

Document No: SMI 0122

Amendment No: 4

Substation Maintenance Instruction

Use and handling of sulphur hexafluoride (SF₆)

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Substation Maintenance Instruction

ASSET PLANNING AND PERFORMANCE

Document No : SMI 122
 Amendment No : 4
 Approved By : HAP&P
 Approval Date : 20/6/2023

SMI 122 USE AND HANDLING OF SULPHUR HEXAFLUORIDE (SF₆)

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1.0 PURPOSE

To set out in detail the minimum requirements for the use and handling of sulphur hexafluoride (SF₆) gas and associated arc decomposition products in or from electrical equipment and storage devices.

2.0 SCOPE

This instruction will be read in conjunction with Substation Maintenance Instruction SMI 100 – *Minimum requirements for maintenance of transmission and zone substation equipment* and Company Procedure GPE 0063 - *National Greenhouse and Energy Reporting Requirements*. It defines the minimum requirements for handling SF₆ gas used in electrical equipment and the requirements for minimising SF₆ emissions to the atmosphere.

This document is not intended to deviate from the respective and applicable Australian Standards.

3.0 REFERENCES

Board Policy (Environment) 4.0 – Environment
Company Policy (Network) 9.2.5 – Network Asset Design
Company Policy (Network) 9.9.1 – Network Asset Maintenance
Company Procedure (Environment) GPE 0063 – National Greenhouse and Energy Reporting Requirements
Company Procedure (Health & Safety) GSY 1066 – Worksite Hazard and Risk Assessment
Company Procedure (Procurement & Logistics) GSU 0012 – Selection and approval of disposal method
Branch Workplace Instruction (System Control) WCB 2067 – Attendance at Installations Involving SF₆ (Sulphur Hexafluoride) Gas Insulation
Substation Design Instruction SDI 545 – Acceptable purity limits for SF₆ gas
Substation Maintenance Instruction SMI 100 – Minimum requirements for maintenance of transmission and zone substation equipment
Substation Maintenance Instruction SMI 118 – Transmission and zone substation maintenance data entry and defect prioritisation
Substation Maintenance Instruction SMI 119 – Transmission and zone substation data entry, asset structure and details
Electrical Safety Rules
Network Management Plan (December 2013 Review)
Electricity Supply Act 1995 (as amended)
Occupational Health and Safety Act 2000
AS/NZS 1715:2009 - Selection, Use and Maintenance of Respiratory Protective Equipment
AS 62271.4:2015 – High-voltage switchgear and controlgear; Part 4: Handling procedures for sulphur hexafluoride (SF₆) and its mixtures
IEEE C37.122.3-2011 – IEEE Guide for Sulphur Hexafluoride (SF₆) Gas Handling for High-Voltage (over 1000 Vac) Equipment
IEC 60480:2004 - Guidelines for the checking and treatment of sulfur hexafluoride (SF₆) taken from electrical equipment and specification for its re-use
ENA National Electricity Network Safety Code (Doc 01-2008)
NGER - Reporting hydrofluorocarbons and sulphur hexafluoride gases guideline (July 2022)

4.0 DEFINITIONS AND ABBREVIATIONS

Closed pressure system

SF₆ containing equipment that is replenished only periodically by manual connection to an external gas source.

GIS

Gas-insulated metal-enclosed switchgear

PPE

Personal protective equipment

PPMV

Parts per million by volume

Respirator

Device worn over the nose and mouth to prevent the inhalation of noxious substances, for example, a gas mask.

Sealed pressure system

SF₆ containing equipment for which no further gas or vacuum processing is required during its expected operating life.

SF₆

Sulphur hexafluoride gas

SF₆ recovery

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

5.0 ACTIONS

By-products of SF₆ are highly toxic. Therefore, all Endeavour Energy employees and contractors must comply with the contents of this Standard and AS 62271.4:2015 when handling equipment containing (or which contained) SF₆ gas.

SF₆ gas is a greenhouse gas. It has a global warming potential 23,900 times greater than carbon dioxide. Therefore, SF₆ must not be evacuated to the atmosphere during maintenance of SF₆ equipment. SF₆ gas contained in equipment must be recovered using a commercially available SF₆ recovery machine. At least 99.9% of the SF₆ must be recovered from the equipment prior to opening.

Some equipment containing SF₆ is incapable of withstanding a vacuum. Therefore, special methods will need to be adopted for evacuating SF₆ from this switchgear. The Asset Performance Manager must be contacted prior to commencing maintenance on such equipment.

5.1 SF₆ gas characteristics

SF₆ is a synthetic gas formed by six (6) atoms of fluorine gathered around a centrally situated atom of sulphur. Under normal conditions, it is about five (5) times heavier than air, and under conditions of insufficient mixing with air the gas has a tendency to accumulate at low-lying areas. Clean, unused SF₆ gas has no colour, smell or taste. It is non-combustible, insoluble in water, very stable and chemically inert at room temperatures. SF₆ is one of the least reactive known gases and in normal conditions does not attack any substance with which it comes into contact.

Pure SF₆ is not toxic. However, toxic gaseous and/or toxic solid by-products (switching powder) are formed when the gas is subjected to very high temperatures, typically above 500°C. Decomposition may occur if there is an electric arc, spark or other electrical discharge within it. The quantity of SF₆ decomposition products within an item of equipment depends on the cumulative arc energy that has been supplied to it. A load-break switch is likely to contain much smaller quantities of decomposition products than a high breaking-capacity circuit breaker with a history of frequent fault clearances.

If present in high concentrations (greater than 19%), SF₆ gas presents a risk of asphyxiation. Mixing of SF₆ with air by convection and diffusion is slow. However, the gases, once mixed, will not separate under normal conditions.

SF₆ is a highly stable synthetic gas, which has excellent dielectric properties and arc quenching capabilities. Therefore, SF₆ is used extensively in electrical equipment.

5.2 Safety

5.2.1 SF₆ gas leakage

The SF₆ gas content in switchgear and equipment depends on their design. Typically, an SF₆ circuit breaker will contain about 15-20kg of gas, while a typical GIS installation will contain about 4,000kg of SF₆.

When a leak occurs, SF₆ gas may accumulate in cable ducts, basements or other low-lying areas. This could present a danger of asphyxiation due to oxygen deficiency. In the event of a leak, low-lying areas must be well ventilated or breathing apparatus must be worn prior to entering these areas (refer to clause 5.2.5).

Any person present in a building at the time of a major SF₆ gas leak (catastrophic failure of SF₆ equipment or an audible gas leak) must evacuate the building immediately. It is not possible to detect new or clean SF₆ gas by smell because it is completely odourless; however, SF₆ that has been subjected to electrical arcing or discharge (decomposed SF₆) has a very strong, distinctive odour. The smell is similar to hydrogen sulphide (H₂S) and is usually like that of rotten eggs.

Upon arrival at a building where it is suspected that there is a possibility that a major internal SF₆ filled equipment fault has occurred, or upon opening the access door, if there is a strong unpleasant odour, no attempt must be made to enter unless an approved respirator is being worn and additional ventilation has been provided such that gas concentrations fall to acceptable values (refer to clause 5.2.2).

Further indication of a significant concentration of decomposed SF₆ in air is irritation of the upper respiratory tract and eyes.

When a major fault has occurred in outdoor SF₆ filled equipment, the area must be approached with caution. If there is any evidence of SF₆ decomposition products, employees and/or contractors must keep clear, remain upwind of equipment and keep other personnel clear of the affected area. The System Operator must be immediately advised of any suspected major SF₆ leaks or evidence of SF₆ solid decomposition products (*switching powder*).

5.2.2 SF₆ gas concentration limits

The allowable concentrations vary significantly due to the toxic gases that may occur after there is an electric arc, spark or other electrical discharge within the equipment. Toxicity estimations should take into account the concentration of each by-product in relation to the permissible concentrations for the appropriate exposure time.

Whenever there is a possibility that either new or used SF₆ being released to a work area, a calibrated SF₆ detector capable of detecting SF₆ and its by-products must be used in the working environment. A SF₆ detector with a sensitivity of 10 µ L/L (10 ppmv) is recommended.

When a leakage situation is encountered, the OEL (Occupational Exposure Limit) concentration, defined as TWA (Time Weighted Average over an 8 h per day, 40 h per week exposure limit), should be used to analysis exposure limits of SF₆ and decomposed by-products.

Under abnormal conditions e.g. internal arc fault, personnel immediately leave the room of the electric power equipment and the exposure is hence momentary. Under those conditions, the definition of allowable concentrations are:

- C (Ceiling exposure limit) – values never to be exceeded; and
- STEL (Short Term Exposure Limit) – an average exposure of 15 min that should not be exceeded during the 8 hours working time. To be used if a Ceiling Limit is not defined.

The following exposure limits, from AS 62271.4:2015, should not be exceeded when working with SF₆:

Table 1: OELs for SF₆, SO₂, HF, and S₂F₁₀

OEL	SF ₆	SO ₂ ¹	HF ²	S ₂ F ₁₀ ²
Time Weighted Avg (µ L/L)	1,000	2	0.5	Not defined
Short Term Exposure Limit (µ L/L)	Not defined	5	Not defined	Not defined
Ceiling (µ L/L)	Not defined	Not defined	2	0.01
NOTE 1 If SO ₂ cannot be detected with existing equipment, a practical alternative is to limit SF ₆ exposure to less than 200 ppmv. 2 If HF or S ₂ F ₁₀ cannot be detected with existing equipment, a practical alternative is to limit SF ₆ exposure to less than 20 ppmv for working on equipment after fault or affected by an external fire.				

If these values are exceeded, the locations must be ventilated until the concentrations fall to acceptable values. If this cannot be achieved, respirators must be used in accordance with Section 5.2.5.

5.2.3 Pressurised equipment, tools and measuring devices

Equipment and tools used during SF₆ handling potentially contain gaseous/liquid SF₆ under high pressure.

As is the case with any pressurised gas, a sudden escape of SF₆ gives rise to a local drop in temperature and may result in freezing, particularly on metallic items.

Pressurised items must be handled with extreme caution and filling of equipment will be performed slowly and carefully.

5.2.4 Employee training

All work involving SF₆ handling (manufacturing, testing, erection, commissioning, maintenance, service, and dismantling at the end-of-life) must be performed by trained employees and/or contractors or under the supervision of trained employees and/or contractors.

Employees must be aware of the danger of asphyxiation and be familiar with the properties of SF₆ decomposition products and the risks to health.

5.2.5 SF₆ safety measures

The general safety measures for working with SF₆ switchgear are listed in the following table:

Item	Work in the vicinity of switchgear (operation of SF ₆ -switchgear, visual check, room cleaning)	Filling, recovering of SF ₆ gas compartments	Opening of SF ₆ gas compartments, work on open compartments
SF ₆ material safety data sheet/operational manuals	Not required	Mandatory	Mandatory
Training	Mandatory [note]	Mandatory	Mandatory
Gas handling equipment	Not required	Mandatory	Mandatory
Cleaning/neutralising equipment	Not required	Not required	Mandatory
Personal protection equipment	Not required	Not required	Mandatory
Flames	N/A	Not permitted	Not permitted
Welding/smoking	N/A	Not permitted	Not permitted
Drinking/eating	Permitted	Permitted	Not permitted
Note: General information must be provided according to type of work and installation.			

Additionally, Table B.2 from AS 62271.4:2015 gives an overview of the potential risks, safety precautions as well as safety equipment and tools required when opening or entering a gas compartment.

Item	Any compartment which contained normally or heavily arced SF ₆	Any compartment which contained non-arc'd SF ₆
Potential risk	- Fumes of cleaning substances - O₂ starvation - Remaining used SF₆ - Residual reactive gaseous by-products - Solid by-products and adsorber materials	- Fumes of cleaning substances - O₂ starvation - Remaining used SF₆ or other gas from production process
Safety precaution	- Removal of solid by-products and adsorber materials - Ventilation - Measurement of O₂ concentration when	- Ventilation - Measurement of O₂ concentration before entering

Item	Any compartment which contained normally or heavily arced SF ₆	Any compartment which contained non-arc'd SF ₆
	entering • Wear personal protective equipment • Protect solid by-products against hydrolysis	
Safety equipment and tools	• Suction ventilator or vacuum cleaner • O₂ concentration measuring device • Single use protective overalls, protective footwear, hair cap • Acid proof safety gloves • Full face mask (preferred) or, at least, breathing protective mask • Protective goggles • Environmental protection against rain or wind (outdoor only)	• Suction ventilator or vacuum cleaner • O₂ concentration measuring device

5.2.5.1 Respiratory – PPE

The choice of suitable equipment for protection of the respiratory tract will depend upon the situation as follows (reference will be made to clause 5.2.2 for the allowable SF₆ concentration limits and the requirements for using SF₆ detection equipment):

- no specific respiratory tract equipment is usually required for operations involving only the topping up of an enclosure with SF₆ gas, apart from detection equipment, which may be used for checking the condition of the working atmosphere;
- for short-term inspection and work where ventilation can be provided but where the concentration of used SF₆ may exceed the appropriate maximum concentration limits, a facemask with cartridge filter is usually required; and
- for work in an enclosed area where decomposed SF₆ has been discharged, or inside an SF₆ enclosure, a full-face mask respirator with air supply according to European Standard EN 136 or equivalent must be used.

5.2.5.2 Sundry – PPE

PPE requirements for the specific tasks shall be assessed through Endeavour Energy's risk assessment processes (e.g. safe work method statement, job hazard analysis etc). The following PPE, or others as deemed necessary by the work teams, may be used where risk assessments determine it to be required. Equipment selection will depend on the nature of the installation, the work to be carried out, and the quantity of SF₆ gas involved, as well as the degree of decomposition of the SF₆ gas:

- pocketless, hooded, non-permeable disposable industrial grade overalls having elastic ankle and wrist grips, overlapping the footwear and gloves;
- protective footwear;
- protective liquid tight gloves, resistant to solvents and acids. In addition to protective gloves, the use of protective creams is recommended;
- chemical grade industrial goggles for protection against gas and fine dust;
- equipment and visible instructions for first aid treatment;
- equipment for forced ventilation;

- a high efficiency dedicated vacuum cleaner for SF₆ use only, equipped with a filter capable of trapping particles in the micron range, and a non-metallic open-ended nozzle; and
- a notice stating that open fire, smoking, heating to more than 200°C and welding (without special precautions) are prohibited.

5.2.6 Personal hygiene

High standards of personal hygiene are mandatory for employees and/or contractors engaged in work that involves SF₆ decomposition products.

The following personal hygiene requirements must be adhered to:

- no eating, drinking or smoking;
- employees and/or contractors must clean themselves and equipment, using disposable materials, before leaving the work area; and
- protective clothing must be removed and washed thoroughly in accordance with clause 5.4.4 as soon as possible after leaving the work area.

5.3 SF₆ handling

5.3.1 General

SF₆ gas in electrical equipment must be used and handled in accordance with the recommendations contained in AS 62271.4:2015. SF₆ gas losses into the atmosphere must be avoided and the gas must be handled in a closed cycle, to avoid any deliberate release to the environment.

The safety requirements of section 5.2 must be followed when employees and/or contractors are working on or around an installation where SF₆ is handled.

The need to handle SF₆ arises when:

- Filling new SF₆ equipment;
- topping up of SF₆ to rated filling pressure / density;
- transferring SF₆ between vessels (bottles/other);
- the gas has to be recovered or reclaimed from an enclosure or bottle to allow maintenance or repairs due to abnormal release;
- the gas has to be removed at the end of the life of an item of equipment;
- testing gas quality, such as moisture and gas mixture; and,
- various stocktake/procurement activities.

Commercially available gas recovery units, specially designed for use with SF₆, must be used to recover and store SF₆ in cylinders. Such units must be capable of recovering at least 99.9% of gas from the equipment. Reference will be made to the gas recovery equipment manufacturer's instructions prior to use.

The hoses used must not collapse under vacuum. Connectors used in hoses must be of self-sealing design, capable of withstanding a vacuum. Prior to storing, a vacuum must be applied to the hose so that all SF₆ gas trapped in the hose is extracted.

In order to track the leak rate of equipment, the weight of all SF₆ used for topping up equipment must be accurately recorded. SF₆ gas bottles shall be weighed prior to, and after, the top-up of equipment and the values logged against the bottle number and against the equipment.

The Endeavour Energy SF₆ data collection application shall be used for logging all data associated with handling, testing, or use of SF₆.

Where large/unweighable bottles are used by contractors when first filling/commissioning large SF₆ mass equipment, the contractor shall provide a report detailing accurately the mass installed in the GIS switchgear (to the nearest 0.1kgs).

5.3.2 Removal

When SF₆ has to be removed from an enclosure in an indoor installation, it is necessary that the concentrations of potentially toxic decomposition products remain at safe levels in the working area by measuring the concentration of SF₆ gas and by-products. This measurement must be made whenever there is a possibility that used SF₆ has been released into the work area (refer to clause 5.2.2).

Recovered gas must be tested in accordance to the limits listed in Substation Design Instruction SDI 545 – Acceptable purity limits for SF₆ gas, before reuse. If the gas does not meet these limits, it must be reclaimed using appropriate equipment and recycled through approved contractors.

The procedure for the removal of SF₆ gas from gas-filled chambers is detailed in Annexure 1 – Procedures for handling SF₆ below.

Where the equipment gas containment system is of a 'Sealed Pressure System' type (e.g. a gas enclosure that does not have gaskets, gauges, valves, or other facilities to access, measure, or top up gas levels) then Endeavour Energy does not have internal facilities to extract gas from the assets. In such cases, the gas shall be extracted by a qualified contractor during asset disposal. All contractors that dispose of SF₆ gas on behalf of Endeavour Energy shall provide a report detailing accurately the mass of SF₆ recovered from the asset (to the nearest 0.1kgs), once asset disposal is completed. It is the responsibility of the Disposal Management to log SF₆ data from such reports using the Endeavour Energy SF₆ data handling collection application.

5.3.3 Enclosure opening and entering

Manufacturers' instructions must be followed for maintenance, extension or repair and precautions taken to address the following:

- at least 99.9% of the SF₆ must be recovered from the equipment when it is being emptied. An approved SF₆ recovery unit must be used for this purpose. This is subject to exclusions in Section 5.3.4 – Evacuation.
- employees and/or contractors are adequately protected from the effects of any remaining SF₆ and associated SF₆ decomposition products.
- when opening or entering enclosures outdoors, wind could cause solid SF₆ decomposition products (*switching powder*) to be blown away before they can be removed with a vacuum cleaner. Therefore, steps must be taken to prevent this from occurring.
- rain or high ambient humidity will accelerate hydrolysis of certain solid decomposition products, resulting in the production of hydrofluoric acid. Therefore, any solid decomposition products must be removed immediately after the equipment is opened.
- indoor installations must be provided with adequate ventilation such that the SF₆ concentration levels do not exceed the OEL specified in section 5.2.2.

The procedure for opening and entering SF₆ filled chambers is detailed in Annexure 1 – Procedures for handling SF₆ below.

5.3.4 Evacuation

Prior to filling the circuit breaker chamber with SF₆ gas, the chamber needs to be evacuated of impurities such as moisture and gases other than SF₆ (typically air or N₂). This is done by sustaining a vacuum pressure to lower than 2 kPa (0.29psi) for at least 1 hour.

To optimise the evacuation process, it is recommended that a vacuum pump with a residual pressure at the inlet lower than 10 Pa (0.0015 psi) is used. Additionally, the connection diameter is important as a larger diameter connection valve will allow the pump to achieve rated vacuum more quickly, expediting the evacuation process.

For the vacuum pump gauge, it is recommended that the resolution of the gauge is less than 10 Pa (0.0015 psi) is used for accurate readings. The minimum allowable resolution on the vacuum pressure gauge is 100 Pa (0.015 psi).

If these specifications for evacuating SF₆ cannot be met due to the design of the switchgear, alternative procedures may be used subject to approval from the Head of Asset Planning and Performance

5.3.5 Filling

Before filling with new or reclaimed gas, the inserted gas must comply with the limits in Substation Design Instruction SDI 545 – Acceptable purity limits for SF₆ gas. Gas with unacceptable levels of impurities must not be used to fill electrical equipment. For pressurised gas compartments, the gas must be filled to the recommended gas density specified by the manufacturer. Filling of equipment with SF₆, using either manual or automated systems, always must be closely monitored to avoid over-filling of equipment or accidental leakage of SF₆ from hose connectors to the atmosphere.

The gas density value must comply with the manufacturer's recommendations. When filling electrical equipment with SF₆, there must be:

- devices to monitor the gas pressure or the density in the equipment;
- a pressure-reducing regulator and an adjustable over pressure relief device connected to the low pressure output line; and
- an isolating valve for turning off the flow of gas immediately.

The procedure for filling SF₆ filled chambers is detailed in Annexure 1 – Procedures for handling SF₆ below.

5.3.6 Gas quality testing

The measurement of the SF₆ quality is usually done on-site, using portable equipment. Off-site analysis may exceptionally be performed to cross-check unsatisfactory on-site results, by sampling the gas and sending it to a qualified chemical laboratory.

The allowable limits for new, reclaimed and in-service SF₆ gas quality are contained in SDI545.

The total reactive gaseous by-products must be checked first to prevent damage of other portable equipment, if the history of the gas-filled compartment is unknown.

The procedure for testing gas quality in SF₆ filled chambers is detailed in Annexure 1 – Procedures for handling SF₆ below.

The Endeavour Energy SF₆ data collection application shall be used for logging SF₆ test results.

5.3.7 *Storage and transportation*

Storage containers/cylinders must be handled carefully and stored with their outlet valves upwards in a cool, dry, well-ventilated area away from flammable or explosive material. They must be protected from direct sunlight, mounted clear of wet ground and secured to prevent falling over.

Storage containers/cylinders must comply with the local pressure vessel regulations and must be clearly labelled in compliance with the regulations to identify their contents. Storage containers/cylinders containing new gas must be physically separated from those containing used gas.

As with any pressurised gas, there is a risk of explosion of cylinders if they are excessively heated or subjected to a fire.

SF₆ storage containers/cylinders must be stored indoors in a well ventilated area. Transportation of SF₆ within NSW must be performed according to the Australian Code for the Transport of Dangerous Goods by Road & Rail.

The procedures given in the material safety data sheet (MSDS) must be strictly followed.

5.4 Treatment and neutralisation

5.4.1 *General*

SF₆ solid decomposition products and items that have been in contact with SF₆ decomposition products must be treated so that they can be handled, recycled, or disposed of as normal waste. All physical traces of the powder must be dissolved by the neutralising solution.

During treatment, care must be taken to avoid contact with SF₆ solid decomposition products (*switching powder*) and cleaning fluids. Appropriate PPE must be worn (refer to clause 5.2.5). Safety equipment/tools and other items that have been in contact with SF₆ decomposition products and/or absorbers and the like, must be considered as contaminated and neutralised immediately after use.

Where neutralisation treatment cannot be carried out immediately, contaminated items must be collected and placed in approved plastic disposal bags or containers. The plastic bags or containers must be sealed and labelled.

5.4.2 *Neutralising solution*

The neutralisation solution must be sufficiently alkaline during the neutralisation process to effectively neutralise acidic residues. Sodium carbonate/water solution made up of 3kg of sodium carbonate dissolved in 100 litres of water is recommended as the neutralising solution.

Each item requiring soaking must be soaked in this solution for a minimum of one (1) hour. The solution must be regularly monitored and additional sodium carbonate added during the process to maintain that a pH of greater than seven. When using alkaline solutions, care must be taken to avoid contact with skin and eyes. Suitable PPE must be worn at all times.

If skin is to be washed, a sodium bicarbonate/water solution made up of 1kg of sodium bicarbonate dissolved in 100 litres of water is recommended.

5.4.3 Gas enclosure, parts and SF₆ decomposition products

The minimum requirements for treating SF₆ decomposition products, gas enclosures and parts are given below:

a) Low decomposition - no visible powder deposit:

No special action is required.

b) Medium/high decomposition - visible powder deposit:

Enclosures must be filled (if possible) and parts and SF₆ decomposition products must be soaked with neutralising solution. The neutralising solution must then be removed and the enclosure/container rinsed with water. Alternatively, all interior surfaces may be washed thoroughly with a neutralising solution and rinsed with clean water.

For larger enclosures, the loose solid SF₆ by-products may be removed prior to neutralisation using a vacuum cleaner, clearly marked for *SF₆ use only*, fitted with a suitable filter.

5.4.4 Tools, safety equipment and clothing

It is preferable that tools and clothing, including footwear, are reserved for working with SF₆ gas and its associated decomposition products.

After usage, safety equipment and/or tools must be washed in neutralising solution then rinsed with clean water. Items not suitable for washing must be wiped free of visible contamination using rags or clean paper tissues, and wiped over with a rag moistened in neutralising solution. Items of reusable protective clothing may be laundered. However, if clothing is considered contaminated, it must be washed in a neutralising solution and then rinsed in clean water, before laundering in the usual manner.

5.4.5 Miscellaneous items

Miscellaneous items, such as contaminated rags and tissues, must be soaked in neutralising solution prior to disposal (refer to section 5.5).

5.5 Disposal

Refer to Company Procedure (Procurement & Logistics) GSU 0012 – Selection and approval of disposal method when selecting an appropriate disposal method.

This section applies to disposal of equipment that once contained SF₆ gas. Removal of SF₆ gas shall be completed in accordance with Section 5.3.2. All gas shall be removed from an asset prior to disposal. Note that disposal contractors may be capable of both gas extraction and asset disposal, in which case a report shall be provided detailing accurately the mass of SF₆ recovered from the asset (to the nearest 0.1kgs), once asset disposal is completed. It is the responsibility of Disposal Management to log SF₆ data from such reports using the Endeavour Energy SF₆ data handling collection application.

All neutralised items, such as equipment parts, absorbent materials, disposable clothing, vacuum cleaner bags and rags and the like that require disposal, can be disposed of in the usual manner as solid waste, or recycled as scrap metal.

The neutralising solution must be pH neutral at the end of the process to allow it and the associated rinsing water to be disposed of according to local regulations.

Recovered SF₆ gas contained within cylinders can be recycled. To arrange recycling of SF₆ gas, complete FSU0025 – Disposal Checklist and send to it to the Disposal Management mailbox (Disposal.Management@endeavourenergy.com.au).

6.0 AUTHORITIES AND RESPONSIBILITIES

Head of Asset Planning & Performance has the authority and responsibility for approving this instruction.

Asset Performance Manager has the authority and responsibility for making recommendations to the Head of Asset Planning & Performance in respect to this instruction.

Lead Maintenance Engineer has the authority and responsibility for updating this instruction.

Endeavour Energy employees and/or contractors have the authority and responsibility for:

- meeting the requirements of this instruction and Substation Maintenance Instruction SMI 100 – Minimum requirements for maintenance of transmission and zone substation equipment;
- overseeing that all employees and/or contractors comply with the requirements of this instruction;
- following guidelines for proper use, transportation, storage and disposal of equipment, gas and SF₆ decomposition products and other items associated with the work;
- working in accordance with local and statutory requirements;
- maintaining public safety; and
- working in accordance with Endeavour Energy's Electrical Safety Rules.

Endeavour Energy project managers/regional transmission managers have the authority and responsibility for:

- overseeing employees and/or contractors engaged to perform the work have appropriate training and qualifications;
- providing appropriate PPE and monitoring equipment to employees and/or contractors working on SF₆ equipment; and
- entering appropriate equipment details into the **relevant** database as part of the work.

7.0 DOCUMENT CONTROL

Documentation Content Coordinator : Asset Performance Manager

Documentation Distribution Coordinator : Branch Process Coordinator

Annexure 1 – SF₆ Handling Procedures

(adapted from AS 62271.4:2015 & aligned with Endeavour Energy's SF₆ data collection application)

Note: where the Endeavour Energy's SF₆ data collection application is not available at the time of SF₆ handling or use, written data records/logs shall be maintained and uploaded to the relevant database by the technician within 5 business days of the activity.

It is the responsibility of the leading hand and their manager to ensure adequate records are taken and maintained.

EE's SF₆ data collection requirements and process(es) built into the SF₆ data collection application are deemed to satisfy the AS 62271.4 data recording requirements.

SF₆ Handling Procedures for the following scenarios are detailed below:

- 1) Air evacuation, filling and checking SF₆ quality after recovery of SF₆ gas
- 2) Topping-up of SF₆ compartments to the rated filling pressure/density
- 3) Testing SF₆ gas quality on-site
- 4) SF₆ recovery and reclamation

Air evacuation, filling and checking SF₆ quality after recovery of SF₆ gas

This process is applicable to SF₆ compartments that 'at the time' contain a gas other than SF₆.

Step		Procedure
1	Prepare SF ₆ handling equipment	Check that the gas connections are clean and dry, hoses are evacuated and no leaks on connection fittings exist to avoid contamination. Check the validity of the calibration of instruments subject to calibration.
2	Adsorber installation	Quickly insert the adsorber materials in the compartment. Start evacuation immediately afterwards.
3	Evacuation	Connect the vacuum pump and leave it running to reach 2 kPa.
4	Vacuum stabilisation phase	Leave the vacuum pump running for at least 1 hour after reaching 2 kPa and then disconnect the vacuum pump by closing the valve. Read the pressure gauge. ^a
5	Vacuum holding phase (optional)	If the gas quality test for this compartment indicates high moisture or there is evidence of absorbed moisture in the internal components (such as epoxy resin insulators), then the Network Maintenance Manager must be consulted to extend the vacuum duration. Typically 24hrs is deemed suitable, however may extend further.
6	Documentation	The SF ₆ source vessel/bottle shall be weighed prior to filling. The bottle ID, SAP reference for equipment to be filled, date, location, and the pre-filling bottle weight shall be recorded as a minimum.
7	Filling with SF ₆	Connect the SF ₆ container and fill the compartment until the SF ₆ rated filling pressure is reached. Use a safety valve, a regulator to allow a good control of the filling process and a calibrated gauge to avoid overfilling. ^{b c}
8	Documentation	The SF ₆ source vessel/bottle shall be weighed after filling. The bottle ID, SAP reference for equipment filled, date, location, and the post fill bottle weight shall be recorded as a minimum.
9	Pressure/density sensor inspection	Check the functionality of the pressure/density sensor. The operation can be performed during the filling operation and must not be considered as a calibration.
10	Tightness inspection	Check the tightness of at least all permanent connections made on site.
11	SF ₆ quality checking	Wait for at least 12 hours before measuring the moisture content and the SF ₆ purity.
12	Documentation	The SF ₆ purity test results shall be recorded. The bottle ID, SAP reference for equipment containing the gas, date, location, and all purity results as required by SDI0545 shall be recorded as a minimum.

^a SF₆ to be introduced into the gas compartment must comply with the limits contained in SDI 545 – Acceptable purity limits for SF₆ gas.

^b No SF₆ check is required if the gas comes from the supplier in sealed containers, or if the gas is stored in sealed containers with an appropriate label or certificate that it meets the purity limits contained in SDI 545. In all other cases, the SF₆ quality may be checked prior to the filling operation (see Section 5.3.5).

^c If the gas compartment has a small volume, re-filling after SF₆ quality checking may be required.

Topping-up of SF₆ compartments to the rated filling pressure/density

Step		Procedure
1	Documentation	The SF ₆ source vessel/bottle shall be weighed prior to filling. The bottle ID, SAP reference for equipment to be filled, date, location, and the pre-filling bottle weight shall be recorded as a minimum.
2	Prepare SF ₆ handling equipment	Check that the gas connections are clean and dry, hoses are evacuated and no leaks on connection fittings exist to avoid contamination. Check the validity of the calibration of instruments subject to calibration.
3	Topping-up with SF ₆	Connect the SF ₆ container and fill the compartment until the SF ₆ rated filling pressure is reached. Use a safety valve, a regulator to allow a good control of the filling process and a calibrated gauge to avoid overfilling. ^{a b}
4	Documentation	The SF ₆ source vessel/bottle shall be weighed after filling. The bottle ID, SAP reference for equipment filled, date, location, and the post fill bottle weight shall be recorded as a minimum.
5	Pressure/density sensor inspection	Check the functionality of the pressure/density sensor. The operation can be performed during the filling operation and must not be considered as a calibration.
6	Tightness inspection	Check the tightness of at least all permanent connections made on site.
7	SF ₆ quality checking	Wait for at least 12 hours before measuring the moisture content and the SF ₆ percentage. ^{c d}
8	Documentation	The SF ₆ purity test results shall be recorded. The bottle ID, SAP reference for equipment containing the gas, date, location, and all purity results as required by SDI0545 shall be recorded as a minimum.
^a SF₆ to be introduced into the gas compartment must comply with the limits contained in SDI 545 – Acceptable purity limits for SF₆ gas. ^b No SF₆ check is required if the gas comes from the supplier in sealed containers, or if the gas is stored in sealed containers with an appropriate label or certificate that it meets the purity requirements of SDI 545. In all other cases, the SF₆ quality may be checked prior to the filling operation (see Section 5.3.5). ^c If the amount of SF₆ used for re-filling is very small in comparison to the amount of SF₆ in the related compartment, it is not necessary to perform a SF₆ quality check after the re-filling operation. ^d If the gas compartment has a small volume, re-filling after SF₆ quality checking may be required.		

Testing SF₆ gas quality on-site

Step		Procedure
1	Prepare gas quality tester	Check that the test equipment is working properly, the ambient conditions are within the working range, e.g. temperature, the gas connections are clean and dry, hoses are evacuated and no leaks on connection fittings exist to avoid any false measurements. Check the validity of the calibration of instruments subject to calibration. Use short connections to minimise SF ₆ release.
2	Connect the gas quality tester	Connect the gas quality tester. Make tight connections and establish gas flow. ^b
3	Take gas quality readings	Operate the gas quality tester and obtain gas quality results.
4	Documentation	The SF ₆ purity test results shall be recorded. The bottle ID, SAP reference for equipment containing the gas, date, location, and all purity results as required by SDI0545 shall be recorded as a minimum.
5	Disconnect the portable equipment	Stop the gas flow and disconnect the portable equipment. ^c
^a Sampled SF ₆ should be recovered or pumped back into the gas filled compartment. ^b If the gas compartment has a small volume, re-filling after SF ₆ quality checking may be required.		

SF₆ recovery and reclamation

Step		Procedure
1	Documentation	The SF ₆ receiver vessel/bottle shall be weighed prior to filling. The bottle ID, SAP reference for equipment undergoing gas recovery, date, location, and the pre-extraction bottle weight shall be recorded as a minimum.
2	Prepare SF ₆ handling equipment	Check that the SF ₆ handling equipment is properly working, the filters and pre-filters are still active and connected, and the gas connections are clean and dry, hoses are evacuated and no leaks on connection fittings exist to avoid contamination. Check the capacity and the condition of the storage containers are compatible with the gas compartments to be reclaimed. Check the validity of the calibration of instruments subject to calibration.
3	Connect external pre-filters (optional step)	Connect one or multiple external pre-filters between the gas-filled compartment and the inlet of the SF ₆ handling equipment.
4	SF ₆ recovery	Connect the gas-filled compartment. Use the main compressor stage as soon as the SF ₆ residual pressure in the compartment approaches the pressure in the storage container. Use a safety valve and a calibrated gauge to avoid overfilling of the storage container. ^a
5	Minimise residual SF ₆ content	Connect the auxiliary compressor stage when the SF ₆ residual pressure in the compartment approaches 100 kPa and leave it running until a pressure lower than 2 kPa is reached.
6	Documentation	The SF ₆ receiver vessel/bottle shall be weighed post filling. The bottle ID, SAP reference for equipment undergoing gas recovery, date, location, and the post-extraction bottle weight shall be recorded as a minimum.
7	Flood with dry air	Disconnect the compressor and let the air enter slowly into the gas compartment. ^b
8	Settling down of solid by-products (for compartments containing heavily arced SF ₆ gas)	Wait at least 1h to give enough time for the remaining solid by-products to settle down in the gas compartment.
9	Open the gas compartment	Comply with safety rules outlined in Section 5.3. Carefully open the gas compartment.
10	Remove solid by-products and adsorbers when present	Immediately use vacuum cleaner or wipe with a clean lint free rag to collect the solid by-products, if present. Place adsorber materials in a plastic bag. Seal the plastic bag with tape and tag it.
11	Neutralisation, if required	If solid by-products were collected, use 10 % by weight soda solution or equivalent to wash and neutralise all parts and then wash with clean water.
^a In case of liquid storage the weight of the storage container is controlled in order to avoid overfilling. The filling factor is smaller than 0,8 kg/L for safety reasons. ^b Dry air or N ₂ from the bottle may be introduced in the compartment to reduce moisture contamination.		