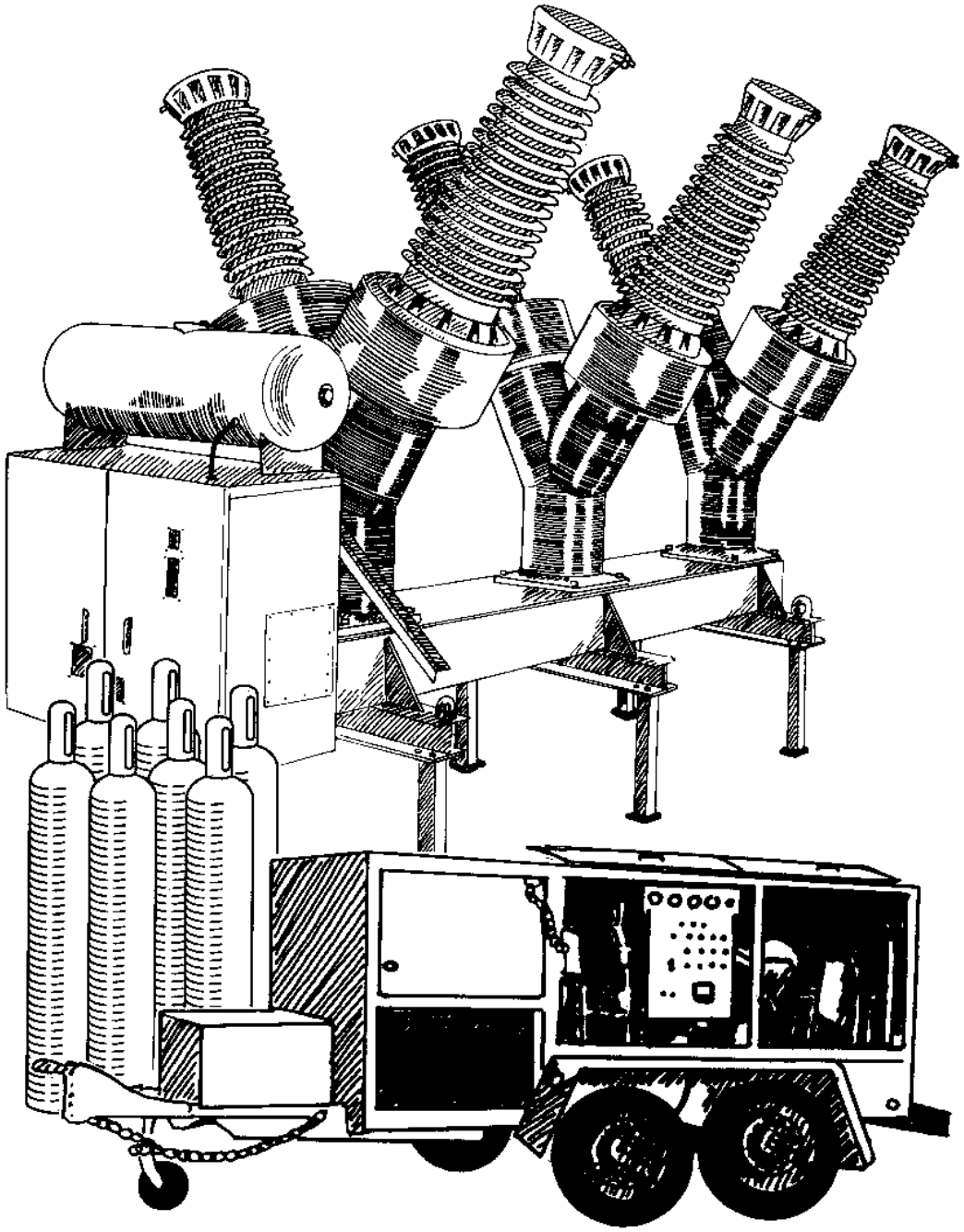
CHAPTER 4

MAINTENANCE AND HANDLING OF GAS INSULATION

FEBRUARY 1994



POWER SYSTEM MAINTENANCE MANUAL

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA ·

WESTERN

AREA POWER ADMINISTRATION

MAINTENANCE AND HANDLING OF GAS INSULATION

FEBRUARY 1994

WESTERN AREA POWER ADMINISTRATION
POWER SYSTEM MAINTENANCE MANUAL
CHAPTER 4

Approved for Publication and Distribution

Steven F. Schweitzer
Director, Division of
Power System Maintenance

3/7/94

Date

Acknowledgements

Thanks to the following ad hoc work group members for their efforts in developing this document:

Dan DeGracie, Environmental Office, Phoenix, Arizona

Suzette Farrar, NSR Information Inc., Golden, Colorado

Mark Hollenbeck, Division of Transmission Lines and Substation Maintenance, Montrose, Colorado

James Milbrandt, Division of Substation Maintenance, Huron, South Dakota

James Propst, Division of System Engineering, Loveland, Colorado

Chuck Rich, Division of Power System Maintenance, Golden, Colorado

Larry Romero, Division of Power System Maintenance, Golden, Colorado

Ken Schriner, Safety Office, Montrose, Colorado

Disclaimer

Preface

This document is issued by the Western Area Power Administration (Western) and is designed to provide guidelines and recommendations for the maintenance and proper handling of gas insulation. Primarily, this includes sulfur hexafluoride (SF_6) gas, SF_6 byproducts, and nitrogen gas. Please call the Division of Power System Maintenance (A6210) or use the proposed revision page if any corrections or comments should be made concerning this document.

PROPOSED REVISION TO PSMM CHAPTER 4,
MAINTENANCE AND HANDLING OF GAS INSULATION

Type of Suggested Revision:

☐ Addition, ☐ Deletion, ☐ Rewording, ☐ Other: (Circle one) _____

PSMM Chapter 4, Section Number: _____

SUGGESTED NEW WORDING:

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

REASON FOR REVISION:

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Revision Recommended By: _____ Mail Code: _____
Name

Date: _____ If additional space is needed, attach necessary pages.

Please return to: Western Area Power Administration
Division of Power System Maintenance, Attn: A6200
P.O. Box 3402
Golden, CO 80401

Table of Contents

List of Figures

Page

List of Tables

1. Purpose

The purpose of this chapter is to establish general guidelines for the maintenance and handling of sulfur hexafluoride (SF_6) gas, SF_6 byproducts and nitrogen (N_2) gas. The maintenance and handling of gas-insulated equipment housed in buildings or gas-insulated substations (GIS) are beyond the scope of this chapter and, therefore, not included.

2. Scope

These guidelines and procedures supplement the requirements of Western Area Power Administration's (Western) Power System Safety Manual (PSSM). The information contained in this document shall be complied with by all Western operation and maintenance (O&M) employees performing work on any SF_6 insulated equipment or handling gases at Western facilities. If a conflict exists between the requirements contained in this chapter and those contained in the PSSM, the PSSM shall prevail until the conflict is resolved.

3. Definitions and Interpretations

3.1 Definitions.

Faulted Gas - Any unfiltered SF_6 gas which has been exposed to an electric arc, corona, or extreme heating [250°C (480°F) or above]. (i.e. any SF_6 gas in energized electrical equipment)

Nonfaulted Gas - Any SF_6 gas which has not been exposed to an electric arc, corona, or extreme heating. (i.e. SF_6 gas from manufacturers, SF_6 gas in cylinders, reclaimed SF_6 gas)

SF_6 Byproducts – The breakdown products of SF_6 gas when exposed to an electric arc, corona, or extreme heating. The specific types and amounts of SF_6 byproducts depend on factors such as magnitude and duration of an interrupting arc, material in the equipment, and contamination levels of moisture and air.

3.2 Interpretations. The following interpretations shall be applied throughout this chapter:

"Will" – Mandatory, but allowing the responsible employee or party some discretion as to when, where, and how.

"Shall or Must" – Mandatory under normal conditions.

"Should" – Advisory. "Should" statements represent the best advice available at the time of printing.

"May" – Permissive choice.

"Caution" – An indication that minor injury may result.

"Warning" – An indication that injury or death may result.

4. Responsibilities

O&M Managers and Supervisors (first and second line) are responsible for ensuring maintenance personnel receive training and are provided with the appropriate equipment and the required personal protective equipment (PPE) for handling gases and byproducts.

Job supervisors must ensure workers understand and follow safety and health requirements when performing work on gas-insulated equipment.

Workers have the right and responsibility to understand and follow safety and health requirements for handling gases and any byproducts when performing work on equipment.

5. General Requirements

5.1 Material Safety Data Sheet (MSDS). Maintenance personnel will review MSDS's to become aware of the potential hazards which may occur when handling insulating gases, cleaning solvents, etc.

5.2 Gas-Filled Cylinders.

5.2.1 Quantity. Different methods are used to determine the quantity of products in cylinders. Weight is used to measure SF_6. Pressure is used to measure N_2. The full-capacity weight or pressure is stamped on the cylinder. The approximate quantity of contents in a partially-filled cylinder can be determined by measuring the pressure or weighing the cylinder and comparing it to the full capacity.

5.2.2 Transportation. Cylinders must be securely lashed in an upright position or loaded into racks securely attached to the vehicle or packed in boxes or crates of such dimensions to prevent their overturning, or securely loaded in a horizontal position. Transport in accordance with Federal, State, and local regulations.

5.2.3 Safety. Cylinders are extremely heavy. Workers must use caution when handling them. Hoses, valves, gauges, and fittings will be regularly inspected and kept in good working order. The following precautions shall be observed while storing, transporting, or handling the cylinders:

(1) Use mechanical lifting devices, such as carts and dollies.

(2) Do not lift by the protective cap, drop, throw, or roll. After securing the protective cap, the cylinder may be lifted from a horizontal position to a vertical position by the bottle neck or using a lifting device.

(3) Store away from a direct source of heat, including direct sunlight, to avoid dangerous pressure from developing. Do not allow cylinders to be subjected to temperatures above 120°F (49°C).

(4) Store in an area free of exposure to flammable material.

(5) Store with protective cap on and in an upright and secured position.

(6) Do not store on damp ground or in contact with moisture.

(7) Do not slam them together or against other solid objects.

(8) To prevent contamination, do not add unfiltered gas to cylinders.

(9) Always keep the protective cap in place when not in use or during transportation.

(10) Identify a leak using gas detecting devices.

(11) Defective cylinders should be marked "DEFECTIVE" and returned to the supplier.

5.3 Confined Space Entry. Workers must adhere to confined space entry regulations.

6. SF_6 Insulation

6.1 Characteristics.

6.1.1 SF_6. SF_6 gas, in its nonfaulted form, is colorless, odorless, tasteless, nonflammable, noncorrosive, and heavier than air. It may liquefy when exposed to cold temperatures. For additional information, see Appendix A.

6.1.2 SF_6 Byproducts. SF_6 byproducts consist mainly of sulfur fluorides, metal fluorides, and secondary decomposition products. Metal fluorides may appear as a white or tan powder within the equipment. Common byproducts and hazards are listed in Tables 1 and 2.

Table 1
Common SF_6 Solid Byproducts

Compound Name	Formula	Remarks
Aluminum Trifluoride	AlF_3	Absorbs water, Extremely corrosive
Copper Fluoride	CuF_2	Absorbs water, Extremely corrosive

Table 2
Threshold Limit Values* (TLV's) of
SF_6 Gas and its Common Gaseous Byproducts

Compound Name	Formula	TLV*(ppm)	Remarks
Sulfur hexafluoride	SF_6	1000	Pure SF_6 gas
Thionyl fluoride	SOF_2	1	Rotten egg odor. See notes 1 and 4
Sulfuryl fluoride	SO_2F_2	5	See notes 1 and 4
Thionyl tetrafluoride	SOF_4	0.5	Strong odor. See notes 1 and 4
Sulfur dioxide	SO_2	2	Strong odor. See notes 1, 3, and 4
Hydrofluoric acid	HF	3	Strong odor. See notes 1, 3, and 4
Hydrogen sulfide	H_2S	10	Rotten egg odor.
Sulfur tetrafluoride	SF_4	0.1	Strong odor. See notes 2, 3, and 4
Disulfur difluoride	S_2F_2	0.5	See note 2
Disulfur decafluoride	S_2F_{10}	0.025	See notes 2 and 5
Sulfur difluoride	SF_2	1	See notes 1 and 4
Tungsten hexafluoride	WF_6	0.1	See notes 1 and 4
Silicon tetrafluoride	SiF_4	0.6	See notes 1 and 4
Carbon tetrafluoride	CF_4	1000	See notes 1 and 4
Carbon disulfide	CS_2	10	See note 4
Carbon monoxide	CO	50	See note 4

Notes: *These values are standards set for worker exposure protection during a 40-hour work week. Exposure to these concentrations day after day are believed to have no adverse effect on employees.

1. This gaseous byproduct is of chief concern because it exists in the gaseous state under normal conditions and is toxic.

2. This gaseous byproduct is toxic but tends to react among other similar gases or with moisture to form SF_6, SO_2, and HF, or oxyfluorides such as SOF_2, SO_2F_2, and SOF_4.

3. This gaseous byproduct is very reactive or corrosive.

4. It is possible to filter this gaseous byproduct from the SF_6 gas by flowing it through activated charcoal or alumina filters.

5. At this time, it is not possible to measure this TLV.

6.2 Personal Protective Equipment.

6.2.1 Nonfaulted Gas. Direct contact with liquid SF_6 may cause tissue freezing. Workers handling SF_6, excluding transportation, will wear the following PPE:

(1) Chemical Safety Goggles – Chemical safety goggles shall be worn at all times while handling liquid SF_6.

(2) Gloves – Gloves shall be worn when handling cylinders and transferring liquid SF_6.

(3) Breathing Apparatus – Air-supplied respirators or self-contained breathing apparatus (SCBA) shall be worn in an oxygen deficient atmosphere. An oxygen deficient atmosphere contains less than 19.5 percent oxygen.

6.2.2 Faulted Gas. SF_6 gas-insulated equipment which has been energized shall be assumed to contain SF_6 byproducts unless the gas has been analyzed and confirmed not to contain harmful levels of byproducts (see Tables 1 and 2). NOTE: If the breaker was operated between the time the sample was taken and when the breaker was removed from service, there may be new or additional byproducts present. Appropriate procedures should be followed and PPE should be worn as listed below.

The following PPE shall be worn while opening and cleaning equipment containing faulted SF_6 gas:

(1) Coveralls – Disposable coveralls, such as polylaminated Tyvek, shall be worn when handling SF_6 byproducts.

(2) Gloves – Disposable gloves, such as neoprene or chlorinated polyethylene (CPE), shall be worn and securely taped to the coveralls when handling solid SF_6 byproducts. Gloves shall be compatible with solvents and byproducts.

(3) Slip-On Boots – Disposable boots, such as latex, shall be worn when handling solid SF_6 byproducts.

(4) Chemical Safety Goggles – Chemical safety goggles shall be worn when handling SF_6 byproducts.

(5) Breathing Apparatus – Breathing apparatus shall be worn when handling SF_6 byproducts. Recommended types include air-supplied breathing apparatus or respirators with a high efficiency particulate air (HEPA)/organic vapor/acid gases cartridge. An air-supplied respirator or SCBA shall be worn in an oxygen deficient atmosphere.

6.3 First Aid.

6.3.1 Nonfaulted Gas. Recommended first aid procedures for treating contact with nonfaulted SF_6 liquid or gas are as follows:

(1) Skin or Eye Contact with Liquid SF_6

(a) Symptoms – Frostbite, redness, pain, open wounds.

(b) Treatment – DO NOT wait for symptoms to appear. Treat the affected body area immediately as follows:

(1) DO NOT apply direct heat to the affected body area, rub the affected area, or remove the victim's clothes.

(2) Slowly warm the affected body area with lukewarm water.

(3) **Seek medical attention.**

(4) If liquefied SF_6 gets into the eyes, bandage both eyes and **seek medical attention.**

(2) Inhalation

(a) Symptoms – Pale or blue skin, headache, sluggish, tingling in the arms and legs, altered hearing, possible unconsciousness.

(b) Treatment

(1) Move victim to fresh air.

(2) Remove or loosen all restrictive clothing.

(3) If breathing is difficult, administer oxygen if available.

(4) **Seek medical attention.**

(5) If not breathing, **call for medical assistance** and administer cardiopulmonary resuscitation (CPR).

6.3.2 Faulted Gas. Recommended first aid procedures for treating contact with faulted SF_6 are as follows:

(1) Eye Contact

(a) Symptoms – Irritation, redness, blurred vision, pain.

(b) Treatment

(1) Flush eyes immediately with water for a minimum of 15 minutes while lifting eyelids to ensure a complete rinse.

(2) After flushing with water, irrigate eyes with a saline solution, if available, and cover both eyes with sterile bandages.

(3) DO NOT use boric acid because of its drying qualities.

(4) **Seek medical attention immediately.**

(2) Skin Contact

(a) Symptoms – Redness, irritation, swelling, pain.

(b) Treatment

(1) Flush area with water for a minimum of 15 minutes.

(2) Remove contaminated clothing carefully so that other skin does not become irritated.

(3) Again, flush area with water.

(4) **Seek medical attention immediately.**

(3) Inhalation

(a) Symptoms – Shortness of breath, pale or blue skin, headache, sluggish, tingling in the arms and legs, altered hearing, possible unconsciousness.

(b) Treatment

(1) Move victim to fresh air.

(2) Remove or loosen all restrictive clothing.

(3) If breathing is difficult, administer oxygen if available.

(4) **Seek medical attention immediately.**

(5) If not breathing, **call for medical assistance** and administer CPR.

(4) Ingestion – To avoid ingestion, DO NOT eat or smoke while handling SF_6. Workers shall wash their hands after handling SF_6 gas and byproducts.

(a) Symptoms – Nausea, vomiting, sluggishness.

(b) Treatment

(1) Rinse mouth to remove any contaminants.

(2) Give plenty of water to drink to dilute the ingested chemicals.
DO NOT induce vomiting.

(3) **Seek medical attention immediately.**

6.4 Gas Carts. Gas carts are designed and constructed to safely handle and process SF_6 gas. To further enhance the safe handling and processing of SF_6 gas and prevent the cart from getting contaminated with faulted gas, the carts will be equipped with a pre-scrubber, teflon-lined hoses, and approved high-pressure fittings.

Gas carts need to be properly maintained and operated according to manufacturer's recommendations. PPE for faulted gas must be worn while processing gas. If the gas cart becomes contaminated, refer to the manufacturer's recommendations for decontamination.

6.5 Electrical Equipment. Consult manufacturer's recommendations for specific maintenance procedures on electrical equipment containing SF_6 gas. For additional information on a maintenance procedure which minimizes exposure to SF_6 faulted gas and its byproducts, see appendix B.

6.5.1 Gas Analysis. Moisture and byproducts analyses can indicate equipment problems and potential hazards. These analyses can also provide useful information for assessing safety and health risks. Two analyses commonly used are:

(1) Moisture Analysis – Moisture content will accelerate SF_6 decomposition during arcing and corona conditions. Moisture will cause corrosion in electrical equipment. Moisture content should be checked every 12 months.

(2) Byproducts Analysis – Prior to opening the tank for maintenance, gas contained within electrical equipment should be sampled for SF_6 byproducts. It is recommended that the gas samples be sent to a laboratory for analysis of the byproducts shown in Table 2.

Appendix C outlines a suggested SF_6 gas sampling procedure. This procedure or one recommended by a commercial laboratory should be used.

CAUTION: When taking gas samples, a small amount of SF_6 will unavoidably escape to the atmosphere. As a minimum, a half-mask respirator, chemical safety goggles, and gloves shall be worn.

6.5.2 Filling Equipment. Electrical equipment shall be filled in accordance with manufacturer's recommendations. It is possible to find moisture in new SF_6 gas cylinders. A good practice is to filter gas through a gas cart before it enters any electrical equipment. When adding SF_6 gas, an in-line dryer may be substituted for a gas cart.

SF_6 may be withdrawn from the cylinder as either a gas or liquid. When the cylinder is upright, SF_6 will discharge as a gas. When the cylinder is inverted, SF_6 will discharge as a liquid.

After filling, the moisture level should be checked in accordance with manufacturer's recommendations. If this level is not within the specified limits, refilter the gas and follow manufacturer's recommendations.

6.5.3 Filling Equipment With Mixed Gas (SF_6/N_2). Due to the effects of sub-zero temperatures on SF_6 gas, some electrical equipment require an SF_6/N_2 mixture. Consult manufacturer's recommendations for filling and adding gas. Test equipment is available for verifying gas mixtures. The following example for an Asea Brown Boveri circuit breaker illustrates a typical filling procedure.

Example: A circuit breaker requires a total gas pressure of 87 pounds per square inch (psi) at 70°F (see Table 3). Fifty-three (53) percent must be SF_6 and 47 percent must be N_2 according to the manufacturer's requirements. The 53 percent of SF_6 is added first and is calculated from a complete vacuum to 39.3 psi positive pressure. Once the SF_6 pressure has settled, the remaining 47.8 psi is made up of N_2, giving a total gauge pressure of 87 psi.

Table 3
Typical Filling Procedure to Ensure Proper SF_6/N_2 Mixture (53 percent/47 percent)

	Ambient Temp.(°F)										
	-50	-30	-10	10	30	50	70	90	110	130	150
SF_6/N_2 (psi)	63.4	67.5	71.3	75.4	79.5	83.4	87.1	90.8	94.8	99.1	103.4
SF_6 (psi)	26.8	29.0	31.0	33.1	35.3	37.4	39.3	41.4	43.4	45.7	48.0
N_2 (psi)	36.6	38.5	40.3	42.3	44.2	46.0	47.8	56.7	51.4	53.4	55.4

6.5.4 Reclaiming Gas. Reclaiming is a safe method of retaining and purifying SF_6 gas for reuse. This purification process is designed to remove moisture and SF_6 byproducts. Consult the gas cart manufacturer's recommendations for reclaiming procedures. All reasonable efforts should be made to prevent the SF_6 gas from escaping into the atmosphere during maintenance, inspection, and gas handling.

6.5.5 Handling Solid SF_6 Byproducts. All opening and cleaning procedures shall be performed wearing appropriate PPE (see section 6.2.2). Before opening an access door, use a gas cart to evacuate the gas-filled equipment and backfill it with dry air or nitrogen. The pressure inside the equipment must equal atmospheric pressure prior to opening the access door. Electrical equipment shall be vacuumed using a vacuum cleaner with a HEPA filter capable of collecting particles down to 0.3 microns. This vacuum cleaner shall be dedicated and specifically labeled "For Use Only on SF_6 Equipment." The inside of the equipment shall be vacuumed whether powder is visible or not. After vacuuming, the inside of the equipment must be wiped down with an appropriate cleaning solution. If entry into the equipment tank is necessary, follow confined space entry procedures. Tools shall be cleaned after use.

6.5.6 Disposal. Waste generated from maintenance of gas-insulated equipment must be handled in a safe and responsible manner. This waste includes disposable protective clothing, cleaning rags, molecular sieves from equipment and gas carts, vacuum filters, etc.

All waste generated during maintenance must be designated as hazardous or nonhazardous. Waste designation is dependent upon Federal, State, and local regulations.

Nonhazardous waste should be disposed of as solid waste in accordance with applicable State and local regulations.

If it is unknown whether the disposable material is a hazardous waste, it should be collected in double plastic bags, sealed, labeled, and placed in a DOT-approved container. This waste should be kept dry and prevented from contacting other materials. The Area Environmental Affairs Office should be contacted for guidance in the characterization and/or testing of the waste.

Hazardous waste requires proper accumulation (as described above), labeling, and disposal. Area Environmental Affairs Offices and Hazardous Waste Management Plans should be consulted for direction regarding all disposal procedures.

7. Nitrogen Gas

7.1 Background. Nitrogen is used in a wide variety of electrical equipment, such as hydraulic accumulators, SF_6 gas-insulated circuit breakers, and power transformers. Nitrogen is also used as a drying agent to remove moisture.

7.2 Characteristics. Nitrogen is a colorless, odorless, tasteless gas which comprises 80 percent of the atmosphere. It liquifies at extremely low temperatures. In excess, nitrogen may act as an asphyxiant causing suffocation. Nitrogen is an inert gas (non-reactive) and has a dew point lower than -50°C (-58°F).

Nitrogen can be obtained in high-pressure steel cylinders or in some locations in insulated low-pressure containers in liquid form. Cylinders should not be completely emptied, but should be returned to the supplier with at least 25 psi of residual pressure. An unused cylinder of nitrogen normally contains 2200 psi at ambient temperature. Regulators are used with nitrogen cylinders because of the high pressure. These regulators must always be used except when precharging hydraulic accumulators. Only approved high-pressure fittings are adequate. Pipe fittings, galvanized or black, should never be used.

Regulators are manufactured in one and two stages. A two-stage regulator should always be used for filling transformers, circuit breakers, and other low-pressure equipment requiring good regulation. Single-stage regulators work well for filling equipment with pressure requirements above 10 psi.

7.3 Safety. Nitrogen is an asphyxiant and confined space entry procedures apply. High-pressure nitrogen can be very dangerous if it is unregulated while discharging.

7.4 First Aid. Pure nitrogen is indistinguishable from pure air without oxygen level monitors and will cause asphyxiation.

(1) Symptoms – Pale or blue skin, headache, sluggish, tingling in the arms and legs, altered hearing.

(2) Treatment

(a) Move victim to fresh air.

(b) Remove or loosen all restrictive clothing.

(c) If breathing is difficult, administer oxygen if available.

(d) **Seek medical attention.**

(e) If not breathing, **call for medical assistance** and administer CPR.

8. References

AccuDri SF_6 Technical Bulletin, Allied Chemical Corporation, 1991.

"Experience with Solid Arcing Byproducts in SF_6-Insulated Equipment," Frank Chu, **Transmission and Distribution,** April 1981.

Handling SF_6 Arc Products in High-Voltage Equipment, Glander, Public Service Electric and Gas Company.

Handling Sulfur Hexafluoride, SF_6, G.M. Ihle, Bonneville Power Administration, 1983.

New England Electric System Experience with GE Arc Products, R.W. Goff, New England Electric System.

"Power System Clearance Procedures,**" Power System Operations Manual,** Chapter 1, Western Area Power Administration, January 1989.

Power System Safety Manual, Western Area Power Administration, February 1989.

Safe Work Practices for Outdoor SF_6 Gas-Insulated Power Apparatus, R.E. Minkwitz Sr., New England Electric System.

Section 302 of Public Law 95-91, The Department of Energy Organization Act, August 4, 1977.

SF_6, An Applications and Technical Manual, Air Products and Chemicals, Inc.

SF_6 Gas Analysis Service, Mastroianni and Jackson, Allied Chemical Corporation, 1980.

SF_6 Gas Analysis Service Analytical Data and Case Histories, Jackson and Munecs, Allied Chemical Corporation, 1982.

U.S. Department of Labor (OSHA), Title 29, Code of Federal Regulations, Part 1910, Occupational Safety and Health Standards and Part 1926, Safety and Health Regulations for Construction.

U.S. Department of Transportation, Title 49, Code of Federal Regulations, Part 172, Hazardous Materials Table, Special Provisions, Hazardous Materials Communications Requirements and Emergency Response Information Requirements.

U.S. Environmental Protection Agency, Title 40, Code of Federal Regulations, Part 261, Identification and Listing of Hazardous Waste and Part 262, Standards Applicable to Generators of Hazardous Waste.

Appendix A - Additional SF_6 Information

A.1 SF_6 Gas. SF_6 gas has high dielectric properties, unique arc-quenching ability, excellent thermal stability, and good thermal conductivity. Because of these characteristics, it is used extensively in electrical and electronic equipment such as circuit breakers, switches, and microwave components. SF_6 gas absorbs free electrons generated during a circuit interruption arc which changes the characteristics of the gas. After exposure to an energy field, the gas returns to its previous form. This reformation is not always 100 percent efficient and SF_6 byproducts are formed.

The type and amount of SF_6 byproducts depend on the magnitude and duration of the arc, any contaminants present in the gas, and the type of metals in the electrical equipment. SF_6 gas-insulated circuit breakers are equipped with desiccants designed to remove moisture and SF_6 byproducts. The commonly used desiccants are aluminum oxide, activated alumina, or molecular sieve. These desiccants are not designed to handle large amounts of moisture and SF_6 byproducts. Units which have experienced electrical problems or internal failures may contain abnormally high levels of byproducts.

Secondary decomposition products result from byproducts chemically reacting with other byproducts or contaminates. As an example, sulfur fluorides and metal fluorides may react with the contaminant moisture. This reaction may yield hydrofluoric acid. Hydrofluoric acid is extremely corrosive and will react with electrical equipment components.

A.2 SF_6 Cylinders. SF_6 is shipped as a liquefied gas in steel cylinders. Any SF_6 gas purchased by Western for use in electrical equipment must meet the specifications of the American National Standards Institute (ANSI) C59.173 and the American Society for Testing and Materials (ASTM) D 2472-81.

Appendix B - Suggested Maintenance Procedure

The safe handling of faulted SF_6 gas and its byproducts during the maintenance of SF_6 circuit breakers has been a concern for maintenance personnel and substation designers. In addressing this concern, such measures as constructing dedicated washrooms at the substation facilities or storing large volumes of water at the worksite during breaker maintenance have been proposed for rinsing a worker's body in the event of coming into contact with any faulted SF_6 or its byproducts.

The following procedure will minimize the risks of coming into contact with the faulted gas and its byproducts, therefore eliminating the need for special measures.

(1) During work planning, collectively discuss the potential hazards of the task to determine what measures are needed to mitigate the identified hazards.

(2) Draw a gas sample from the breaker prior to maintenance to analyze the condition of the gas and assess the measures required for handling the gas.

(3) Use an SF_6 gas reclaimer to process the gas. This will handle the gas in a closed-loop system during the removal and storage process thus preventing the worker from coming into contact with any faulted gas.

(4) After removing the SF_6 gas from the breaker, fill the breaker with nitrogen or dry air and allow at least 15 minutes before purging the gas from the breaker. This not only pressurizes the breaker to an atmospheric condition but also dilutes or neutralizes any of the gaseous residues remaining inside the breaker.

(5) After purging the gas from the breaker, open the breaker, and clean the inside of the breaker using a vacuum cleaner with a HEPA filter regardless of the condition of the gas. This procedure will remove any solid byproducts that may be present in the breaker and not detected in the gas sample. Also, it will remove any other loose material from the breaker assemblies. The breaker should also be wiped down with a rag to ensure that all powders and material have been removed.

    NOTE: When first opening the breaker and if the gas sample indicates no gaseous byproducts, solid byproducts may be present. To avoid contacting any solid byproducts the minimum PPE should be coveralls, gloves, a respirator with a HEPA/organic vapor/acid gases cartridge, and chemical safety goggles until the breaker is wiped down. If the gas sample indicates at least one gaseous byproduct exceeding the threshold limit values (TLV), the minimum PPE that should be worn until the breaker is wiped down includes: coveralls, gloves, chemical safety glasses, and air-supplied respirator or SCBA.

It is highly recommended that a small portable eye-wash, such as those used in battery rooms, be located at the worksite for emergency use. The Headquarters Division of Environmental Affairs has investigated the possiblity of the used water being classified as a hazardous waste. The conclusion was that it is not possible for the waste water to contain enough concentration of the byproducts to be considered a hazardous waste. It may be discharged onto the ground and not contained.

Appendix C - Suggested SF_6 Gas Sampling Procedure

To assure the validity of the SF_6 gas sample, it is important that the proper steps be followed when collecting the samples. Using the suggested procedure below in conjunction with taking the proper precautions during the sampling operations will enhance the quality of the gas samples. Refer to figure C.1 for the identification and position of the valves mentioned in the procedure.

1. Valve **4** (breaker sampling valve) should be in a closed position. NOTE: If the breaker does not have a sampling valve, the gas sampling equipment must include an emergency shutoff in place of the breaker sampling valve.
2. Make the equipment connections shown in figure C.1 and verify that the connections are tightened.
3. Close valve **2** (purging valve).
4. Open valve **1** (vacuum system valve).
5. Open valve **3** (cylinder valve).
6. Start the vacuum pump to evacuate the assembly to less than 140 microns.
7. After reaching a vacuum of 140 microns or less, continue running the vacuum pump for about 3 minutes to remove any moisture entrapped in the system.
8. Close valve **1** and leave the vacuum pump running to avoid an oil back-up condition in the lines.
9. Read the vacuum gauge pressure to check for a leak in the system. If the pressure rises in excess of 50 microns per minute, this indicates a leak in the sampling system. If a leak exists, check all connections and repeat the above steps until the sampling system can hold the proper vacuum.
10. With the pressure under 200 microns, open valve **4** slowly and allow the sampling system to reach equilibrium with the breaker pressure.
11. Close valve **4** and wait about a minute.
12. Open valve **2** to vent the system.
13. Close valve **2**.
14. Open valve **1** to stabilize the sampling system to approximately 150 microns.
15. To ensure moisture and impurities are removed from the sampling system, repeat steps 8 through 14 twice.
16. With the system pressure at 150 microns, close valve **1** and open valve **4**.
17. As the system pressure reaches equilibrium with the breaker pressure, close valve **3** tightly.
18. Close valve **4** tightly.
19. Open valve **2** to bleed the system.
20. Close valve **2** and slightly open valve **1** to further bleed the SF_6 trapped in the system.
21. Open and close valve **2** two or three times to continue bleeding the system.
22. Open valves **1** and **2** completely.
23. Turn off the vacuum pump and disconnect the sampling equipment.
24. Remove the filled sample cylinder and transport to a laboratory for analysis.

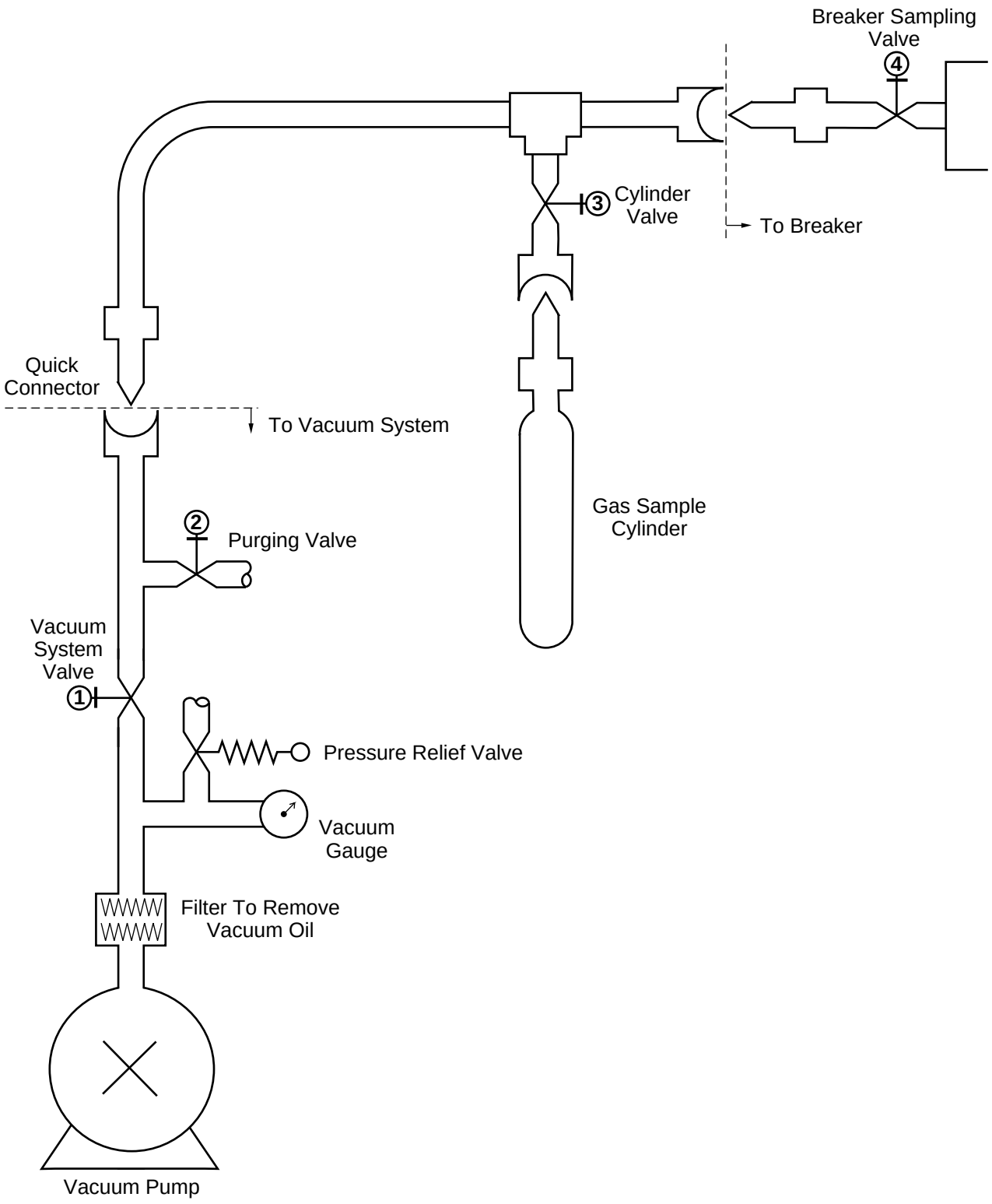


Figure C.1

SF_6 Gas Sampling Equipment