Guidelines – Sulphur Hexafluoride Management

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**   Shall be the Process Owner and is the person assigned authority and responsibility for managing the whole process, end-to-end, which may extend across more than one division and/or functions, in order to deliver agreed business results.*

***   This person will have the power to grant the process owner the authority and responsibility to manage the process from end to end.*

**** Frequency period is dependent upon circumstances– maximum is 5 years from last issue, review, or revision whichever is the latest. If left blank, the default shall be 1 year unless otherwise specified.*

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Revision	**Date**	**Description**
0	11/04/2016	Original issue

STAKEHOLDERS *The following positions shall be consulted if an update or review is required:*	
Manager Engineering & Project Services	Regional Asset Managers
Manager Capacity Management Services	Manager Asset Management Services
Manager Health and Safety	Manager Land, Environment, Native Title & Heritage
Field Practices Coordinator	Technical Training Coordinator

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1 PURPOSE

This guideline exists as a reference for the responsible management of the insulation gas sulphur hexafluoride (SF_6). SF_6 is an inert gas, but decomposed components (as a result of electrical arcing or naked flames) are toxic and hazardous. It therefore warrants methodical and careful handling.

Sulphur hexafluoride is a greenhouse gas, and wilful venting to the atmosphere is illegal (refer to Section 9). Horizon Power has a legal duty to report use and leakage.

2 APPLICATION

This guideline is intended for Horizon Power staff and their nominated representatives involved with the specification, procurement, installation, commissioning, maintenance and decommissioning of SF_6 equipment. SF_6-filled equipment and cylinders should be managed and tracked in accordance with this guideline.

It also applies to Horizon Power staff and their nominated representatives involved with the transport of SF_6 (for refilling or other purposes), and any operations such as leak detection and clean-up.

Field personnel should also refer to the FIM, FI 4.14 [3], which describes the minimum requirements for safe handling, storage, maintenance, repair, transport and disposal of equipment containing SF_6 gas.

3 NORMATIVE REFERENCES

3.1 Referenced Documents (Horizon Power)

[1]. *Environmental Procedure 03 Waste Management*, CS10# 2195833, draft at the time of writing this document

[2]. *Environmental Procedure 04 Liquid Chemical Storage and Handling*, CS10# 1900645, draft at the time of writing this document

[3]. *Field Instruction 4.14 - Storage, Handling, Transport and Disposal of Sulphur Hexafluoride (SF_6) Gas*, CS10 2353174

[4]. *Risk Management Framework*, CS10# 2760190 available from http://powerlink/our-structure/corporate/legal-and-risk/risk/Pages/default.aspx

[5]. *Specification – Technical Requirements for Distribution Reclosers (HPC-8DJ-07-0003-2014)*, CS10# 2927702, available from http://horizonpower.com.au/contractors-suppliers/contractors/manuals-and-standards/ under the *Specifications* tab

[6]. *Specification – Technical Requirements for Ring Main Units (RMU) (HPC-8DJ-14-0001-2013)*, CS10# 1911746, available from http://horizonpower.com.au/contractors-suppliers/contractors/manuals-and-standards/ under the *Specifications* tab

3.2 Referenced Documents (Other)

[7]. *AS/NZS 1716/2012 Respiratory protective devices*, Standards Australia, available from SAI global http://www.saiglobal.com/

[8]. *AS/NZS 60335.2.69:2003 Household and similar electrical appliances—Safety Part 2.69*: Particular requirements for wet and dry vacuum cleaners, including power brush, for industrial and commercial use, Standards Australia, available from SAI global http://www.saiglobal.com/

[9]. *AS 62271.1:2012 High-voltage switchgear and controlgear Part 1: Common specifications*, Standards Australia, available from SAI global http://www.saiglobal.com/

[10]. *AS IEC 62271.4:2015 High-voltage switchgear and controlgear Part 4: Handling procedures for sulphur hexafluoride (SF_6) and its mixtures*, Standards Australia, available from SAI global http://www.saiglobal.com/

[11]. *AS/NZS 2791:1996 High-voltage switchgear and controlgear—Use and handling of sulphur hexafluoride (SF_6) in high-voltage switchgear and controlgear*, Standards Australia, available from SAI global http://www.saiglobal.com/

[12]. *Australian Code for the Transport of Dangerous Goods by Road & Rail*, also known as the *Australian Dangerous Goods Code*, published by the National Transport Commission, edition 7.3, August 2014, available from http://www.ntc.gov.au/heavy-vehicles/safety/australian-dangerous-goods-code/

[13]. *BS EN 136:1998 Respiratory protective devices. Full face masks. Requirements, testing, marking,* British Standards Institution, available from SAI global http://www.saiglobal.com/

[14]. *ENA DOC 022-2008 ENA Industry Guideline for SF_6 Management*, Energy Networks Association, available from SAI global http://www.saiglobal.com/

[15]. *IEC 60376:2005 Specification of technical grade sulfur hexafluoride (SF_6) for use in electrical equipment*, International Electrotechnical Commission, available from SAI global http://www.saiglobal.com/

[16]. *IEC 60480:2004 Guidelines for the checking and treatment of sulfur hexafluoride (SF_6) taken from electrical equipment and specification for its re-use*, International Electrotechnical Commission, available from SAI global http://www.saiglobal.com/

[17]. *Technical Guidelines for the Estimation Of Greenhouse Gas Emissions By Facilities In Australia* - National Greenhouse and Energy Reporting (Measurement) Determination 2008, Department of the Environment, Commonwealth of Australia, available from http://www.environment.gov.au/climate-change/greenhouse-gas-measurement/publications/nger-technical-guidelines-2014

3.3 Legislation

[18]. *Ozone Protection and Synthetic Greenhouse Gas (Import Levy) Act 1995*

[19]. *Ozone Protection and Synthetic Greenhouse Gas (Import Levy) Regulations 2004*

[20]. *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989*

[21]. *Ozone Protection and Synthetic Greenhouse Gas Management Regulations 1995*

[22]. *Environmental Protection (Unauthorised Discharges) Regulations 2004*, Environmental Protection Act 1986, Government of Western Australia

3.4 Definitions

Adsorber

A material to which a gas, liquid or dissolved solid will adhere to the surface of. Equipment chambers for SF_6 usually contain adsorbers to adsorb arced by-products.

Arced SF_6

SF_6 gas which has been subject to operations where breaking fault current.

CGA

Compressed Gas Association (CGA). Gas cylinder fittings used for attachments to gas cylinder valves. These carry the association name e.g. CGA 590.

DISS

Diameter Index Safety System (DISS), high integrity fittings used for attachments to gas cylinders. Compared to CGA fittings, they are for higher purity and higher integrity applications.

HF

Hydrofluoric (HF) acid, is a toxic breakdown product of SF_6. It is typically a gas, with a boiling point of approximately 19°C. Symptoms of exposure are delayed. Due to its high reactivity, it does not have a very long life. A detailed description of health affects is provided in Appendix B.

PPE

Personal Protective Equipment (PPE)

ppm wt

Parts per million (by weight). Also known as pmmm. Equivalent to mg/kg.

ppmv

Parts per million (by volume). Equivalent to µL/L.

SO_2

Sulphur dioxide (SO_2), a toxic breakdown product of SF_6. It is typically a gas (boiling point approximately -10°C). A detailed description of health affects is provided in Appendix B.

SOF_2

Thionyl fluoride (SOF_2), a toxic breakdown product of SF_6. It decomposes over time in the presence of moisture into SO_2 and HF. It is a colourless gas with a pungent odour (akin to rotten eggs), condensing at approximately -43°C. A detailed description of health affects is provided in Appendix B.

TLV

Threshold Limit Value (TLV), an exposure limit which all persons can safely tolerate. Unless stated otherwise, it indicates the 'time-weighted average' (TWA) daily exposure of eight hours (40 hour week). Other limits defined are a ceiling (not to be exceeded at any time), and short-term exposure limit (STEL), where exposure should not exceed 15 minutes.

4 INTRODUCTION

4.1 Physical Properties

SF_6 is very stable and inert, in normal conditions it does not react with other substances. It is colourless and odourless, and five-times heavier than air (under normal conditions). It slowly mixes with air by convection and diffusion, and once mixed, does not separate. As it does not react with other gasses, it has a very long life. Its density (at one atmosphere and 20°C) is approximately 6 kg/m^3.

When used in electrical equipment as an insulator, the normal pressure range is between 0.1 MPa and 0.9 MPa.

The threshold limit value (TLV, time-weighted average) for SF_6 is 1,000 ppmv (equivalent to 6,100 mg/m^3) [10].

4.2 Decomposition Process

SF_6 decomposes in the presence of certain metals above the temperature of 200°C, and will decompose on its own at temperatures above 500°C. Electrical arcing (through normal operations or interruption of fault currents) causes decomposition. Naked flames may also cause decomposition.

4.3 Decomposition Hazards

The main contributor to the toxicity of decomposed SF_6 is SOF_2 (thionyl fluoride), which can decompose to SO_2 (sulphur dioxide) and HF (hydrofluoric acid), both damaging to one's health. Health impacts are detailed in Appendix B.

4.4 Risk to Personnel

Where equipment suffers an internal fault, and gas is discharged into an equipment room, the likelihood of significant concentrations of toxic by-products warrants careful handling. In most other circumstances, including equipment leakage, the likelihood of toxic by-products being of sufficient concentration to harm personnel is very rare [10].

4.5 SF_6-filled Equipment

Equipment is to be classed according to three categories:

1) Controlled Pressure – replenishment of lost gas is done automatically from an internal or external gas source.
2) Closed Pressure – replenishment of lost gas is done manually.
3) Sealed Pressure – gas is 'sealed for life', and vessels are not opened during the operational life.

Sealed and closed pressure systems are by far the most common. Vessels are typically pressurised to between 0.1 and 0.3 MPa in HV equipment with operating voltages less than 52 kV, and between 0.3 and 0.9 MPa for equipment rated at higher voltages.

The quantity of SF_6 in equipment is usually stated in kg, and varies depending on the switchgear tank size. The quantity in ring main units varies from 2 to 5 kg. For gas-insulated switchgear, quantity is 4 to 6 kg per cubicle.

4.5.1 Monitoring of SF_6-filled Equipment

In line with Horizon Power's Asset Class Management Plans, SF_6 gas levels are to be recorded during routine equipment inspections. Where a trend of lowering SF_6 gas pressure is observed, the cause of the leak is to be investigated and rectified where possible, in accordance with the equipment manufacturer's instructions.

5 RISK MANAGEMENT

The following guidance is provided for use in managing risk around SF_6.

5.1 Consequences

Common hazards have been provided in Table 1, with consequences rated using the *Risk Management Framework* [4]. These hazards and ratings are provided as guidance only for the development of risk assessments. When assessing specific risks, the relevant hazards and their consequence rating should be reviewed.

Table 1 Hazards related to SF_6 Management

No.	Hazard	Consequence Rating
	Hazards Related to Toxic Chemicals	
H1	Hazardous concentration (exceeding TLV) of SF_6 toxic by-products (SOF_2, SO_2, and HF) causing injury or death	(5) Catastrophic (multiple fatalities)
H2	Hazardous concentration (exceeding TLV) of SF_6 causing injury through oxygen starvation	(5) Catastrophic (multiple fatalities)

No.	Hazard	Consequence Rating
	Hazards Related to Pressure	
H3	Rapid drop in temperature causing freezing and very cold surfaces, causing injury	(2) Minor (reversible disability or impairment)
H4	Over-pressurisation of vessel, catastrophic failure by explosion, causing injury or death	(5) Catastrophic (multiple fatalities)
H5	Overheating of vessel due to heat, causing catastrophic failure by explosion, causing injury or death	(5) Catastrophic (multiple fatalities)
	Hazards Related to Electricity	
H6	Equipment catastrophic failure (due to insufficient insulation), causing injury or death	(5) Catastrophic (multiple fatalities)
H7	Equipment failure (inoperable due to insufficient insulation), causing loss of electricity supply	Depends on equipment and redundancy

When reducing risk, the most effective means is the elimination of the hazard. This is impractical in most cases, since there is usually no alternative to SF_6-insulated switchgear. In some instances, management of the gas can be passed to specialist subcontractors. For example, a subcontractor that does SF_6 recycling may also do collection and transport of the gas cylinders.

5.2 Likelihood

Table 2 provides examples of risk events, and indicates likelihood. Likelihoods have been estimated using the *Risk Management Framework* [4]. These estimations are based on probability of the risk event, which may depend on several coincident events.

For several risks, control measures can reduce the likelihood. In many instances, reduction in likelihood may not be enough to warrant a different likelihood category. For example, a reduction of likelihood from 1 in 60 years to 1 in 200 years would not change the likelihood category from 'rare'.

Table 2 Risk Events and Indicative Likelihoods

Event	Related Hazard	Likelihood
Poisoning by toxic by-products from faulted equipment	H1 (toxic by-products)	If these guidelines are not followed: (4) Unlikely (one occurrence within 20 years) If these guidelines are followed: (5) Rare (one occurrence within 50 years)
Suffocation in presence of equipment or cylinders that have leaked	H2 (oxygen starvation)	If these guidelines are not followed: (5) Rare (one occurrence within 50 years) If these guidelines are followed: (5) Rare (one occurrence within 50 years)
Injury from contact with freezing surface, during filling or evacuating gas	H3 (freezing surface due to decompression)	If these guidelines are not followed: (2) Likely (one occurrence within 2 years) If these guidelines are followed: (5) Rare (one occurrence within 50 years)
Explosion when filling or evacuating gas from equipment	H4 (over-pressurisation)	If these guidelines are not followed: (5) Rare (one occurrence within 50 years) If these guidelines are followed: (5) Rare (one occurrence within 50 years)
Fire near SF_6 equipment or cylinders	H5 (over-heating of vessel)	If these guidelines are not followed: (4) Unlikely (one occurrence within 20 years) If these guidelines are followed: (5) Rare (one occurrence within 50 years)
Catastrophic circuit breaker failure due to leakage and insufficient gas harming operators	H6 (equipment fault due to insufficient insulation)	(4) Unlikely (one occurrence within 20 years), dependent on both equipment reliability
Circuit breaker fail (tripping upstream breakers) due to insufficient gas	H7 (loss of supply due to insufficient insulation)	(4) Unlikely (one occurrence within 20 years), dependent on both equipment reliability

For some risks, several events must coincide for the risk to occur. An example of this is provided in Appendix E.

6 PROCUREMENT

6.1 Licenses, Reporting Requirements and Import Levies

These requirements only apply where Horizon Power procure SF_6 cylinders or equipment from an overseas vendor.

A license is required to import equipment or cylinders containing SF_6. This is required by the *Ozone Protection and Synthetic Greenhouse Gas Management Act* [20]. The associated *Regulations* [21] allow the import of equipment without a license, provided the SF_6 contained in the equipment is less than 10 kg in total (clause 3.(6)).

Quarterly reporting is required for the import of SF_6 (clause 46A of the Act [20]) with the exception of equipment containing less than 10 kg of SF_6 as described above.

Where non-exempt equipment or cylinders are procured from overseas vendors, Horizon Power is liable to pay import duties under clause 3A of the *Ozone Protection and Synthetic Greenhouse Gas Import Levy Act* [18]. This sets the import levy at $165 per tonne of CO_2 equivalent. For every 1 kg of SF_6, the carbon dioxide equivalent is 23,900 tonnes, imposing an import levy of $3,940 per 1 kg of SF_6 [19].

6.2 Gas Cylinders

The quantity ordered should exceed the quantity required, as not all the gas contained in the cylinder can be used. Cylinders are pressurised at a higher pressure than equipment. As the quantity of gas in the cylinder is reduced (as it is used), the pressure drops. When the pressure in the cylinder approaches the pressure of the vessel being filled, the remaining gas cannot be transferred.

6.3 SF_6-filled Equipment

For closed pressure systems, the following activities should be considered:

- Requirement to fill equipment on site. Ideally equipment is filled in the factory.
- Requirement to top up on site. Ideally no top up is required on site.

For closed and sealed pressure systems, the prospective vendor should bundle recycling of the equipment and SF_6 with the product.

7 TRANSPORT AND STORAGE

7.1 SF_6-filled Equipment

Where equipment has in-built pressure meters, these should be checked at each stage of transport. Equipment should be transported as per Horizon Power policy for that item, and manufacturer's instructions.

7.2 SF_6 Cylinders

a) Cylinders containing **new or recycled** SF_6 gas are coloured green, brown or dark blue. Cylinders containing **used** SF_6 gas are coloured yellow, as this indicates toxicity. Cylinders should not be coloured red, white, bright blue or black.

b) Cylinders are typically supplied with SF_6 pressurised to liquid (2.2 MPa). The vendor should state a maximum ambient temperature for storage, and this should be complied with. Cylinders carry a risk of explosion if subjected to intense heat (as for any pressurised gas).

c) Cylinders should be shielded from solar radiation or other sources of heat, and stored away from any flammable or explosive material. Cylinders containing used SF_6 should be stored separately from those containing new gas.

d) Cylinders should be stored with their outlet valves upwards, to minimise the chance of damaging the valves.

e) Cylinders should be properly secured at all times to prevent tipping (when vertical) or rolling (when horizontal). This may be in the form of a cylinder stand, wall bracket, or secured with straps or chains.

f) Cylinders should be transported using trolleys suitable for that purpose.

g) When transported by means of a crane or other lifting device, slings and magnets should not be used.

h) Labelling of gas cylinders should comply with AS 4484. SF_6 cylinders containing **new or recycled** SF_6 gas shall carry a 2.2 hazard class label to the *Code for the Transport of Dangerous Goods* [12].

Figure 1 Class 2.2 Hazard Class Label

i) SF_6 cylinders containing **used** SF_6 gas shall carry a 2.3 hazard class label to the *Code for the Transport of Dangerous Goods* [12]. Where it is suspected the used SF_6 may contain harmful by-products, a 2.3+8 hazard class label should be used.

Figure 2 Class 2.3 Hazard Class Label

Figure 3 Class 8 Hazard Class Label

8 FILLING

Only qualified and authorised contractors shall undertake the filling of SF_6 equipment. Refer to Appendix H for further details regarding the filling of equipment with SF_6 gas and standards which should be followed.

9 VENTING IS ILLEGAL

Sulphur hexafluoride is a greenhouse gas and is covered by the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* (OPSGG) [20]. The venting of SF_6 gas to the atmosphere is considered as a *Discharge of scheduled substance* in accordance with Section 45B of the OPSGG Management Act. Personnel shall take all reasonable precautions to prevent the venting of SF_6 gas to the atmosphere.

10 LEAK RESPONSE AND CLEAN UP

The typical maximum leakage rates for SF_6 switchgear in normal operation is 1 % to 3 % per annum, but is normally less than 1 %. At these rates, the concentrations of SF_6 gas or its by-products leaked per day are considered to have negligible risk (Section 3 and Annex C of AS 2791 [11]).

For leakages as the result of internal fault or exhaust, the concentrations of SF_6 and its by-products may be significantly higher, and caution should be exercised when attending a SF_6 release due to a fault.

The below procedures are for the response to and clean-up of a rapid release of significant quantities of SF_6 and potential by-products.

Prior to commencement of works, the level of SF_6 within the equipment in question should always be assessed to ascertain if a leak has occurred.

10.1 Safety and First Aid

Unless the composition of SF_6 gas in operational equipment can be confirmed, all SF_6 shall be considered as *arced* or *used*. Precautions stated in sections 10.4.2 and 10.5 should be used with PPE in line with Appendix C. SF_6 which has only been subjected to low current discharges (not breaking fault current) is unlikely to contain decomposition products at a concentration to causing adverse effects (Section B.1.2 of AS 2791 [11]).

However where contact of contaminated parts with skin is either confirmed or suspected, the skin should be washed with a bicarbonate soda solution (using 10 g of soda for every one litre of water).

10.2 Treatment of Outdoor Leaks of Non-Arced SF_6

In most cases, leaked SF_6 will be dispersed by convection. Low lying areas where the gas may pool should be checked and treated in accordance with the guidelines for indoor procedures (section 10.4).

10.3 Treatment of Outdoor Leaks of Arced SF_6

a) As with 10.2 above, leaked SF_6 gas and by-products will normally be dispersed by convection. As HF gas is lighter than air, it should also disperse naturally.

b) Temporary shelters should be erected for contaminated outdoor areas. These should prevent ingress of rain, and act as wind breaks, to prevent the scattering of harmful by-products. As moisture will encourage production of harmful by-products, shelters and work practices should be organised to prevent moisture ingress.

c) Where access to low lying areas is required, the procedure outlined in section 10.5 shall be followed.

d) If a vessel has experienced a significant SF_6 gas leak due to an internal fault, care should be exercised when handling plant or equipment, including in voids and cable pits. Procedures of section 10.4.2, 10.4.3 and 10.5 shall be followed, any solid by-products should be collected as described in section 10.6. They should then be neutralised, along with contaminated parts, tools and clothing, as described in section 11.

e) Additionally, if high moisture content is present due either from rainfall, high humidity or damp, gaseous and solid HF can dissolve to form hydrofluoric acid. If it is suspected that water is contaminated, a specialist contractor should be employed to neutralise and remove any contaminated water and soil and ensure equipment is decontaminated prior to undertaking works.

10.4 Treatment of Indoor Leaks of Non-Arced SF_6 (including outdoor buildings and compounds)

10.4.1 Evacuation

Where cylinders or equipment has leaked a significant amount of SF_6, personnel should evacuate immediately and avoid low areas where the gas may have pooled and caused a shortage of oxygen.

A ban on naked flames should be instituted until ventilation has dispersed all SF_6. Refer to section 10.4.3 for ventilation requirements.

10.4.2 Verification of Sufficient Oxygen

Personnel should wear a full face mask with external air supply (as described in Appendix C). A confined space gas detector should be used (measuring concentration of both oxygen and also sulphur dioxide) to verify safe levels of oxygen (minimum 19.5% by volume, maximum 23.5% by volume). Where there is indication of sulphur dioxide, this should be interpreted as evidence of arcing, and the precautions stated in section 10.5 should be followed prior to ventilation.

The wearing of face masks is not required when the following is verified:

1) Safe oxygen levels are above 19.5% and below 23.5% (by volume), and
2) SF_6 levels do not exceed the TLV time weighted average of 1000 ppmv.

PPE appropriate for the room may be worn; there is no specific PPE required in the presence of SF_6.

10.4.3 Ventilation

A suction ventilator (as described in Appendix C) should be temporary installed in the room. Additional ventilation should be installed in the room to adequately clear SF_6 from below-ground areas (e.g. cable trenches).

A portable SF_6 detection device should be used periodically at several points in the room to determine the effectiveness of the ventilation, and when to cease ventilation.

10.5 Treatment of Indoor Leaks of Arced SF_6

Where leaks of either cylinders or equipment are noticed, personnel should immediately evacuate as described in section 10.4.1, and verify sufficient oxygen levels as described in section 10.4.2. Where confined space gas detectors indicate presence of sulphur dioxide, the presence of toxic by-products should be assumed.

Clothing, eye protection, gloves and shoe protection (as described in Appendix C) should also be worn. Where oxygen levels are deemed safe by the confined space gas detector, the full-face mask with air supply should be replaced with one with filters (as described in Appendix C).

10.6 Solid By-Products

Solid by-products should be cleaned up using a 'class H' vacuum cleaner as described in Appendix C. The bag should be removed, sealed in a plastic bag with tape, and labelled.

By-products should then be neutralised by soaking in alkaline solution, as described in section 11.2.

11 NEUTRALISATION OF CONTAMINATED PARTS, TOOLS AND CLOTHING

Gloves and eye protection should be worn at all times when handling both the contaminated parts and the neutralising solution.

11.1 Parts Contaminated with Non-Arced SF_6

All contaminated parts, tools and clothing should be soaked using the solution and time provided in Table 3.

Table 3 Neutralisation Soak Times for Parts Contaminated with Non-Arced SF_6 [10]

Neutralising Agent	Soak Time (hours)
Washing soda (sodium carbonate) solution (0.1 kg/L)	1

Following the soak, the parts, tools or clothing should be thoroughly rinsed with water.

11.2 Parts Contaminated with Arced SF_6

All contaminated parts, tools and clothing should be soaked with a solution and time provided in Table 4. The alkaline will combine with the acid to form calcium sulphate (gypsum) or calcium fluoride (fluorspar).

Table 4 Neutralisation Soak Times for Parts Contaminated with Arced SF_6 [10]

Neutralising Agent	Soak Time (hours)
Washing soda (sodium carbonate) solution (0.1 kg/L)	48
Lime solution (saturated)	24

Following the soak, the parts, tools or clothing should be thoroughly rinsed with water.

11.3 Disposal of Neutralising Solution

Neutralising solution shall not be disposed into the sewerage or stormwater system, as it is alkaline (high pH), can be harmful to plants and animals, and exceeds limits placed by the *Environmental Protection (Unauthorised Discharge) Regulations 2004* under the *Environmental Protection Act (EPA)* [22].

Neutralising solution shall be stored and transported in accordance with Horizon Power environmental procedures [1] [2], and disposed of by a specialist subcontractor for toxic waste removal.

12 REPORTING

12.1 Importation and Exportation

There are legislative requirements for reporting of importation and exportation of SF_6.

Where Horizon Power procures SF_6-filled equipment and SF_6 cylinders from vendors within Australia, these do not apply. Similarly, where Horizon Power returns equipment and cylinders for recycling or destruction to other companies within Australia, the requirements do not apply.

Quarterly reporting for importation and exportation of SF_6 is required as described in section 6.1. Where equipment is imported, and the total SF_6 imported is below 10 kg, this reporting requirement does not apply.

Report content must contain information as per clause 901 of the *Ozone Protection and Synthetic Greenhouse Gas Management Regulations 1994* [20]. Copies of the report shall be kept for five years. The required content is as follows:

- Name of the importing officer and the relevant Horizon Power address
- The import license number
- The calendar quarter of the report
- The number of SF_6 equipment imported and exported during the quarter
- The total amount of SF_6 imported and exported during the quarter

12.2 Greenhouse Gas Emissions Accounting

There are legislative requirements for reporting greenhouse gas emissions. For the accounting of SF_6 emissions, Horizon Power uses “National default emission standard accounting”. This method estimates SF_6 emission using the in-service amount of SF_6 and an annual emission rate called the Default Leakage Rate [17].

12.3 Reporting discharge of SF_6

Discharges of SF6 gas, being either accidental or through faulted equipment, shall be reported to the Horizon Power Environment & Land group at the earliest convenience. These discharges should be added to the amounts calculated using the default leakage rate (described above in section 12.2), *for inclusion within the annual statutory National Greenhouse and Energy Reporting Act report*.

13 TRAINING

Horizon Power staff that work with SF_6 equipment and with cylinders of the gas should have training on how it should be handled.

Table 5 Suggested Training

Activity	Training Type	Training Frequency
Commissioning of SF_6-filled equipment	Written and practical*	2 years
Operation of SF_6-filled equipment	Written and practical	2 years
Maintenance of SF_6-filled equipment	Written and practical	2 years
Decommissioning of SF_6-filled equipment	Written and practical*	2 years
Storage and transport of equipment or cylinders	Written	3 years
Filling and recovery of SF_6	Written and practical	2 years
SF_6 quality testing	Written and practical	2 years
Leak detection	Written	3 years
Clean up of SF_6 leaks	Written and practical	2 years
Neutralisation of contaminated parts	Written and practical	2 years

*Practical training not necessary for sealed systems

APPENDIX A REVISION INFORMATION

(Informative) Horizon Power has endeavoured to provide standards of the highest quality and would appreciate notification if any errors are found or even queries raised.

Each Standard makes use of its own comment sheet which is maintained throughout the life of the standard, which lists all comments made by stakeholders regarding the standard.

A comment sheet **HPC-2NK-17-0030-COM** found in **CS10# 3472969**, can be used to record any errors or queries found in or pertaining to this standard, which can then be addressed whenever the standard gets reviewed.

Date	Rev No.	Notes
11/04/2016	0	Original issue.

APPENDIX B HEALTH EFFECTS OF TOXIC MATERIALS

The threshold of sense through smell (the olfactory threshold) of the decomposed by-products is similar in quantity to the TLV. The result is that personnel should notice SF_6 by-products by their pungent smell and, if actions are taken immediately, the risk of being poisoned is very low.

Listed below are all hazards related to SF_6 and its decomposed components [10].

Table 6 Threshold Limit Values of SF_6 Decomposition Materials (ppmv)

Material	Time-weighted Average	Short-term exposure limit	Ceiling
Hydrofluoric Acid (HF)	0.5	Not defined	2
Sulphur dioxide (SO_2)	2	5	Not defined

B1 HYDROFLUORIC ACID (HF)

As a liquid, it is a contact poison. The fluoride ion readily penetrates the skin, and so it can cause destruction of deep tissue layers and bones. Pain and skin damage associated with exposure may be delayed by 12 to 24 hours. Without rapid neutralisation, tissue destruction may continue for days and result in loss of limbs or death.

Known as hydrogen fluoride when in gaseous form. As a gas it is highly dangerous, as it irritates eyes, nose and respiratory tract. It can cause blindness by rapid destruction of the corneas.

Exposure to hydrofluoric acid warrants immediate medical attention.

B2 SULPHUR DIOXIDE (SO_2)

Sulphur dioxide can cause adverse respiratory effects including bronchoconstriction and increased asthma symptoms.

B3 THIONYL FLUORIDE (SOF_2)

In the presence of moisture, this gas decomposes to sulphur dioxide (SO_2) and hydrogen fluoride (gas) or hydrofluoric acid (liquid) (HF).

APPENDIX C REQUIREMENTS – PPE AND CLEAN-UP TOOLS

Artificial Ventilation

Ventilation should be suction-based, with the outflow directed upwards and outwards of the enclosed area. The operation of the ventilation should be apparent when running e.g. motor noise, and apparent when ceased.

Clothing

Dust-proof overalls to be worn over normal clothes. Overalls should be without pockets, hooded, non-permeable (e.g. bonded polypropylene) with elastic around ankles and wrists. The overalls should overlap gloves and shoe covers. Shoe covers should be worn over shoes.

Confined Space Gas Detector

These detectors should alarm when oxygen is outside the acceptable range (19.5% to 23.5%), and should also alarm for presence of sulphur dioxide (SO_2). The sensitivity of the alarm for sulphur dioxide should be representative of the environment, as it may be emitted from local pollution or natural sources (e.g. bush fires). A useful comparison would be to take a reading a suitable distance outside the affected area.

Gloves

Acid resistant made of PVC, rubber or neoprene. These should provide some thermal protection if used for filling or depressurising cylinders or equipment.

Eye Protection

Protective eye-wear should be suitable for work in harsh chemical environments and industrial grade.

Full face mask with air supply

This must meet the standard BS EN 136.

Full face mask with filters

Must be equipped with a changeable active charcoal filter. Combined filters of type A2/B2/E2/K2 and P3 (to AS/NZS 1716), capable of providing protection against particles of diameter greater than 1 μm.

Shelter

This should prevent ingress of rainwater from above, and cover the area within 1 m of the contaminated switchgear. The shelter should be of sufficient strength to withstand wind gusts appropriate for the forecast weather. Shelters should not be airtight but be structured to allow some natural ventilation.

Vacuum Cleaner

A 'class H' vacuum cleaner (AS/NZS 60335.2.69 [8]) should be used. This class of vacuum cleaners are commonly used for proper pick-up of asbestos dust. A non-metallic open-ended nozzle should be used.

APPENDIX D REQUIREMENTS FOR SPECIFICATION OF CYLINDERS SF_6-FILLED EQUIPMENT AND SF_6

The guidelines in this section should be written in to specifications for cylinders and equipment as appropriate.

D1 New SF_6

Specification of the incorrect purity can result in needlessly pure insulating gas (that may not represent the best economic value), or impure insulating gas that does not meet the dielectric strength requirement of equipment. Table 7 below shows the detailed typical impurities of various grades of SF_6.

Table 7 Purity of Commercial Available SF_6

Impurity (ppm wt)	99.9% (3N)	99.99% (4N)	99.999 (5N)	Maximum allowed by AS 2791
CF_4	≤ 400	≤ 18	≤ 3	500
Air	≤ 400	≤ 6	≤ 0.8	500
Water	≤ 0.65	≤ 0.12	≤ 0.12	15
Acidity expressed as HF	≤ 0.3	≤ 0.01	≤ 0.01	0.3
Hydrolysable fluorides expressed as HF		≤ 0.03	≤ 0.01	1.0

Purchasing SF_6 with a claimed purity of 99.9% would meet the standard requirements of AS 2791. Purchasing SF_6 of a purity higher than 99.9% is not warranted and may not be economical.

Specification by purity alone (e.g. 99.9%) does not guarantee compliance with the Australian standard (AS 2791). Purity should be specified as per Table A4 of AS 2791 for both new and recycled gas. This is shown as the last column above in Table 7. SF_6 purchased should be accompanied with certificates that certify compliance with IEC 60376 [15].

In line with AS 62271.1, when ordering replacement SF_6 it should be specified that the maximum allowable moisture content shall be such that the maximum dew point is -5°C when measured at 20°C (section 5.2 of AS 62271.1 [9]). Moisture content measurements vary depending on the temperature, and correction should be made for measurements made at temperatures other than 20°C (refer to IEC 60376 and IEC 60480).

The balance gas may be air, argon, helium, or nitrogen.

D2 Recycled SF_6

Recycled SF_6 should be specified to have impurities within limits specified by IEC 60480 [16]. The moisture content should meet the requirement of section 5.2 of AS 62271.1 [9].

D3 Cylinders

When shipped in cylinders, SF_6 is pressurised to liquid form, typically 2.2 MPa or higher.

Where gas is purchased from an overseas vendor, cylinders imported should:

1) Comply with appendix B of AS 2030.1
2) Be manufactured to an appropriate standard (ISO or CEN)
3) Be filled to a pressure not exceed that by the IMDG (International Maritime Dangerous Good) code
4) Have labelling in English
5) Be exported after use, and not be reused within Australia

D4 Cylinder Valves

Cylinders should have shrouds or valve protection rings to physically protect the valve, as shown in Figure 4.

Figure 4 Cylinder with shroud for valve protection

For cylinders supplied within Australia, valves should be type-tested to comply with AS 2473.1 (including leakage tests appropriate for liquefied gas).

D5 Cylinder Fittings

The choice of balancing gas dictates the fittings that should be used for the cylinder.

If air is used as the balancing gas, fittings should be specified as CGA-590 or DISS-716.

If argon, helium or nitrogen is used as the balancing gas, fittings should be specified as CGA-580 or DISS-718.

D6 Cylinder Colour

Refer to section 7.2, SF_6 Cylinders.

D7 Cylinder Labels

Refer to section 7.2, SF_6 Cylinders.

D8 SF_6-filled Equipment

The maximum leak rate for equipment should be specified as shown below in Table 8.

Table 8 Maximum Leak Rates

Rated Equipment Line-to-line Voltage (kV)	Allowable Annual Leakage Rate (%)
≤ 52 kV	0.1 %
> 52 kV	0.5 %

APPENDIX E EXAMPLE OF ESTIMATING LIKELIHOOD

As an example, the risk event of suffocation due to SF_6 leaked from equipment (GIS switchboards) relies on several events, listed below. The estimations are arbitrary and are intended to illustrate the method:

1) Visiting a GIS switchboard that has a leak during its service life

   There are 60 GIS boards in service, each of these is visited once a year. A leak occurs every year in one of these 60 GIS boards. The result is that one leaking GIS board is found for every 60 visits.

2) Personnel do not check the pressure gauge

   Estimated to occur for one visit of every 24 visits (with sixty visits made per year)

3) Personnel enter a depressed area where oxygen concentration is low

   Estimated to occur for one visit of every twelve visits (with sixty visits made per year)

All three events need to occur for the hazard to occur. The likelihood of the each of the above events can be calculated to one event in every 17,280 visits (60 × 24 × 12 = 17,280). If 60 visits are made per year, the event happens once every 288 years.

This example, while arbitrary, illustrates that a coincidence of several unlikely events is often beyond the *Risk Management Framework* [4] category of 'rare', which is defined as one occurrence every 50 years.

APPENDIX F SF_6 RECOVERY

Where possible, SF_6 recovery is to be undertaken by an approved contractor in accordance with manufacturer's instructions, or AS IEC 62271.4 [10] where manufacturer's instructions are not available.

F1 RESPONSIBLE USE

As SF_6 is classed as a greenhouse gas, emission of SF_6 to the atmosphere must be kept to the lowest practicable levels possible.

Where practicable and technical feasible, SF_6 gas should be reused, recovered, recycled and reclaimed.

F2 CYLINDERS FOR USED SF_6

Cylinders for used SF_6 (that has not yet been recycled) should be coloured a hue of yellow, indicating toxicity. Labelling should be as per section 7.2. Prior to filling a cylinder with used SF_6, the cylinder should be evacuated with a vacuum pump to provide a low pressure (ideally less than 2 kPa). A sufficient pressure differential should be achieved between the equipment chamber pressure and the destination cylinder pressure.

F3 EQUIPMENT CONTAINING NON-ARCED OR NORMALLY ARCED SF_6

Normally-arced SF_6 gas is gas which has been subject to the breaking of load current only. If it cannot be confirmed that the SF_6 gas has not broken fault current, it should be assumed the gas is heavily-arced.

Recovery of SF_6 should be done in accordance with manufacturer's recommendations. Where these are unavailable, section 5 of AS IEC 62271.4 [10] should be used.

Prior to flooding the gas compartment with air, partial pressure of SF_6 shall be lower than 2 kPa (as required by section 5 of AS IEC 62271.4 [10]). Where evacuation to 2 kPa is not possible (e.g. equipment is damaged), dilution should be used.

F4 EQUIPMENT CONTAINING HEAVILY-ARCED SF_6

Heavily-arced SF_6 gas is gas which has been subject to the breaking of fault current.

Recovery of SF_6 should be done in accordance with manufacturer's recommendations. Where these are unavailable, section 5 of AS IEC 62271.4 [10] should be used.

When flooding a compartment (following evacuation of the used SF_6), N_2 should be used.

Clean up of by-products and contaminated parts should be done in accordance with the procedure in section 10.

F5 CYLINDERS AND SAMPLE BAGS

F5.1 CONSOLIDATION OF USED SF_6 FOR RECYCLING

To minimise transport and recycling costs, it is appropriate to consolidate used SF_6 to the minimum number of cylinders. Cylinders may then be grouped into two categories:

1) Full cylinders for future recycling, and
2) Empty cylinders with residual used SF_6, which may be reused to capture reclaimed SF_6.

Used gas in sample bags (from SF_6 quality testers) should also be consolidated.

Consolidation of used gas into liquid form is impractical due to the need for cooling aggregates and high pressure differentials.

Dual-stage regulators and safety (relief) valves should be used to ensure the delivery pressure does not exceed the maximum pressure allowable by the receiving vessel.

All cylinders used for unrecycled SF_6 gas should be coloured yellow and carry a hazard class label, as described in section 7.2.

F5.2 CONSOLIDATION OF NEW SF_6 FROM PARTIALLY USED CYLINDERS

Consolidation of new or recycled SF_6 to a minimum number of cylinders should only be done where economical.

This consolidation should be done by a SF_6 recycling company, or a company with similar expertise. Compressors and vacuum pumps used should be purpose-made for SF_6 or high-purity (medical grade) gasses. All equipment used must be suitable for the pressures involved. In addition to this, purpose-made filters should be used to remove impurities introduced by compressors and vacuum pumps.

F6 DESTRUCTION OF SF_6

Destruction of SF_6 should be carried by a specialist contractor.

APPENDIX G EQUIPMENT FOR RECOVERY OF SF_6

G1 VACUUM PUMPS

Vacuum pumps are necessary to:

1) Evacuate equipment chambers prior to filling with new or recycled SF_6
2) Evacuate used SF_6 from equipment, near-empty cylinders, and test instrument sample bags
3) Empty cylinders with residual used SF_6, which may be reused to capture reclaimed SF_6.

Cylinders or chambers with residual SF_6 gas must not have gas evacuated to the atmosphere.

Vacuum pumps should have two-stage operation, with a delivery of at least 6 m^3/h.

Where it is found that used gas contains a high degree of harmful by-products, the vacuum pump should be cleaned in accordance with manufacturer's instructions. Contaminated parts should be neutralised as described in section 11.

G2 RECOVERY EQUIPMENT

A standard gas compressor should be used for consolidating used SF_6 into cylinders (as described in section F5.1).

Where it is found that used gas contains a high degree of harmful by-products, the compressor should be cleaned in accordance with manufacturer's instructions. Contaminated parts should be neutralised as described in section 11.

G3 PRESSURE REGULATORS

Regulators used for transferring SF_6 gas from a pressurised vessel should be suitable for the delivery pressure, and should include an adjustable over-pressure relief device in the output line.

Regulators should be purpose made for 'critical purity' use and use a stainless steel diaphragm.

A single-stage or dual-stage regulator should be chosen for the application:

1) A single-stage regulator reduces the cylinder pressure to the outlet pressure (delivery pressure) in one step. As the cylinder pressure drops, so will the outlet pressure. It is appropriate to use this when precise control of the delivery pressure is not required.
2) A dual-stage regulator reduces the cylinder pressure to a working pressure in two steps. The delivery pressure is constant and not affected by the decreasing cylinder pressure. Use of a dual-stage regulator is important when precise control of the delivery pressure is required.

G4 SF_6 TEST EQUIPMENT

Test equipment should be selected that has ranges and appropriate accuracy for the purpose it is being used.

Gas recovery bags used should be made specifically for that purpose.

APPENDIX H FILLING OF EQUIPMENT WITH SF_6

H1 GENERAL PRECAUTIONS

In all cases, normal precautions associated with gas cylinders should be exercised. SF_6, like other gases, drops in temperature when depressurised, and can cause rapid freezing. Workers manipulating equipment should ensure PPE contains thermally insulated gloves. Where freezing impedes the filling of equipment, tank heaters should be used.

Pressure regulators and safety valves used should be calibrated and tested in accordance with their respective manufacturer's recommendations.

H2 FILLING EQUIPMENT

Filling switchgear should be carried out as per manufacturer's recommendations, to ensure:

- A safe working environment for workers
- Adequate gas is present in the switchgear for safe operation
- The switchgear vessel is not over pressurised
- Leakage is minimised

In the absence of manufacturer's recommendations, the procedure described in section 3.2 of AS IEC 62271.4 [10] should be followed.

H3 TOPPING UP EQUIPMENT

Where equipment indicates pressure below the operational limit, the nature of the leak should be investigated prior to topping up, in accordance with the equipment manufacturer's recommendations.

Topping up pre-filled switchgear should be carried out as per manufacturer's recommendations.

In the absence of manufacturer's recommendations, the procedure described in section 3.3 of AS IEC 62271.4 [10] should be followed.

H4 SEALED EQUIPMENT

Where sealed equipment indicates a loss of pressure below operational limits, the manufacturer should be consulted prior to any refilling or recommissioning.