring equal amounts of water are washed down after the solution.

Disposable overalls, canisters, filter bags and cloths should also be treated in this way before being disposed of safely as normal waste. After neutralisation; tools, clothes and removed components may be wiped down and re- used without further treatment.

Equal quantities of water should be poured down the nearest foul water drain or cesspool after the solution.

3.1.23. Procedure for Disposing of End of Life SF_6 Equipment

This procedure ensures the SF_6 gas is fully recovered from electrical equipment at the end of its life and the gas-filled compartments and internal parts can be handled, recycled or disposed of as normal waste.

3.1.23.1. Recovering SF_6 Gas

Prior to recovery, samples of SF_6 gas taken from each gas-filled compartment should be tested to determine its quality. The same procedure for handling used SF_6 should be adopted. SF_6 gas can either be recovered and reclaimed using a gas service cart or stored in suitably marked gas cylinders for reclamation by the SF_6 supplier. If the used SF_6 gas has to be transported then the requirements previously outlined for transporting used SF_6 (see Section 3.3.2) should be followed.

3.1.23.2. Assessing Decomposition Products

The type and level of decomposition products depends upon the application of equipment and its service history. Where SF_6 has been used in switchgear compartments for electrical insulation only, relatively low levels of decomposition products may be present. Conversely, where SF_6 has been used for arc extinction in circuit breakers the levels will be significantly higher. Expected degrees of SF_6 decomposition for various applications are given in Table 5.

Table 5 Expected degrees of SF_6 decomposition

Application	SF_6 Category	SF_6 Decomposition
GIS Busbars Cable Box	Non-arced SF_6	From zero to a few tenths of a percent by volume
GIS Earth Switch GIS Disconnector	Normally arced SF_6	Light powder deposits
Load Break Switch Ring Main Unit Circuit Breaker	Normally arced SF_6	Up to a few percent by volume Light powder deposits
Any gas filled compartment in which abnormal arcing has occurred	Heavily arced SF_6	Could exceed 5 % by volume Medium to heavy powder deposits

3.1.23.3. Non-Arced SF_6

It is expected that HV GIS busbars, cable boxes and other non-switching gas-filled compartments will be in this category with low levels of decomposition products and no visible deposits of powder. Providing this is the case no special treatment of gas-filled compartments is required and non-recoverable parts can be disposed as normal waste.

3.1.23.4. Normally Arced SF_6

HV load break switches, ring main units and circuit breakers are expected to fall into this category signified by light powder deposits.

In this case the gas-filled compartment should be filled with a neutralising solution and left for 1 hour, then rinsed with clean water. Alternatively, the compartment interior should be washed thoroughly with the solution and then rinsed with clean water.

3.1.23.5. Heavily Arced SF_6

Gas-filled compartments in which abnormal arcing has occurred (e.g. internal fault) can be expected to have high levels of SF_6 decomposition products. Medium to heavy powder deposits should first be removed using a suitable vacuum cleaner. Filter materials and vacuum cleaner bags should be removed and stored in sealed containers prior to neutralisation or disposal. The same neutralisation procedure outlined in Section 3.5.4.4 should then be followed.

4. References

4.1 External Documentation

Reference	Title
BS 5415-2.2	Safety of electrical motor operated industrial and commercial cleaning appliances.
BS EN 166	Personal eye protection
BS EN 14387	Respiratory protective devices
BS EN 60376	Specification for technical grade sulphur Hexafluoride for use in electrical equipment
BS EN 60480	Guidelines for the checking and treatment of sulphur Hexafluoride taken from electrical equipment and specification for its reuse
IEC 62271-4	High voltage switchgear and controlgear – Use and handling of sulphur Hexafluoride
IEC 62271-200	High voltage switchgear and controlgear –AC metal enclosed switchgear and controlgear for rated voltages > 1kV up to and including 52 kV
IEC 62271-203	High voltage switchgear and controlgear – Gas insulated metal enclosed switchgear and controlgear for rated voltages > 52 kV
ENA EREC G69	Guidance on working with sulphur Hexafluoride
2002 No. 2677	Control Of Substances Hazardous To Health Regulations 2002
1990 c. 43	Environmental Protection Act 1990
1998 No. 2306	The Provision And Use Of Work Equipment Regulations 1998
2009 No. 1348	The Carriage Of Dangerous Goods And Transportable Pressure Containers Regulations 2009
2015 No. 310	The Fluorinated Greenhouse Gas Regulations 2015
SI 1996/972	The Special Waste Regulations 1996
SI 1997/251	The Special Waste (Amendment) Regulations 1996.
SI 2005/894	The Hazardous Waste (England and Wales) Regulations 2005.
BS EN 141	Specification for closely woven cotton fabrics (L28 and L34) for aerospace purposes
BS EN 143	Respiratory protective devices. Particle filters. Requirements, testing, marking
BS EN 140	Respiratory protective devices. Half masks and quarter masks. Requirements, testing, marking
BS EN 60335-2-69	Household and similar electrical appliances. Safety . Particular requirements for wet and dry vacuum cleaners, including power brush for commercial use

4.2 Internal documentation

Reference	Title
MNT/004	Policy for the Inspection and Maintenance of Overhead Systems
MNT/005	Policy for the Inspection and Maintenance of Ground Mounted Plant
NSP/007/027	Guidance on Substation Design: Pressure Systems and Vessels

5. Definitions

Reference	Title
SCADA	Supervisory Control and Data Acquisition System
SF_6	Sulphur Hexafluoride Gas
ppmv	Parts per Million by Volume
ppmw	Parts per Million by Weight
Adsorber	A material that allows for the accumulation of gases on its surface
Non-arced SF_6	SF_6 gas having less than approximately 0.1% by products as typically found in any compartment after filling and prior to energising or any compartment which has not experienced arcing
Technical grade SF_6	SF_6 gas having a very low level of impurities
Used SF_6	SF_6 gas removed from electrical equipment typically during repair or maintenance.

6. Authority for issue

CDS Assurance

I sign to confirm that I have completed and checked this document and I am satisfied with its content and submit it for approval and authorisation.

		Sign	Date
Sarah Phillips	CDS Administrator	Sarah Phillips	14/01/16

Author

I sign to confirm that I have completed and checked this document and I am satisfied with its content and submit it for approval and authorisation.

Review Period - This document should be reviewed within the following time period.

Standard CDS review of 3 years	Non Standard Review Period & Reason	
Yes	Period: 3 Years	Reason:

		Sign	Date
G Hammel	Senior Policy and Standards Engineer	Ged Hammel	14/01/16

Technical Assurance

I sign to confirm that I am satisfied with all aspects of the content and preparation of this document and submit it for approval and authorisation.

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D Blackledge	Senior Policy and Standards Engineer	David Blackledge	14/01/16
M Storey		Mike Storey	14/01/16

Approval

Approval is granted for publication of this document.

		Sign	Date
C Holdsworth	Policy and Standards Manager	Chris Holdsworth	14/01/16

Authorisation

Authorisation is granted for publication of this document.

		Sign	Date
M Nicholson	Head of System Strategy	Mark Nicholson	22/01/16

Appendix A – Instructions in Writing (Road) for SF_6

USED SULPUR HEXAFLOURIDE FROM ELECTRICAL INSTALLATIONS (May contain toxic and corrosive decomposition products like hydrogen fluoride and thionyl fluoride)	
CLASS:	2
ITEM:	2TC ADR
CARGO:	• Colourless, liquefied pressure gas, often with pungent odour • Insoluble in water
NATURE OF HAZARD:	• Contact with liquid can cause skinburns and damage to eyes • Gas can poison by inhalation • The gas may cause irritation to eyes and air passages • Gas is invisible, heavier than air and spreads along the ground. • Gas produces mist on contact with moist air • Heating will cause pressure rise and risk of bursting
PROTECTIVE DEVICES:	• Full face respiratory protective device • Leather or thick textile gloves • Eyewash bottle with clean water
EMERGENCY ACTIONS:	• Stop the engine. • Mark roads and warn other road users • Keep public away from danger area • Keep upwind of danger area • No naked lights. • No smoking • Wear protective equipment before entering danger area
SPILLAGE:	• Shut off leaks if possible without risk • Allow spilled liquid to evaporate – do not breathe the gas • Warn everybody in sewers, basements and workpits – danger of suffocating without warning • Aquatic toxicity : 1 (slightly toxic because of possible impurities)
FIRE:	• The substance is not combustible • Keep container cool by spraying with water if exposed to fire • Use waterspray to “knock down” vapour produced in a fire
FIRST AID:	• In case of contact with liquid, immediately flush eyes with plenty of water for several minutes • In case of contact with liquid, thaw frosted parts with water, then remove clothing carefully • Seek medical treatment when anyone has symptoms apparently due to; - contact of the liquid with eyes - inhalation or - due to deficiency of oxygen.