FACILITIES INSTRUCTIONS,
STANDARDS AND TECHNIQUES
VOLUME 3-16

MAINTENANCE OF POWER CIRCUIT BREAKERS

Internet Version of This Manual Created
December 1999

HYDROELECTRIC RESEARCH AND
TECHNICAL SERVICES GROUP

The Appearance of the Internet Version of This
Manual May differ From the Original, but the Contents Do Not

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
DENVER, COLORADO

Maintenance of Power Circuit Breakers
Volume 3-16

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SECTION I - IMPORTANCE OF ADEQUATE MAINTENANCE

The maintenance of circuit breakers deserves special consideration because of their importance for routine switching and for protection of other equipment. Electric transmission system breakups and equipment destruction can occur if a circuit breaker fails to operate because of a lack of preventive maintenance. The need for maintenance of circuit breakers is often not obvious as circuit breakers may remain idle, either open or closed, for long periods of time. Breakers that remain idle for 6 months or more should be made to open and close several times in succession to verify proper operation and remove any accumulation of dust or foreign material on moving parts and contacts.

SECTION 2 - MAINTENANCE OF MOLDED CASE CIRCUIT BREAKERS

2.1. FREQUENCY OF MAINTENANCE.- Molded case circuit breakers are designed to require little or no routine maintenance throughout their normal lifetime. Therefore, the need for preventive maintenance will vary depending on operating conditions. As an accumulation of dust on the latch surfaces may affect the operation of the breaker, molded case circuit breakers should be exercised at least once per year. Routine trip testing should be performed every 3 to 5 years.

2.2. ROUTINE MAINTENANCE TESTS.- Routine maintenance tests enable personnel to determine if breakers are able to perform their basic circuit protective functions. The following tests may be performed during routine maintenance and are aimed at assuring that the breakers are functionally operable. The following tests are to be made only on breakers and equipment that are deenergized.

2.2.1. Insulation resistance test.- A megohmmeter may be used to make tests between phases of opposite polarity and from current-carrying parts of the circuit breaker to ground. A test should also be made between the line and load terminals with the breaker in the open position. Load and line conductors should be disconnected from the breaker under insulation resistance tests to prevent test mesurements from also showing resistance of the attached circuit. Resistance values below 1 megohm are considered unsafe and the breaker should be inspected for possible contamination on its surfaces.

2.2.2. Millivolt drop test.- A millivolt drop test can disclose several abnormal conditions inside a breaker such as eroded contacts, contaminated contacts, or loose internal connections. The millivolt drop test should be made at a nominal direct-current voltage at 50 amperes or 100 amperes for large breakers, and at or below rating for smaller breakers. The millivolt drop is compared against manufacturer's data for the breaker being tested.

2.2.3. Connections test.- The connections to the circuit breaker should be inspected to determine that a good joint is present and that overheating is not occurring. If overheating is indicated by discoloration or signs of arcing, the connections should be removed and the connecting surfaces cleaned.

2.2.4. Overload tripping test.- The proper action of the overload tripping components of the circuit breaker can be verified by applying 300 percent of the breaker rated continuous current to each pole. The significant part of this test is the automatic opening of the circuit breaker and not tripping times as these can be greatly affected by ambient conditions and test conditions.

2.2.5. Mechanical operation.- The mechanical operation of the breaker should be checked by turning the breaker on and off several times.

SECTION 3 - MAINTENANCE OF LOW-VOLTAGE CIRCUIT BREAKERS

3.1. FREQUENCY OF MAINTENANCE.- Low-voltage circuit breakers operating at 600 volts alternating current and below should be inspected and maintained very 1 to 3 years, depending on their service and operating conditions. Conditions that make frequency maintenance and inspection necessary are:

a. High humidity and high ambient temperature.

b. Dusty or dirty atmosphere.

c. Corrosive atmosphere.

d. Frequent switching operations.

e. Frequent fault operations.

f. Older equipment.

A breaker should be inspected and maintained if necessary whenever it has interrupted current at or near its rated capacity.

3.2. MAINTENANCE PROCEDURES. - Manufacturer's instructions for each circuit breaker should be carefully read and followed. The following are general procedures that should be followed in the maintenance of low-voltage air circuit breakers:

a. An initial check of the breaker should be made in the TEST position prior to withdrawing it from to enclosure.

b. Insulating parts, including bushings, should be wiped clean of dust and smoke.

c. The alignment and condition of the movable and stationary contacts should be checked and adjusted according to the manufacturer's instruction book.

d. Check arc chutes and replaces any damaged parts.

e. Inspect breaker operating mechanism for loose hardware and missing or broken cotter pins, etc. Examine cam, latch, and roller surfaces for damage or wear.

f. Clean and relubricate operating mechanism with a light machine oil (SAE-20 or 30) for pins and bearings and with a nonhardening grease for the wearing surfaces of cams, rollers, etc.

g. Set breaker operating mechanism adjustments as described in the manufacturer's instruction book. If these adjustments cannot be made within the specified tolerances, it may indicate excessive wear and the need for a complete overhaul.

h. Replace contacts if badly worn or burned and check control device for freedom of operation.

I. Inspect wiring connections for tightness.

j. Check after servicing circuit breaker to verify the contacts move to the fully opened and fully closed positions, that there is an absence of friction or binding, and that electrical operation is functional.

SECTION 4 - MAINTENANCE OF MEDIUM-VOLTAGE CIRCUIT BREAKERS

4.1. FREQUENCY OF MAINTENANCE.- Medium-voltage circuit breakers which operate in the range of 600 to 15,000 volts should be inspected and maintained annually or after every 2,000 operations, whichever comes first. The above maintenance schedule is recommended by the applicable standards to achieve required performance from the breakers.

4.2. SAFETY PRACTICES.- Maintenance procedures include the safety practices indicated in the ROMSS (Reclamation Operation & Maintenance Safety Standards) and following points that require special attention.

a. Be sure the circuit breaker and its mechanism are disconnected from all electric power, both high voltage and control voltage, before it is inspected or repaired.

b. Exhaust the pressure from air receiver of any compressed air circuit breaker before it is inspected or repaired.

c. After the circuit breaker has been disconnected from the electrical power, attach the grounding leads properly before touching any of the circuit breaker parts.

d. Do no lay tools down on the equipment while working on it as they may be forgotten when the equipment is placed back in service.

4.3. MAINTENANCE PROCEDURES FOR MEDIUM-VOLTAGE AIR CIRCUIT BREAKERS.- The following suggestions are for use in conjunction with manufacturer's instruction books for the maintenance of medium-voltage air circuit breakers:

a. Clean the insulating parts including the bushings.

b. Check the alignment and condition of movable and stationary contacts and adjust them per the manufacturer's data.

c. See that bolts, nuts, washers, cotter pins, and all terminal connections are in place and tight.

d. Check arc chutes for damage and replace damaged parts.

e. Clean and lubricate the operating mechanism and adjust it as described in the instruction book. If the operating mechanism cannot be brought into specified tolerances, it will usually indicate excessive wear and the need for a complete overhaul.

f. Check, after servicing, circuit breaker to verify that contacts move to the fully opened and fully closed positions, that there is an absence of friction or binding, and that electrical operation is functional.

4.4. MAINTENANCE PROCEDURES FOR MEDIUM-VOLTAGE OIL CIRCUIT BREAKERS.- The following suggestions are for use in conjunction with the manufacturer's instruction books for the maintenance of medium-voltage oil circuit breakers:

a. Check the condition, alignment, and adjustment of the contacts.

b. Thoroughly clean the tank and other parts which have been in contact with the oil.

c. Test the dielectric strength of the oil and filter or replace the oil if the dielectric strength is less than 22 kV. The oil should be filtered or replaced whenever a visual inspection shows an excessive amount of carbon, even if the dielectric strength is satisfactory.

d. Check breaker and operating mechanisms for loose hardware and missing or broken cotter pins, retaining rings, etc.

e. Adjust breaker as indicated in instruction book.

f. Clean and lubricate operating mechanism.

g. Before replacing the tank, check to see there is no friction or binding that would hinder the breaker's operation. Also check the electrical operation. Avoid operating the breaker any more than necessary without oil in the tank as it is designed to operate in oil and mechanical damage can result from excessive operation without it.

h. When replacing the tank and refilling it with oil, be sure the gaskets are undamaged and all nuts and valves are tightened properly to prevent leakage.

4.5. MAINTENANCE PROCEDURES FOR MEDIUM-VOLTAGE VACUUM CIRCUIT BREAKERS.- Direct inspection of the primary contacts is not possible as they are enclosed in vacuum containers. The operating mechanisms are similar to the breakers discussed earlier and may be maintained in the same manner. The following two maintenance checks are suggested for the primary contacts:

a. Measuring the change in external shaft position after a period of use can indicate extent of contact erosion. Consult the manufacturer's instruction book.

b. Condition of the vacuum can be checked by a hi-pot test. Consult the manufacturer's instruction book.

SECTION 5 - MAINTENANCE OF HIGH-VOLTAGE CIRCUIT BREAKERS

5.1. FREQUENCY OF INSPECTIONS.- Most manufacturers recommend complate inspections, external and internal, at intervals of from 6 to 12 months. Experience has shown that a considerable expense is involved, some of which may be unnecessary, in adhering to the manufacturer's recommendations of internal inspections at 6- to 12-month intervals. With proper external checks, part of the expense, delay, and labor of internal inspections may be avoided without sacrifice of dependability.

5.1.1. Inspection schedule for new breakers.- A temporary schedule of frequent inspections is necessary after the erection of new equipment, the modification or modernization of old equipment, or the replication of old equipment under different conditions. The temporary schedule is required to Correct internal defects which ordinarily appear in the first year of service and to correlate external check procedures with internal conditions as a basis for more conservative maintenance program thereafter. Assuming that a circuit breaker shows no serious defects at the early complete inspections and no heavy interrupting duty is imposed, the following inspection schedule is recommended:

6 months after erection	Complete inspection and adjustment
12 months after previous inspection	Complete inspection and adjustment
12 months after previous inspection	Complete inspection and adjustment
12 months after previous inspection	External checks and inspection; if checks are satisfactory, no internal inspection
12 months after previous inspection	Complete inspection and adjustment

5.1.2. Inspection schedule for existing breakers.- The inspection schedule should be based by the interrupting duty imposed on the breaker. It is advisable to make a complete internal inspection after the first severe fault interruption. If internal conditions are satisfactory, progressively more fault interruptions may be allowed before an internal inspection is made. Average experience indicates that up to five fault interruptions are allowable between inspections on 230 kV and above circuit breakers, and up to 10 fault interruptions are allowable on circuit breakers rated under 230 kV. Normally, no more than 2 years should elapse between external inspections or 4 years between internal inspections.

5.2. EXTERNAL INSPECTION GUIDELINES.- The following items should be included in an external inspection of a high-voltage breaker.

a. Visually inspect PCB externals and operating mechanism. The tripping latches should be examined with special care since small errors in adjustments and clearances and roughness of the latching surfaces may cause the breaker to fail to latch properly or increase the force necessary to trip the breaker to such an extent that electrical tripping will not always be successful, especially if the tripping voltage is low. Excessive "opening" spring pressure can cause excessive friction at the tripping latch and should be avoided. Also, some extra pressure against the tripping latch may be caused by the electromagnetic forces due to flow of heavy short-circuit currents through the breaker. Lubrication of the bearing surfaces of the operating mechanism should be made as recommended in the manufacturer's instruction book, but excessive lubrication should be avoided as oily surfaces collect dust and grit and get stiff in cold weather, resulting in excessive friction.

b. Check oil dielectric strength and color for oil breakers. The dielectric strength must be maintained to pre vent internal breakdown under voltage surges and to enable the interrupter to function properly since its action depends upon changing the internal arc path from a fair conductor to a good insulator in the short interval while the current is passing through zero. Manufacturer's instructions state the lowest allowable dielectric strength for the various circuit breakers. It is advisable to maintain the dielectric strength above 20 kV even though some manufacturer's instructions allow 16 kV. Detailed instructions for oil testing are found in FIST Volume 3-5.

If the oil is carbonized, filtering may remove the suspended particles, but the interrupters, bushings, etc., must be wiped clean. If the dielectric strength is lowered by moisture, an inspection of the fiber and wood parts is advisable and the source of the moisture should be corrected. For these reasons, it is rarely worthwhile to filter the oil in a circuit breaker while it is in service.

c. Observe breaker operation under load.

d. Operate breaker manually and electrically and observe for malfunction. The presence of excessive friction in the tripping mechanism and the margin of safety in the tripping function should be determined by making a test of the minimum voltage required to trip the breaker. This can be accomplished by connecting a switch and rheostat in series in the trip-coil circuit at the breaker (across the terminals to the remote control switch) and a voltmeter across the trip coil. Staring with not over 50 percent of rated trip-coil voltage, gradually increase the voltage until the trip-coil plunger picks up and successfully trips the breaker and record the minimum tripping voltage. Most breakers should trip at about 56 percent of rated trip-coil voltage. The trip-coil resistance should be measured and compared with the factor test value to disclose shorted turns.

Most modern breakers have trip coils which will overheat or burn out if left energized for more than a short period. An auxiliary switch is used in series with the coil to open the circuit as soon as the breaker has closed. The auxiliary switch must be properly adjusted and successfully break the arc without damage to the contacts.

Tests should also be made to determine the minimum voltage which will close the breaker and the closing coil resistance.

e. Trip breaker from protective relays.

f. Check operating mechanism adjustments. Measurements of the mechanical clearances of the operating mechanism associated with the tank or pole should be made. Appreciable variation between the value found and the setting when erected or after the last maintenance overhaul is erected or after the last maintenance overhaul is usually an indication of mechanical trouble. Temperature and difference of temperature between different parts of the mechanism effect the clearances some. The manufacturers' recommended tolerances usually allow for these effects.

g. Doble test bushings and breaker.

Table I - Maximum Contact Resistance

Air circuit breakers			Oil circuit breakers		
kV	**Amperes**	**Microhms**	**kV**	**Amperes**	**Microhms**
5-15	600	100	7.2-15	600	300
	1200	50		1200	150
	2000	50		2000	75
				4000	40
			23-24	All	500
			46	All	700
			69	600	500
				1200	500
				2000	100
			115-230	All	800

h. Measure contact resistance. As long as no foreign material is present, the contact resistance of high-pressure, butt-type contacts is practically independent of surface condition. Nevertheless, measurement of the electrical resistance between external bushing terminals of each pole may be regarded as the final "proof of the pudding." Any abnormal increase in the resistance of this circuit may be an indication of foreign material in contacts, contact loose in support, loose jumper, or loose bushing connection. Any one of these may cause localized heating and deterioration. The amount of heat above normal may be readily calculated from the increase in resistance and the current.

Resistance of the main contact circuits can be most conveniently measured with a portable double bridge (Kelvin) or a "Ducter." The breaker contacts should not be opened during this test because of possible damage to the test equipment.

Table 1 gives maximum contact resistances for typical classes of breakers.

I. Make time-travel or motion-analyzer records. Circuit breaker motion analyzers are portable devices designed to monitor the operation of power circuit breakers which permit mechanical coupling of the motion analyzer to the circuit breaker operating rod. These include high-voltage and extra- high-voltage dead tank and SF_6 breakers and low-voltage air and vacuum circuit breakers. Motion analyzers can provide graphic records of close or open initiation signals, contact closing or opening time with respect to initiation signals, contact movement and velocity, and contact bounce or rebound. The records obtained not only indicated when mechanical difficulties are present but also help isolate the cause of the difficulties. It is preferable to obtain a motion-analyzer record on a breaker when it is first installed. This will provide a master record which can be filed and used for comparison with future maintenance checks. Tripping and closing voltages should be recorded on the master record so subsequent tests can be performed under comparable conditions.

Time-travel records are taken on the pole nearest the operating mechanism to avoid the inconsistencies due to linkage vibration and slack in the remote phases.

5.3. INTERNAL INSPECTION GUIDELINES.- An internal inspection should include all items listed for an external inspection, plus the breaker tanks or contact heads should be opened and the contacts nd interrupting parts should be inspected. These guidelines are not intended to be a complete list of breaker maintenance but are intended to provide an idea of the scope of each inspection.

A specific checklist should be developed in the field for each type of inspection for each circuit breaker maintained.

5.4. TYPICAL INTERNAL BREAKER PROBLEMS.- The following difficulties should be looked for during internal breaker inspections:

a. Tendency for keys, bolts (especially fiber), cotter pins, etc, to come loose.

b. Tendency for wood operating rods, supports, or guides to come loose from clamps or mountings.

c. Tendency for carbon or sludge to form and accumulate in interrupter or on bushings.

d. Tendency for interrupter to flash over and rupture static shield or resistor.

e. Tendency for interrupter parts or barriers to burn or erode.

f. Tendency for bushing gaskets to leak moisture into breaker insulating material.

Fortunately, these difficulties are most likely to appear early in the use of a breaker and would be disclosed by the early internal inspections. As unsatisfactory internal conditions are corrected and after one or two inspections show the internal conditions to be satisfactory, the frequency of internal inspections may safely be decreased.

5.5. INFLUENCE OF DUTY IMPOSED.-

5.5.1. Influence of light duty.- Internal inspection of a circuit breaker which has had no interruption duty or switching since the previous inspection will not be particularly beneficial although it will not be a total loss. If the breaker has been energized, but open, erosion in the form or irregular grooves (called tracking) on the inner surface of the interrupter or shields may appear due to electrostatic charging current. This is usually aggravated by a deposit of carbon sludge which has previously been generated by some interrupting operation. If the breaker has remained closed and carrying current, evidence of heating of the contacts may be found if the contact surfaces were not clean, have oxidized, or if the contact pressure was improper. Any shrinkage and loosening of wood or fiber parts (due to loss of absorbed moisture into the dry oil) will take place following erection, whether the breaker is operated or not. Mechanical operation, however, will make any loosening more evident. It is worthwhile to deliberately impose several switching operations on the breaker before inspection if possible. If this is impossible, some additional information may be gained by operating the breaker several times after it is deenergized, measuring the contact resistance of each pole initially and after each operation.

5.5.2. Influence of normal duty.- The relative severity of duty imposed by load switching, line dropping, and fault interruptions depends upon the type of circuit breaker involved. In circuit breakers which employ an oil blast generated by the power arc, the interruption of light faults or the interruption of line charging current may cause more deterioration than the interruption of heavy faults within the rating of the breaker because of low oil pressure. In some designs using this basic principle of interruption, distress at light interrupting duty is minimized by multiple breaks, rapid contact travel, and turbulence of the oil caused by movement of the contact and mechanism. In designs employing a mechanically driven piston to supplement the arc-driven oil blast, the performance is more uniform. Still more uniform performance is usually yielded by designs which depend for arc interruption upon an oil blast driven by mechanical means. In the latter types, erosion of the contacts may appear only with heavy interruptions. The mechanical stresses which accompany heavy interruptions are always more severe.

These variations of characteristic performance among various designs must be considered when judging the need for maintenance from the service records and when judging the performance of a breaker from evidence on inspection. Because of these variations, the practice of evaluating each fault interruption as equivalent to 100 no-load operations, employed by some companies, is necessarily very approximate although it may be a useful guide in the absence of any other information.

5.5.3. Influence of severe duty.- Erosion of the contacts and damage from severe mechanical stresses may occur during large fault interruption. The most reliable indication of the stress to which a circuit breaker is subjected during fault interruptions is afforded by automatic oscillograph records. Deterioration of the circuit breaker may be assumed to be proportional to the energy dissipated in the breaker during the interruption. The energy dissipated is approximately proportional to the current and the duration of arcing; that is, the time from parting of the contacts to interruption of the current. However, the parting of contacts is not always evident on the oscillograms, and it is sometimes necessary to determine this from indicated relay time and the known time for breaker contacts to part. Where automatic oscillograph records are available, they may be as useful in guiding oil circuit breaker maintenance as in showing relay and system performance.

Where automatic oscillographs are not available, a very approximate, but nevertheless useful, indication of fault duty imposed on the circuit breakers may be obtained from relay operation targets and accompanying system conditions. All such data should be tabulated in the circuit breaker maintenance file.

SECTION 6 - MAINTENANCE OF SF_6 GAS CIRCUIT BREAKERS

6.1. PROPERTIES OF SF_6 (SULFUR HEXAFLUORIDE) GAS. -

a. Toxicity.- SF_6 is odorless, colorless, tasteless, and nontoxic in its pure state. It can, however, exclude oxygen and cause suffocation. If the normal oxygen content of air is reduced from 21 percent to less than 13 percent, suffocation can occur without warning. Therefore, circuit breaker tanks should be purged out after opening.

b. Toxicity of arc products.- Toxic decomposition products are formed when SF_6 gas is subjected to an electric arc. The decomposition products are metal fluorides and form a white or tan powder. Toxic gases are also formed which have the characteristic odor of rotten eggs. Do not breathe the vapors remaining in a circuit breaker where arcing or corona discharges have occurred in the gas. Evacuate the faulted SF_6 gas from the circuit breaker and flush with fresh air before working on the circuit breaker.

c. Physical properties.- SF_6 is one of the heaviest known gases with a density about five times the density of air under similar conditions. SF_6 shows little change in vapor pressure over a wide temperature range and is a soft gas in that it is more compressible dynamically than air. The heat transfer coefficient of SF_6 is greater than air and its cooling characteristics by convection are about 1.6 times air.

d. Dielectric strength.- SF_6 has a dielectric strength about three times that of air at one atmosphere pressure for a given electrode spacing. The dielectric strength increases with increasing pressure; and at three atmospheres, the dielectric strength is roughly equivalent to transformer oil. The heaters for SF_6 in circuit breakers are required to keep the gas from liquefying because, as the gas liquifies, the pressure drops, lowering the dielectric strength. The exact dielectric strength, as compared to air, varies with electrical configuration, electrode spacing, and electrode configuration.

e. Arc quenching.- SF_6 is approximately 100 times more effective than air in quenching spurious arcing. SF_6 also has a high thermal heat capacity that can absorb the energy of the arc without much of a temperature rise.

f. Electrical arc breakdown.- Because of the arc-quenching ability of SF_6, corona and arcing in SF_6 does not occur until way past the voltage level of onset of corona and arcing in air. SF_6 will slowly decompose when exposed to continuous corona.

All SF_6 breakdown or arc products are toxic. Normal circuit breaker operation produces small quantities of arc products during current interruption which normally recombine to SF_6. Arc products which do not recombine, or which combine with any oxygen or moisture present, are normally removed by the molecular sieve filter material within the circuit breaker.

6.2. HANDLING NONFAULTED SF_6.

The procedures for handling nonfaulted SF_6 are well covered in manufacturers' instruction books. These procedures normally consist of removing the SF_6 from the circuit breaker, filtering and storing it in a gas cart as a liquid, and transferring it back to the circuit breaker after the circuit breaker maintenance has been performed. No special dress or precautions are required when handling nonfaulted SF_6.

6.3. HANDLING FAULTED SF_6.-

6.3.1 Toxicity.-

a. Faulted SF_6 gas.- Faulted SF_6 gas smells like rotten eggs and can cause nausea and minor irritation of the eyes and upper respiratory tract. Normally, faulted SF_6 gas is so foul smelling no one can stand exposure long enough at a concentration high enough to cause permanent damage.

b. Solid arc products.- Solid arc products are toxic and are a white or off-white, ashlike powder. Contact with the skin may cause an irritation or possible painful fluoride burn. If solid arc products come in contact with the skin, wash immediately with a large amount of water. If water is not available, vacuum off arc products with a vacuum cleaner.

6.3.2 Clothing and safety equipment requirements.- When handling and removing solid arc products from faulted SF_6, the following clothing and safety equipment should be worn:

a. Coveralls.- Coveralls must be worn when removing solid arc products. Coveralls are not required after all solid arc products are cleaned up. Disposable coveralls are recommended for use when removing solid arc products; however, regular coveralls can be worn if disposable ones are not available, provided they are washed at the end of each day.

b. Hoods.- Hoods must be worn when removing solid arc products from inside a faulted dead-tank circuit breaker.

c. Gloves.- Gloves must be worn when solid arc products are hahdied. Inexpensive, disposable gloves are recommended. Nondisposable gloves must be washed in water and allowed to drip-dry after use.

d. Boots.- Slip-on boots, nondisposable or plastic disposable, must be worn by employees who enter eternally faulted dead-tank circuit breakers. Slip-on boots are not required after the removal of solid arc products and vacuuming. Nondisposable boots must be washed in water and dried after use.

e. Safety glasses.- Safety glasses are recommended when handling solid arc products if a full face respirator is not worn.

f. Respirator.- A cartridge, dust-type respirator is required when entering an internally faulted dead-tank circuit breaker. The respirator will remove solid arc products from air breathed, but it does not supply oxygen so it must only be used when there is sufficient oxygen to support life.

The filter and cartridge should be changed when an odor is sensed through the respirator. The use of respirators is optional for work on circuit breakers whose interrupter units are not large enough for a man to enter and the units are well ventilated.

Air-line-type respirators should be used when the cartridge type is ineffective due to providing too short a work time before the cartridge becomes contaminated and an odor is sensed.

When an air-line respirator is used, a minimum of two working respirators must be available on the job before any employee is allowed to enter the circuit breaker tank.

6.3.3 Disposal of waste.- All materials used in the cleanup operation for large quantities of SF_6 arc products shall be placed in a 55-gal drum and disposed of as hazardous waste. The following items should be disposed of:

a. All solid arc products

b. All disposable protective clothing

c. All cleaning rags

d. Filters from respirators

e. Molecular sieve from breaker and gas cart

f. Vacuum filter element.