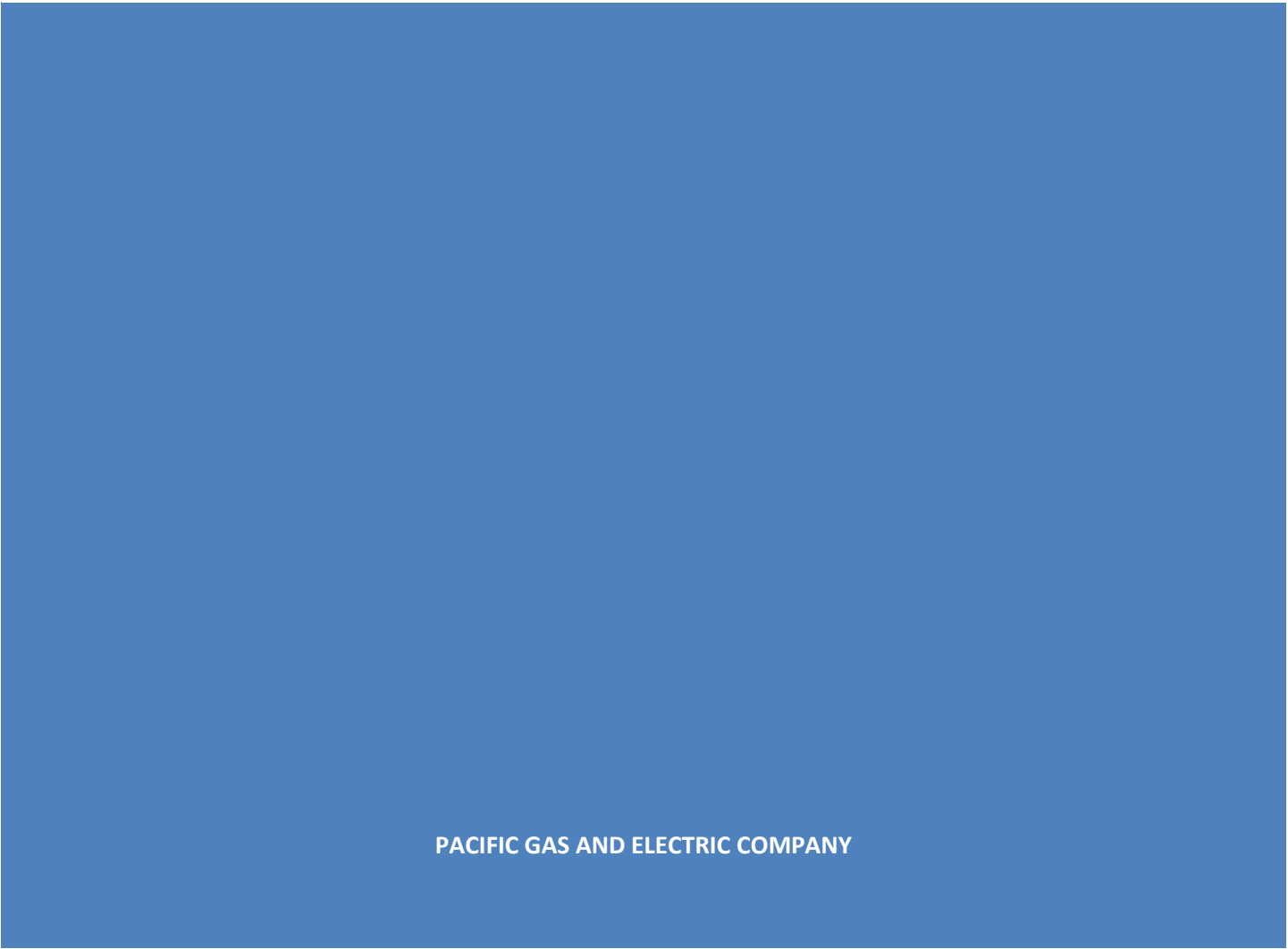


*SUBSTATION MAINTENANCE
AND CONSTRUCTION MANUAL
CIRCUIT BREAKERS BOOKLET*



PACIFIC GAS AND ELECTRIC COMPANY

Circuit Breakers

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Attachment

Attachment 1, “Transmission Asset Management Transmission Overstressed Circuit Breakers
Annual Report–Year 2019”

Circuit Breakers

Section 1: Introduction

I. Purpose

The [*Substation Maintenance and Construction Manual \(SMCM\)*](#), “Circuit Breakers,” booklet provides information to substation maintenance employees about installing, maintaining, and safely handling all varieties of transmission and distribution power circuit breakers. It covers all Company substation circuit breakers, including those that are in service, in storage, or being received and installed.

II. Safety

A. Manufacturer’s Instructions

1. **Always** use the manufacturer’s instructions for more detailed information, including safety precautions, when performing any maintenance.
2. Most manufacturer’s instructions contain important safety information. Not all of that information is listed in the [*SMCM*](#).
3. Employees are responsible for understanding the maintenance and safety requirements for each piece of equipment before beginning work.

B. Using Manual, Slow-Closing Devices

For circuit breakers equipped with manual, slow-closing devices:

1. **Never** use the slow-closing device to operate an energized circuit breaker. These devices are designed strictly for operating a cleared, de-energized circuit breaker for maintenance.
2. After making any mechanical adjustments and/or installing or re-assembling any circuit-breaker components, slow-close the circuit breaker by hand before attempting electrical operations.
3. **Always** refer to the manufacturer’s instructions for the proper procedure for slow-closing a circuit breaker. Some manufacturers do not recommend slow-closing specific types of circuit breakers.

C. Using and Labeling Manually Actuated, Mechanical Opening Devices

1. All circuit breakers, except some of the sulfur hexafluoride (SF₆) types, are equipped with manually actuated, mechanical operating devices. The manufacturers mark these devices with a decal or metal plate that reads, “Emergency Trip.” Some devices also have an arrow pointing to the handle.

Section 1, Subsection II.C.2

2. All circuit breakers with manually actuated, mechanical opening devices marked “Emergency Trip” **must be relabeled** using new decals that read, “Maintenance Opening Device Only, Do Not Operate When Breaker Is Energized” (Code 372621). Yellow arrow decals (Code 372620) that point to the handle may be used as well.
3. Remove the raised-metal plates marked “Emergency Trip” before affixing the new decal if the plates will distort the decal or interfere with its adhesion.



Caution

Do not use manually actuated, mechanical operating devices to trip an **energized** circuit breaker without obtaining permission from the substation maintenance supervisor.

4. At the discretion of the maintenance supervisor, a manually actuated, mechanical opening device may be operated to trip an energized circuit breaker, but only after performing the following actions.
 - a. Verify the extent of any mechanical or electrical problems to the safest extent possible.
 - b. Based on the inspection results and the breaker’s operating system configuration, the breaker may be operated, if it is safe to do so.

Section 1, Subsection II.D

D. Working on Equipment with Stored-Energy Operators

For equipment with stored-energy operators, ensure that the equipment is placed in a safe condition **before** working on any part of the operating system (i.e., spring-charged, pneumatic, hydraulic, or “pneudraulic”). Refer to the manufacturer’s instructions and safety precautions.



WARNING

Do not attempt to tighten fittings or connections on pressurized hydraulic or pneumatic systems. Doing so could cause a failure and lead to high pressure injection injury. When working on these systems, reduce the operating pressure prior to working on the equipment.

E. Working in Elevated Positions and Protecting Bushings

1. Before working in an elevated position (whether inside or outside a unit), crew members **must** know, understand, and carry out all of the safe work practices applicable to the work they are performing, as required by [Utility Standard D-S0421, “Fall Protection and Prevention.”](#)
2. When working in an elevated position above porcelain bushings, insulators, and other equipment that could be damaged by falling objects or tools, ensure that the equipment is barricaded, shielded, or otherwise protected from possible damage.

F. Overstressed Transmission Class Circuit Breakers

1. Any circuit breaker could fail to interrupt a fault. Overstress conditions occur when the magnitude of a short circuit exceeds the interrupting capability of the circuit breaker. Circuit breakers with significant overstress could have a higher chance of failing to interrupt a fault. A circuit breaker failing to interrupt a fault could present a safety hazard. The probability of a failure when personnel are present is very low. However, taking some simple precautions to reduce exposure will further reduce the risk of employee injury.

Section 1, Subsection II.E.2.

2. Follow the precautions below when working near any energized circuit breaker:

**WARNING**

- **Do not stand near or underneath tank vents on circuit breakers. The resulting internal arc energy could cause hot oil or gasses to be expelled from the vents and subsequent fire. The likelihood of a tank rupture is extremely low. The arc may also cause an internal phase-to-ground fault.**
- **Do not stand near pressure relief discs on SF₆ circuit breakers. Hot gases could be expelled from the pressure relief disc. The arc may also cause an internal phase-to-ground fault.**

3. [Table 1, “Overstress Transmission Circuit Breakers Identified in 2019,”](#) on Page 5, includes a list of circuit breakers that could be subjected to a significant overstress condition, depending on the magnitude of the fault. The significant overstressed transmission breakers are planned to be mitigated (by either reducing the fault level or replacing the breaker) within 5 years. All other overstressed transmission breakers will be mitigated within 8 years. For more information, see Attachment 1, “Overstress Transmission Circuit Breakers Identified in 2019.”

Check with Substation Asset Strategy for any changes. Annual updates are planned for July of each year per [Utility Procedure TD-3350P-19, “Substation Overstressed Circuit Breaker Identification.”](#)

Circuit Breakers

Section 1, Subsection II.F.3., continued

Table 1. Overstress Transmission Circuit Breakers Identified in 2019 (Sorted by Substation Name)

SAP Equipment I.D.	Substation	CB #	Nominal Voltage (kV)	Manufacturer	Model	Interrupt Medium	2018- 2019 %Overstress
40995457	BANTA	72	60	Pacific Electric Manufacturing	JE42E	OIL	99%
40995909	EL CERRITO G	142	115	General Electric	FK1155000	OIL	135%
40995893	EL CERRITO G	112	115	Westinghouse	GM5	OIL	105%
40995892	EL CERRITO G	152	115	General Electric	FK4393500	OIL	99%
40995918	EL CERRITO G	162	115	General Electric	FK1155000	OIL	99%
40995917	EL CERRITO G	192	115	General Electric	FK1155000	OIL	99%
40995922	EL PATIO	142	115	Westinghouse	GM5A	OIL	144%
40995921	EL PATIO	312	115	General Electric	FK1155000	OIL	99%
40995919	EL PATIO	332	115	General Electric	FK1155000	OIL	99%
40995944	EVERGREEN	42	60	Federal Pacific Electric	JE42E	OIL	99%
40996001	GATES	292	230	Federal Pacific Electric	RHE9023015000	OIL	111%
40996199	INDUSTRIAL ACRES	72	60	Pacific Electric Manufacturing	JE42E	OIL	109%
40992643	KERN PP	262	115	Siemens	TCP121402000	SF6	110%
40992646	KERN PP	142	115	Siemens	TCP121402000	SF6	110%
40992645	KERN PP	282	115	Siemens	TCP121402000	SF6	110%
40992644	KERN PP	272	115	Siemens	TCP121402000	SF6	110%
40996358	LODI	22	60	Pacific Electric Manufacturing	JE42E	OIL	109%
41114454	MIDWAY	732	500	Asea Brown Boveri	550PM4032	SF6	106%
40991006	MIDWAY	812	500	Asea Brown Boveri	550PM4033	SF6	106%
40990991	MIDWAY	842	500	Asea Brown Boveri	550PM4036	SF6	106%
41116281	MIDWAY	832	500	Asea Brown Boveri	550PM4035	SF6	101%
40991011	MIDWAY	722	500	Asea Brown Boveri	550PM4031	SF6	100%
40991009	MIDWAY	822	500	Asea Brown Boveri	550PM4034	SF6	100%
40991789	MIDWAY	712	500	Asea Brown Boveri	550PM4030	SF6	98%
40996625	MORAGA	712	115	General Electric	FK115100001	OIL	100%
40996624	MORAGA	622	115	General Electric	FK115100001	OIL	99%
40996620	MORAGA	612	115	General Electric	FK115100001	OIL	99%
40996621	MORAGA	642	115	General Electric	FK115100001	OIL	99%

Section 1, Subsection II.F.3., continued

Table 1. Overstress Transmission Circuit Breakers Identified in 2019 (Sorted by Substation Name), continued

SAP Equipment I.D.	Substation	CB #	Nominal Voltage (kV)	Manufacturer	Model	Interrupt Medium	2018- 2019 %Overstress
40996811	PALO ALTO SW STA	412	115	Mc Graw Edison1	AHE481155000	OIL	106%
40996810	PALO ALTO SW STA	442	115	Mc Graw Edison2	AHE481155001	OIL	106%
40996807	PALO ALTO SW STA	452	115	Mc Graw Edison3	AHE481155002	OIL	106%
40996809	PALO ALTO SW STA	512	115	Mc Graw Edison4	AHE481155003	OIL	106%
40996808	PALO ALTO SW STA	552	115	Mc Graw Edison5	AHE481155004	OIL	106%
40997239	SAN LEANDRO U	182	115	General Electric	FK439115	OIL	103%
40997258	SAN LEANDRO U	372	115	General Electric	FK439115	OIL	103%
40997239	SAN LEANDRO U	182	115	General Electric	FK439115	OIL	103%
40997258	SAN LEANDRO U	372	115	General Electric	FK439115	OIL	103%
40997081	SANGER	432	115	ITE	115KM500012	OIL	116%
40997082	SANGER	500	115	ITE	115KM500012	OIL	116%
40997077	SANGER	522	115	ITE	115KM500012	OIL	116%
40997083	SANGER	542	115	General Electric	FK11550002	OIL	116%
40997080	SANGER	552	115	ITE	115KM500012	OIL	112%
40997079	SANGER	662	115	ITE	115KM500012	OIL	116%
40997078	SANGER	412	115	ITE	115KM500012	OIL	110%
42614789	TESLA	842	230	Asea Brown Boveri	245PMG6330B	SF6	105%
41176926	TESLA	382	230	Asea Brown Boveri	242PMG6330	SF6	104%
41138846	TESLA	372	230	Mitsubishi	200SFMT63F	SF6	103%
40993779	TESLA	322	230	Asea Brown Boveri	242PA5020	SF6	99%
41121038	TESLA	312	230	Asea Brown Boveri	242PMG6330	SF6	99%
40993780	TESLA	332	230	Asea Brown Boveri	242PA5020	SF6	98%
41139106	TESLA	342	230	Asea Brown Boveri	PMG6340	SF6	98%
40989907	VACA DIXON	462	230	Mitsubishi	200SFMT40B	SF6	112%
40990423	VACA DIXON	452	230	Mitsubishi	200SFMT40E	SF6	111%
40989908	VACA DIXON	442	230	Mitsubishi	200SFMT40B	SF6	111%

Section 1, Subsection III, continued

III. General Information

A. Using Diagrams

1. **Always** use the elementary and/or connection diagrams when testing or troubleshooting circuit-breaker controls.
2. Maintain these prints in an orderly manner, and ensure they remain in good condition.

B. Inspecting Insulating Oil or Gas

Always ensure that all insulating oil or gas is dry and free of dielectric contaminants before adding it to the circuit breaker. This prevents high-voltage flashovers caused by moisture or other contaminants that conduct electricity.

C. Working on Relays and Meters

Perform relay and meter diagnostic and service work when triggered by [Utility Standard TD-3322S, "Substation Equipment Maintenance Requirements,"](#) Attachment 7, "[Circuit Breaker Maintenance Template.](#)" If possible, perform this work in conjunction with other circuit-breaker maintenance to save on clearance costs.

D. Maintaining Reclosers Used as Substation Circuit Breakers



CAUTION

Always refer to the manufacturer's instructions for more detailed information, including safety precautions, before performing any maintenance.

1. Accumulated Critical Current (ACC)

- a. Overhaul reclosers based on their ACC counts when they are used as substation circuit breakers.
- b. Reclosers with Cooper Form 4C or newer controls are programmable and can be adjusted to indicate when they reach 100% ACC. Use the Duty Cycle function, which is set according to the type of interrupters on the recloser. If a new fault has occurred since the last inspection, use the 4C-control Duty Cycle function to monitor the ACC percentage. Record the ACC percentage on the station inspection form.
- c. When performing **relay tests** on Cooper Form 4C or newer controls, the accumulation of fault current can be disabled **temporarily** by turning off the appropriate codes or items from the menu commands for each phase. Ensure that the fault-current recording is restored after testing the relays. **Do not reset** the accumulated current. See the Cooper manual for complete instructions.
- d. Use the Systems Applications and Products in Data Processing (SAP) Work Management System (WMS) fault tables to track the ACC count on reclosers with 3A controls.

Section 1, Subsection III.D.2.**2. Oil-Filled Reclosers**

- a. Do not perform periodic Breaker Oil Analysis (BOA)[™] tests on oil-filled reclosers.
- b. An oil-filled recloser does not require a separate mechanism service. Perform any necessary service tasks while overhauling the

3. Vacuum-Type Reclosers

A vacuum-type recloser contains either a separate or an integrated operating mechanism in its housing. Perform a vacuum-circuit-breaker mechanism service on this type of recloser when triggered by the Utility Standard TD-3322S [Attachment 7](#) maintenance template.

4. Testing Reclosers

- a. Functional-performance tests are not required on reclosers used as substation circuit breakers.
- b. Test the overcurrent protection on reclosers according to the time-based, nondirectional-overcurrent relay triggers provided in the [Protective Equipment Standard Test Procedures \(PESTP\) Manual](#).

5. Recloser Maintenance Forms

Use the appropriate circuit breaker maintenance form when servicing reclosers that are used as substation circuit breakers. Put “NA” in any fields that do not apply. (See Section 13, “Forms.”)

6. Recloser Internal Batteries**CAUTION**

Use caution when replacing a recloser’s internal batteries. Follow the manufacturer’s instructions to avoid tripping the recloser.

- a. Some reclosers use **internal** batteries, instead of the substation’s main battery, to power the trip-and-close functions. Perform a load check on these internal batteries during the monthly station inspection to verify that the batteries and the internal battery chargers are fully functional.
- b. For additional information about the inspection requirements, test procedures, and criteria for battery replacement, see the inspection tasks for circuit breakers in *SMCM*, [“Substation Inspections,”](#) and the manufacturers’ instructions.

Note: Failed batteries or battery chargers will cause the recloser to malfunction, such as failing to trip or reclose. In general, Cooper lead-acid recloser batteries last approximately 4 years and nickel-cadmium-type batteries last approximately 5 years.

Section 1, Subsection III.E.

E. Adjusting Auxiliary Seal Stack Contacts



CAUTION

Do not change the adjustment of any contacts associated with carrier-relaying or high-speed reclosing schemes. If work must be performed on these contacts, consult with the protection specialist.

F. Maintaining Bushing-Potential Devices (Ohio Brass® Type PB-3A)

For circuit breakers equipped with Ohio Brass® Type PB-3A bushing-potential devices, perform the following tasks.

1. Inspect the protective air compartment for moisture and/or a dirt film while performing a mechanism service. If corrosion, moisture, or a dirt film builds up inside the compartment, it eventually may bridge the air gap and cause a failure.
2. Clean out any moisture or dirt.
3. In highly corrosive areas, line the protective air-gap compartment with a silicone compound (Dow 5, General Electric [GE] 687, or an equivalent) for added protection.

G. Using Heaters

The reliability of all types of circuit breakers depends on properly operating heaters. For vacuum and metalclad circuit breakers, heaters also maintain the integrity of the insulation in the high-voltage cabinets. Because heaters help reduce moisture, heater failure can lead to corrosion in the mechanism cabinets and flashovers in the vacuum and metalclad circuit-breaker, high-voltage cabinets.

1. For heaters installed in circuit-breaker cabinets, perform the following actions.
 - a. Always keep an adequate distance between the heaters and the circuit breaker's control valves, hoses, belts, wiring, and other mechanisms that may be damaged by direct heat.
 - b. Many circuit-breaker control cabinets have heaters designed to handle subfreezing ambient temperatures. When an outdoor circuit breaker has a control cabinet with a heater that is not thermostatically controlled, operate the heater at one half of its rated voltage (i.e., connecting a 240-volt [V] heater at 120 V).
 - c. Preferably, cabinet heater thermostats should be wired for operation. Do not bypass the thermostats. Always keep operating mechanisms dry, clean, and lubricated properly.

Section 1, Subsection III.G.1.c.(1)

- (1) An exception is allowed if older thermostats have been bypassed in cooler, coastal locations and there has been no damage caused by heat. In these cases, thermostats may remain bypassed.
 - (2) Keep thermostats operational in hot valley areas. If they fail, they may be bypassed until replaced. Obtain replacement thermostats from local equipment suppliers.
2. Disconnect or remove heaters installed in or near circuit-breaker control valves if the valves have a failure attributed to excessive heat.

H. Bypassing a Circuit Breaker With High-Side Bank Protection Only

1. Use a special maintenance clearance when a distribution circuit breaker can be maintained only with the circuit breaker bypassed and the distribution circuit left with only high-side bank protection.
2. Do not defer maintenance because of a situation requiring this special clearance. To minimize the risk involved, choose one of the following two methods:
 - a. Transfer all load off the bank so that the circuit breaker can be opened and cleared for work. This **preferred** method provides circuit protection at a lower cost than the alternate method.
 - b. Provide protection for the circuit by installing a recloser rack on the first pole out of the station. This **alternate** method provides adequate protection, but is not preferred because it is more expensive.

I. Using PK Blocks

Note: PK is a GE model designation, not an acronym.

1. Protecting Against Tripping Incidents

- a. Trouble incidents involving PK blocks mounted in distribution feeders have resulted in false trips. There are eight machine bolts on the rear of a PK block used for mounting the potential and current connections. In some cases, these machine bolts have become detached from the PK block and have caused an open-current circuit.
- b. To minimize the possibility of a false trip from ground-relay action, use one of the methods listed in Subsection 1.III.I.2. below to jumper out the current circuit. Complete this task during routine substation work or inspections.
- c. Only qualified substation employees should apply the jumper(s).
- d. For future reference, note all changes on the applicable substation drawings. At this time, it is not recommended to send in the prints for “as-builts.” Instead, keep a corrected copy in the station.

Section 1, Subsection III.I.2.

2. Actions Required for PK Blocks

Of the two options listed below, pick the one that best fits the specific location.

Note: The standard procedures for clearance requests, the necessary isolation measures, and the procedures for returning the equipment to service are not included.

- a. The **preferred** method: Apply a jumper across each of the current circuits on the terminal block closest to the PK block itself. After applying the jumper, note the change on the appropriate print.
- b. An **alternate** method: Apply jumpers to machine bolts across the current circuits. Even if a machine bolt becomes detached, the jumper will still short out the current circuit.

J. Understanding Circuit-Breaker Indicating Lamps

1. Replacing Indicating Lamps With Resistors

- a. Always use caution when replacing a red indicating lamp. **Do not** allow the metal contacts of the lamp to touch the metal housing of the receptacle. It is possible to trip a power circuit breaker inadvertently, if the metal contacts on the lamp touch the energized circuit wiring and the metal housing at the same time.
- b. Also, it is possible to trip a circuit breaker inadvertently when inserting a lamp with the **wrong rating**. Always use a lamp with the correct voltage rating when replacing all colors of indicating lamps.

2. Replacing Indicating Lamp Receptacles Without Resistors

Some circuit breakers have a red indicating lamp assembly in the mechanism cabinet that does not use a resistor to limit the current flow in the trip circuit. This type of assembly is more prone to inadvertent tripping if a lamp of the wrong voltage rating is used or if the lamp's contacts touch the metal receptacle housing. See Figure 1., "Typical Installation of a Receptacle Without a Resistor," and Figure 2., "Receptacle Without a Resistor, Removed From the Mounting," below.

Section 1, Subsection III.J.2., continued



Figure 1.
Typical Installation of a
Receptacle Without a Resistor



Figure 2.
Receptacle Without a Resistor,
Removed From the Mounting

This type of receptacle may be found on some Westinghouse models (i.e., 121GMA, 121GMB, and 144V250) and on some older types of circuit breakers with various voltage ratings.

3. Replacing Indicating Lamp Receptacles Without Resistors

When an inoperative red indicating lamp is discovered in a circuit-breaker control cabinet, check the receptacle for a current-limiting resistor. If there is no resistor, perform the following steps for either one red indicating lamp or multiple red indicating lamps, as appropriate.

a. Circuit Breakers With Only One Red Indicating Lamp

- (1) Remove the circuit breaker from service and replace the lamp. If a trip-circuit malfunction caused the lamp to go out, make the necessary repairs to restore the tripping function. Do not return the circuit breaker to service until the repairs are made.
- (2) At the next scheduled circuit-breaker clearance, replace the red indicating lamp assembly with an approved kit for the appropriate voltage. See [Numbered Document 023607, "Control Switch Handles, Indicating Lamps, Mimic Busses, Charting Tape for Maps, and Arrangements,"](#) for ordering information.

b. Circuit-Breakers With More Than One Red Indicating Lamp

- (1) Verify that the red indicating lamp on the substation switchboard is functioning. Use that lamp to monitor the trip circuit.
- (2) Place an information tag on the red indicating lamp in the circuit-breaker cabinet stating, "**Do not** change this lamp with the breaker in service. Changing the lamp may cause the breaker to trip unintentionally."

Section 1, Subsection III.J.3.(b)(3)

- (3) At the next scheduled circuit-breaker clearance, perform one of the following two options.
 - Remove the red indicating lamp assembly and the associated wiring. Use the red lamp on the switchboard to indicate that the trip circuit is functioning.
 - Replace the receptacle with an approved kit for the appropriate voltage. See [Numbered Document 023607](#) for ordering information.

4. Replacing 24X Indicating Lamps

- a. Use light-emitting diodes (LEDs) when possible. LEDs last longer and use less power than conventional incandescent lamps. Although it costs more to install LEDs initially, the life-cycle cost is lower than incandescent lamps.
- b. 24L-series LED lamps are a suitable replacement for 24X incandescent lamps. They may be installed in GE ET-5 and ET-6, and Westinghouse “Minalite” receptacles without changing the input voltage or the series resistance.
- c. Use Data Display Products (DDP) LED indicating lamps for all new and retrofitted applications. LED lamps are available in five colors: red, amber, green, blue, and white. Cover lenses are available in the same five colors, as well as clear. To obtain the best light intensity, match the appropriate color of the LED lamp to the color of the lens. For example, circuit-breaker control switches require a red LED with a red lens and a green LED with a green lens.

Note: Do not use white LED lamps behind colored lenses, if possible.
- d. See [Numbered Document 023607](#) for ordering information.

K. Manufacturer’s Assistance

1. Many circuit-breaker manufacturers offer “full-service” field employees to provide training and to assist in performing work on their circuit breakers.
2. Some manufacturers also provide training videotapes to familiarize field employees with the equipment and with proper work procedures.
3. Contact the local substation field specialist if assistance from a manufacturer is desired.

IV. Performing Periodic Inspections

See *SMCM*, [“Substation Inspections.”](#) for the periodic inspection procedures for circuit breakers.

Section 1, Subsection V.**V. Performing Periodic Maintenance: Mechanism Service, Overhauls, and Compressor Service**

Perform periodic, circuit-breaker maintenance tasks, including mechanism service and overhauls, according to the triggers found in the Utility Standard TD-3322S [Attachment 7](#) maintenance template, or if required by a condition or trouble.

A. Performing Mechanism Service

1. A mechanism service is a set of periodically scheduled or condition-based maintenance tasks performed on all substation circuit breakers. Each type of circuit breaker requires a similar list of tasks, but the specific procedures may vary.
2. See the Utility Standard TD-3322S [Attachment 7](#) maintenance template for all of the maintenance tasks. Also, refer to Section 6, “Oil Circuit Breakers,” Section 7, “SF₆ Circuit Breakers,” or Section 9, “Vacuum Circuit Breakers,” and the maintenance forms in Section 13, “Forms,” for descriptions about the specific types of circuit breakers being serviced.

B. Performing an Overhaul

1. An overhaul is a set of tasks triggered by the Utility Standard TD-3322S [Attachment 7](#) maintenance template BOA™ test results or ACC count, or a condition or trouble. Overhauling each type of circuit breaker requires a similar list of tasks, but the specific procedures may vary.
2. See the Utility Standard TD-3322S [Attachment 7](#) maintenance template for all of the maintenance tasks. Refer to Section 6, Section 7, or Section 9, and the maintenance forms in Section 13, “Forms,” for descriptions about the specific types of circuit breakers being serviced.

C. Performing a Compressor Service

1. Perform a compressor service when the service is triggered by the Utility Standard TD-3322S [Attachment 7](#) maintenance template. Document the service on Company [Form TD-3322M-F12, “Compressor Service,”](#) found in Section 13, “Forms.”
2. Perform a compressor service for single- and two-stage air compressors, as follows.
 - a. Bleed down the air tank until the compressor starts. Run the compressor long enough to agitate and warm the oil.
 - b. Shut down and clear the compressor.
 - c. Change the oil, using 30-weight, nondetergent oil. Where colder weather conditions exist, a lighter-weight oil may be needed.

Section 1, Subsection V.C.2.c. (continued)

Note: If a new or rebuilt compressor is under warranty, use the type of oil recommended in the manufacturer's or rebuilder's specifications.

- d. Check the compressor belt for wear and proper tightness. Replace or adjust the belt, if necessary.
- e. Ensure that all the pulleys are secure and that the motor hold-down bolts are tight.
- f. Check and clean the intake air filter.
- g. Check the compressor for oil leaks, and repair any leaks that are found.
- h. Check the compressor for air leaks, and repair any leaks that are found. As a general rule, more than 50 operations per month are excessive for an air system and may indicate a leak. Record the average number of operations per month, as found on the station read sheets. Record the number and location of any air leaks that were repaired.
- i. Clean the area around the compressor. Remove any oily residue.
- j. Perform a pressure-relief valve test according to the instructions on the ["Compressor Service"](#) form found in Section 13, "Forms."
- k. Make the compressor available for service and turn on the power. Bleed down the operating pressure, if necessary, and verify that the compressor starts automatically and shuts off at the rated pressure.
- l. Perform a complete, compressor-switch rundown test during a circuit-breaker overhaul, or when necessary, to correct a problem. Follow the instructions in Section 3. Document the run-down test on [Form TD-3322M-F24, "Compressor Rundown,"](#) found in Section 13, "Forms."

D. Performing a Hydraulic-System Service

1. Conduct a hydraulic-system service as follows.
 - a. Turn off the power to the hydraulic pump.
 - b. Check the fluids in the hydraulic system. Add hydraulic fluid, if necessary. Replace the fluid only if it becomes contaminated or jelled.
 - c. Check the nitrogen pre-charge pressure. Follow the procedure in Section 3. Record the results.
 - d. Check the number and hours of hydraulic-pump operations. As a general rule, more than five operations, or 0.2 hours a month, is excessive for a hydraulic system. Refer to the manufacturer's instructions.
 - e. Repair any hydraulic-oil leaks.

Section 1, Subsection V.D.1.f.

- f. Clean up any hydraulic-fluid spills or leaks.
- g. Turn on the power to the hydraulic pump. Ensure that the pump shuts off at the rated operating pressure.
- h. Perform a complete, hydraulic-pump rundown test during a circuit-breaker overhaul, or when necessary, to correct a problem. Follow the procedure in Section 3. Document the rundown test on the [“Compressor Rundown”](#) form, found in Section 13, “Forms.”

VI. Performing Condition or Trouble Maintenance

- A. Perform troubleshooting and diagnostic testing on substation circuit breakers in the event of any “trouble” or “condition” that warrants further investigation or testing. Investigate any malfunction of a circuit breaker or any electrical system problem that could be caused by a circuit-breaker malfunction and, if necessary, schedule the appropriate maintenance as soon as possible.
- B. For more information on diagnostic testing and troubleshooting, see Section 3 for tests that are common to all types of circuit breakers. Refer to the section of the manual that is applicable to the specific type of circuit breaker being investigated (i.e., Section 6, “Oil Circuit Breakers,” Section 7, “SF₆ Circuit Breakers,” or Section 9, “Vacuum Circuit Breakers”).

VII. Recordkeeping and Data Entry

See [Utility Standard TD-3322S](#) for instructions for circuit-breaker maintenance recordkeeping.

- A. Check the completed forms when planning maintenance.
- B. Whenever the interrupters and the main, current-carrying, primary and arcing contacts have been inspected during maintenance work, the headquarters **must** update the wear-assessment percentages in SAP WMS.

VIII. References

The following references are found in *SMCM*, “Circuit Breakers.”

A. Utility Standards (Company)

- 1. [Utility Standard D-S0421, “Fall Protection and Prevention”](#)
- 2. [Utility Standard TD-1465S, “Event Reporting for Gas and Electric Transmission and Distribution”](#)
- 3. [Utility Standard TD-3322S, “Substation Equipment Maintenance Requirements”](#)
- 4. [Utility Standard TD-3324S, “PCB Management in Substations”](#)

Section 1, Subsection VIII.B.

B. Work Procedures (Company)

1. [Utility Procedure TD-3320P-01, "Electric T&D Confined Space Work Procedures"](#)

C. Manuals (Company)

1. [Code of Safe Practices](#)
2. [PCB Management in Substations](#)
3. [PESTP](#)
4. [Protective Grounding Manual](#)
5. *SMCM*
 - a. ["Infrared Inspections"](#)
 - b. ["Insulating Oil"](#)
 - c. ["Arrestors, Bushings, and Insulators,"](#) Subsection II., "High-Voltage Insulation Bushings and Insulators"
 - d. ["Substation Inspections"](#)

D. Engineering Documents (Company)

These documents are available electronically.

1. Engineering Standard No. 14, "Specification for Sulfur Hexafluoride (SF₆)"
2. Engineering Standard No. 32, "Specification for Nitrogen Gas"

E. Numbered Documents (Company)

These documents previously were referred to by their original designations, such as Substation Engineering Standards or Electric Design Standards.

1. [023607, "Control Switch Handles, Indicating Lamps, Mimic Busses, Charting Tape for Maps, and Arrangements"](#)
2. [027818, "Nameplates for General Use"](#)
3. [063122, "Automatic Feature, Relay, Potential Cutout Switches and Nameplates"](#)
4. [069310, "Isolation Transformer Application"](#)

F. American Society for Testing and Materials (ASTM) Standards

1. No. D2472
2. No. G26
3. No. D2029

Section 1, Subsection VIII.G.

G. Other

1. Adapt 9000 Vacuum Manifold System (VMS) instructions
2. Allied Signal Technical Bulletin on Sulfur Hexafluoride
3. Compressed Gas Commodity Association Specifications G-7.1
4. *Industrial Safety Orders*, Title 8, California Administrative Code, Article 76
5. Material Safety Data Sheet for Sulfur Hexafluoride (SF₆)
6. *Western Area Power Administration Maintenance Manual*, Chapter 4

Section 2

Receiving, Storing, and Installing

I. Purpose

This section includes procedures for receiving, storing, and installing new, used, and relocated circuit breakers.

II. Receiving Equipment

A Company employee **must** observe any inspection performed by a contractor at the time of a delivery.

A. Performing Inspections on Delivery

1. Ensure that all bracing and blocking is tight. Movement may have resulted in broken or uprooted braces.
2. Take photographs of the blocking or bracing if it is not secure.
3. Look for any signs of movement or load-shifting. The flatcars usually have steel blocks placed tightly against, or approximately 1/8 inch to 1/4 inch from, the base of the circuit-breaker unit. Bumping against the blocks may cause dents in the base of the unit.
4. Check any anchor tie-downs for tightness and breaks. Excessive looseness may indicate that the unit was shaken during transport.
5. Check for positive pressure on gas circuit breakers.
6. Visually inspect the circuit breaker's tank(s), drain valves, gauges, and paint finish. Damage may indicate that the unit was subject to abnormal movement during loading or shipping.
7. Check the bushings for physical damage.
8. Check that the shipping bill of materials matches the actual shipment to ensure that all the components have been received.

Note: For new equipment, also check for instruction books and drawings.

9. Report any missing equipment or material or any abnormalities to the manufacturer and the asset manager.

B. Maintaining Delivery/Damage Records

1. Shipping Papers and Manifests

- a. Properly fill out all the shipping papers, noting any missing items, damage, or suspected damage.
- b. Write "Exception Taken" and describe the exception(s) on the shipping invoice if equipment is accepted with minor damage.

Section 2, Subsection II.B.2.**2. Freight-Claims Procedure**

Perform the following actions when filing freight claims.

- a. Document every step taken when filing a freight claim for damage or loss of material.
- b. Make copies of all the freight bills, signed delivery receipts, packing lists, and any other documents accompanying the delivery.
- c. Take photos of the damaged material, the condition of the load while still on the truck, or anything else that may help expedite the completion of the claim.
- d. Carefully check all the incoming material for shortages.
- e. Check the shipments for crushed corners, holes, tears in the packaging, or any other signs of mishandling that may have caused freight damage.
- f. When damage, potential damage, or shortages are discovered, note this information on the delivery documents. Include the number of items involved and an exact description of the problem (e.g., a note may state that there are three boxes torn, five boxes short, one box open, and one pallet toppled over).
- g. Have the driver sign the delivery receipt **after** the shortage or damage is documented. Get copies of the receipt and the other delivery documents.
- h. Do not remove any packaging or move the shipment unnecessarily, as this could adversely affect the Company's ability to collect damages.
- i. Contact the carrier's local office to notify them of the loss or damage. The value of the lost or damaged freight determines if the carrier will require an inspection.
 - (1) Generally, if the value is \$500 or less, the carrier will waive an inspection. If that happens, ask for the name of person who states that the inspection will be waived, then write "Inspection waived per (Person's Name)" on the delivery document. The name **must** be included.
 - (2) If the value is over \$500, the carrier probably will send a claims inspector to check the freight. Usually, claims inspectors are contractors hired by the carrier. They should make unbiased inspections.
- j. Get a copy of the inspection report from the inspector.
 - (1) Contact your local field specialist for assistance with breakers damaged during shipping.
 - (2) The Traffic Department files the claim and tracks its status until it is closed.

Section 2, Subsection II.B.2.k.

- k. Do not dispose of the material. The transportation companies have the option of picking up the material for sale or scrap. They can refuse to pay the claim if the material is not available.

III. Storing, Moving, or Relocating Equipment

A. Decisions to Make Before Storing

1. Determine how long the circuit breaker is expected to be in storage.
2. Based on the inspection results on the equipment's arrival, determine if the circuit breaker requires repairs or upgrades, or if an overhaul is needed before placing it in service.
3. Determine the cost of the repairs, upgrades, or overhaul, if required.
4. Before deciding to perform repairs, upgrades, or internal inspections on equipment found to be deficient or suspicious, take into consideration operational needs and budget constraints.
 - a. Make these decisions jointly with the asset manager.
 - b. The asset manager determines who will perform this work.

B. General Storage Requirements

After performing the jobsite receiving inspection, secure and dress the circuit breaker in compliance with the requirements outlined in the manufacturer's instructions. Follow the storage results made in Subsection 2.III.A. above.

Secure the circuit breaker based on the length of time the unit will be stored.

1. Using Rails or Rollers

Check the outline drawings to determine if rails or rollers are required to support the circuit breaker while skidding or sliding it into place.

2. Taking Environmental, Seismic, and Site Precautions

- a. Store the circuit breaker in a location and in a way that meets any Spill Prevention Control and Countermeasure (SPCC) Plan requirements, prevents personal injuries, and protects the unit and surrounding equipment.
- b. Use seismic anchorage where advisable or required.
- c. Locate the circuit breaker clear of energized equipment. Ensure it does not impede the normal traffic flow or the moving of other equipment.

3. Using Pads or Timbers

Place the circuit breaker on concrete pads or wood timbers capable of supporting its weight for the duration of the storage.

Section 2, Subsection III.B.3.a.

- a. If using timbers, space them approximately 2 inches to 4 inches apart to allow for ventilation.
- b. Use treated timbers if storing the circuit breaker for over 6 months.

4. Identifying Packing Materials

Clearly identify, mark, and store any shipping crates or boxes required for the equipment.

5. Storing Bushings

- a. Store any unmounted bushings in a secured location off the ground.
- b. Store oil-filled bushings with the tops elevated at least 15".
- c. Seal or cover the flanges and other openings. Clearly mark them so they are easy to locate, access, and use.

6. Grounding Stored Circuit Breakers

Ground stored circuit breakers as described in the following subsections.

- a. For circuit breakers stored in a substation, ground the frame if the circuit breaker is stored within a touch-potential reach of other grounded equipment. Bonding the bushings is not required. Follow the grounding procedures described in the [Protective Grounding Manual](#).
- b. If the circuit breaker is located in a substation, but is off the ground grid, ground the frame. Follow the grounding procedures described in [Numbered Document 069310, "Isolation Transformer Application."](#)
- c. If the circuit breaker is not stored in a substation, grounding (or bonding) is not required if the cord supplying power to the heaters contains a ground wire.

7. Using Heaters When Storing Equipment

Install or connect space heaters in the control cabinets.

- a. Follow the grounding procedures described in [Numbered Document 069310](#) if storing the circuit breaker in a substation.
- b. Operate the heaters at one-half the normal voltage, and bypass the thermostats.
- c. Use a 200-watt light, if heaters are not available, to ensure that empty, depressurized tanks stay dry.

8. Sealing Doors and Covers

Carefully inspect the doors, cover gaskets, and bolts. Replace them if there is **any** indication that they may leak.

Section 2, Subsection III.B.8.a.

- a. For grooved flanges, use mil specification R-3065, nitrile rubber, Buna N, and 70-durameter gasket material designed for grooved flanges.
- b. For flat flanges, use either Gortex™ or corkoprene gasket material.
- c. Close and torque all the doors and covers. Refer to the manufacturer's instructions for the proper gasket-compression and bolt-torque values.

9. Insulating Gas in Stored Circuit Breakers

- a. Pressurize SF₆ circuit breakers with a positive pressure **not to exceed** 10 pounds per square inch gauge (psig) of SF₆ gas.
- b. Test for moisture both in the SF₆ gas currently in the circuit breaker and in any SF₆ gas to be added. Refer to Section 8, Subsection VIII, Item 4 for maximum moisture levels.

C. Periodically Inspecting and Maintaining Stored Equipment

1. During scheduled inspections, inspect all substation equipment stored at substations, materials facilities, and other Company locations.
2. See the *SMCM*, ["Substation Inspections,"](#) for the periodic inspection procedures for stored equipment.
3. Record the results of the periodic inspections on a regular station-inspection reading sheet (available in the headquarters).
4. Perform any required work in a timely manner to ensure that the breaker is ready to use.
5. Consult the asset manager before removing or replacing any parts.

D. Recordkeeping for Stored Equipment

1. For equipment in the Maintenance Program (SAP WMS), provide the following information on a regular station-inspection reading sheet.
 - The storage date and location.
 - Tests performed.
 - Repairs or repair status.
 - Missing parts or equipment.
 - Any other pertinent information regarding the stored equipment.
2. Keep paper copies of all the receiving and inspection documents.
3. Keep a local equipment logbook in the control or mechanism cabinet. Record any missing components or parts, any parts removed or reinstalled, and the status of any repairs or parts required to place the circuit breaker in service.

Section 2, Subsection III.E.

E. Moving or Relocating SF₆ Circuit Breakers

Before moving or relocating an SF₆ breaker, the gas pressure must be lowered for safe handling. Refer to Section 7, Subsection II.J.



WARNING

Moving or relocating a SF₆ circuit breaker with normal SF₆ operating pressure can result in the release of the SF₆ gas and its bi-products. It is also possible to damage the circuit breaker bushings, which could result in bushing shrapnel projected into the work area exposing employees to a hazard.

IV. Installing Circuit Breakers

A. Installation Tasks

1. General Inspection Items

This subsection includes general installation tasks. Not all tasks apply to all types of circuit breakers. Also refer to and follow the manufacturer's set-up and installation instructions.

Note: Occasionally, new types of circuit breakers are introduced that may require specific checks in addition to those listed here.

- a. Externally inspect the circuit breaker for any factory defects or shipping damage.
- b. Inspect the mechanism and linkages for any factory defects or shipping damage.
- c. Document the required tests and inspections on Company forms found in Section 13, "Forms," as follows.
 - (1) New circuit breakers: Use Company [Form TD-3322M-F10, "Installation Form for New Distribution Circuit Breakers,"](#) or [Form TD-3322M-F26, "Installation Form for New Transmission Circuit Breakers."](#)
 - (2) Relocated circuit breakers: Use the appropriate "Mechanism Service" and "Overhaul" forms.

Note: Perform a mechanism service for relocated, transmission-class, SF₆ circuit breakers. Perform an overhaul if within 80% of ACC.

Section 2, Subsection IV.A.2.

2. Legal Requirements and Tests for Pressure Vessels

By law, pressure vessels must be protected by at least one safety (i.e., pressure-relief) device and by other indicating and controlling devices such as pressure gauges and governor pressure switches. Direct, spring-loaded safety valves also are required. The valve's lifting device must be capable of easily unseating the disc at 75% of the valve's open pressure.

- a. Test the lifting devices during installation and when compressor and relief-valve testing is triggered by Utility Standard TD-3322S, "Substation Equipment Maintenance Requirements," [Attachment 7, "Circuit Breaker Maintenance Template."](#)
 - (1) To test, pressurize the vessel to 75% of the pressure at which the safety valve is set to open. Then, manually open the valve using the lifting device.
 - (2) Use hearing protection during this test.
 - (3) Document the test results on the ["Installation Form for New Transmission Circuit Breakers,"](#) found in Section 13, "Forms."
- b. Verify that the device properly re-seats and does not leak.

3. Checking Insulating Gas

Ensure that any insulating gas is dry and free of dielectric contaminants **before** introducing it into the circuit-breaker tank. This prevents high-voltage flashovers caused by moisture and other contaminants.

4. Testing High Potential (High Pot) During Installation

Perform high-pot tests on new, high-voltage components for vacuum circuit breakers.

- a. Refer to Section 9, Subsection IX.B. for safety precautions and testing procedures. Refer to the manufacturer's instructions for the test-voltage level.
- b. High-voltage components also should be megger-tested to ground with a test voltage of 2,500 V.

5. Properly Locating Distribution-Breaker Control Cabinets

All vacuum circuit breakers have a local control switch (Device 52CS) mounted either in the circuit-breaker cabinet or adjacent to the circuit breaker in the protective relay/Supervisory Control and Data Acquisition (SCADA) cabinet.

Note: Do not confuse this switch with the mechanical maintenance operating device.

Section 2, Subsection IV.A.5.a

- a. To protect employees who are using this control switch to operate the circuit breaker, install **new** protective relay/SCADA cabinets away from the breaker high voltage compartment. The location of the cabinet relative to the circuit breaker is designed to provide a barrier between the operator and the breaker.
- b. See Figure 3, “Standard Location of a Circuit-Breaker Control Cabinet,” below for the location of the circuit-breaker control cabinet. Note that the control cabinet is on the “Main” or “Bus 1” side. Do not deviate from this location without permission from the responsible engineer (RE) and the station’s maintenance and operating supervisor. They must agree on the alternate location.

Note: The requirement for cabinet locations, described above, does not apply when circuit breakers are replaced in an **emergency** situation and there is no intent to replace the relay/SCADA cabinets.

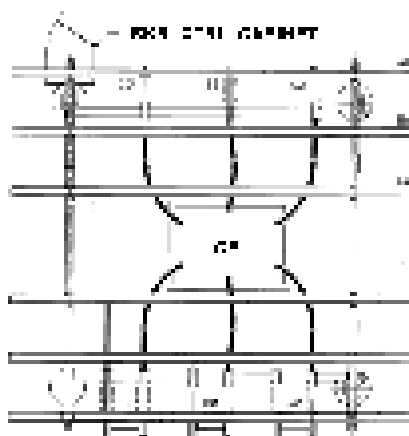


Figure 3.
Standard Location of a Circuit-Breaker Control Cabinet

- c. If the control cabinet for a vacuum circuit breaker is installed in a configuration that **does not** provide a similar barrier, use additional bolts for the high-voltage compartment on the side nearest to the control switch (Device 52CS). These additional bolts help protect employees who are operating the control switch if there is a catastrophic failure of a vacuum bottle or an internal fault.
- d. When additional bolting is necessary, follow these instructions.
 - (1) Install 3 hold-down bolts (½-inch) evenly along the bottom edge of the vacuum-interrupter cabinet on the side facing the breaker’s electrically operated control switch, Device 52CS.
 - (2) Ensure that the upper edge is contained either by a metal overlap or by using 3 additional hold-down bolts, evenly spaced along the top edge of the cabinet. Place bolts only on the side of the cabinet that faces the control switch.

Section 2, Subsection IV.A.6.

6. Checking for Leaks

Check to ensure that there are no oil, mechanism air, SF₆, or hydraulic-fluid leaks.

7. Performing Additional Installation Tasks for SF₆ Circuit Breakers

- a. Perform an internal inspection while installing 500-kilovolt (kV)-class SF₆ circuit breakers and any SF₆ circuit breakers with bushings that must be assembled in the field.
- b. **Do not** perform an internal inspection when installing 230 kV-and-below, SF₆ circuit breakers that are “preassembled” with mounted bushings and sealed tanks.
- c. **Exception:** Perform an internal inspection on any SF₆ circuit breakers that show signs of possible internal problems during the installation diagnostic testing. If a potential problem is discovered, contact the local substation field specialist, who will contact the supplier and coordinate a warranty inspection.

8. Testing Insulation

Follow the guidelines below when testing insulation.

- a. Test the insulation on metalclad buses and associated equipment:
 - When they are installed.
 - After a bus failure or repair.
 - After adding to a bus.
 - When a questionable insulation condition indicates it is necessary.
- b. Perform the test using a 2,500 V megger. Test both phase-to-phase and phase-to-ground.

Note: The minimum resistance for metalclad-bus conductors is 500 megohms.

- c. Record all the test results.

9. Sealing Ducts

Seal all used or unused cable ducts with Duxseal™.

10. Performing a Job Walk-Down and Tests After Installation

- a. Conduct a thorough job walk-down before energizing the circuit breaker. Perform the walk-down with a representative from the local maintenance headquarters.

Section 2, Subsection IV.A.10.b.

- b. The installation crew leader will notify the local substation maintenance headquarters of a convenient time to perform this inspection. It should be scheduled to allow the installation crew enough time to correct any abnormalities.
- c. Verify that all the newly installed equipment and related disconnect switches are operating properly.
- d. For future maintenance purposes, clearly mark any tools, parts, and extra instructions that were sent by the manufacturer along with the circuit breaker. Store them neatly in the substation control room.

B. Energizing the Circuit Breaker

- 1. Before the circuit breaker is energized, the supervisor in charge of the installation must review all of the test reports to ensure that the breaker is ready to test, energize, and load.
- 2. After energizing the circuit breaker, perform the load, direction, and other checks and tests required by the [PESTP](#) Manual.

C. Inspecting the Circuit Breaker Using Infrared After Installation

- 1. Perform an infrared scan of the equipment and all safely accessible new connections after the unit has been carrying load for at least one complete load cycle (approximately 1 week). Refer to *SMCM*, [“Infrared Inspections.”](#)
- 2. Record the actual results and the ambient temperatures as benchmark references for future trending.

D. Recordkeeping for Installation

- 1. Forward the completed copies of the new circuit breaker installation form (either distribution or transmission), and the manufacturer’s installation checklist, or the completed Mechanism Service and Overhaul forms for relocated circuit breakers, to the substation maintenance headquarters. (See Section 13, “Forms.”)
- 2. Enter the installed and energized dates, nameplate and equipment data, and any pertinent problems or details, including items that must be known if the unit is moved to another location, in the Maintenance Program.
- 3. After installing the circuit breaker, send the completed forms, the nameplate data, and any other information that would be useful for planning future maintenance, to the local maintenance headquarters. Verify that headquarter personnel received this information.

Section 3

Diagnostic Tests

I. Purpose

Diagnostic tests are used to analyze the condition of circuit breakers and to help troubleshoot and isolate various problems related to circuit-breaker performance. The diagnostic tests described in this section are common to all circuit breakers and are in addition to the diagnostic tests contained in sections specific to a circuit-breaker type (i.e., Section 6, “Oil Circuit Breakers,” Section 7, “SF₆ Circuit Breakers,” and Section 9, “Vacuum Circuit Breakers”).

Test circuit breakers because of a known “condition” or “trouble,” or as triggered by Utility Standard TD-3322S, “Substation Equipment Maintenance Requirements,” [Attachment 7, “Circuit Breaker Maintenance Template.”](#)

II. Safety Precautions

Follow the safety precautions described below before performing any diagnostic tests.

A. Review all safety warnings and cautions. Refer to:

1. Section 1.
2. The section that applies to the specific circuit-breaker type (i.e., Section 6, “Oil Circuit Breakers,” Section 7, “SF₆ Circuit Breakers,” and Section 9, “Vacuum Circuit Breakers”).
3. The manufacturer’s instructions.

Use these references as a guide when performing any maintenance.

B. Cut out any relay schemes that may affect other equipment.

C. Ensure that employees are familiar with all applicable Company safety rules and equipment procedures and remain in compliance with them at all times.

III. Performing In-Service Diagnostics

A. Safety

1. Maintain a minimum safe working distance from the energized parts of the equipment.
2. Take precautions to prevent gas or oil leaks and to ensure that diagnostic testing does not affect service reliability.

Section 3, Subsection III.B.**B. Recordkeeping**

1. Enter all diagnostic test results on the appropriate maintenance forms. (See Section 13, “Forms,” for a list of available forms.)
2. If required, complete an “Electric Substation Notification” in the Maintenance Program (SAP WMS).

C. Infrared Testing

An infrared scan can detect hot or warm spots, indicating loose fittings and connections or high-contact resistance. Refer to *SMCM*, [“Infrared Inspections,”](#) for additional information.

1. Perform an infrared inspection of the tanks and connections after a new or relocated circuit breaker has been placed in service, is carrying load, and is up to its normal operating temperature (preferably during peak loading).
2. Set the camera with a narrow temperature bandwidth. Scan all sides of the tanks.
 - a. Look for temperature differences between the tanks and for abnormal hot spots. Hot spots may indicate excessive heating or coking of the contacts or the presence of high-resistance connections in the tanks.
 - b. If the scan indicates problems, perform additional diagnostic testing and/or an open-tank inspection.
3. Record the test results and the ambient temperature as described in the *SMCM* [“Infrared Inspections”](#) booklet. Use the test data as a baseline reference for future trending.
4. Perform future infrared scans as triggered by Utility Standard TD-3322S, [Attachment 5, “Station and Headquarters Maintenance Template,”](#) or whenever infrared testing can be used to investigate possible trouble areas.

IV. Performing Out-of-Service Diagnostics

Most diagnostic testing is performed on out-of-service equipment. Before performing any tests, ensure that an out-of-service circuit breaker is safe for testing by following the specific instructions for that unit.

A. Recordkeeping

1. Enter all diagnostic test results on the appropriate maintenance forms found in Section 13, “Forms.”
2. Enter a summary of the performed tests in the Maintenance Program. Complete a SAP WMS “Electric Substation Notification,” if required.

Section 3, Subsection IV.B.

B. Measuring Trip-Voltage and Close-Voltage Signal Levels

When a circuit breaker fails to electrically close or open, perform trip-voltage and close-voltage tests using a voltmeter. **Do not** perform these tests unless the circuit breaker is out of service.

1. Use the elementary and connection diagrams as a reference when testing the controls.
2. Use a multimeter that has been set to the appropriate voltage scale to check the voltage of the trip or close signal.
3. With the circuit breaker properly cleared, take voltage readings at the trip or close coil (where possible) as the signal is applied.
4. If the measured signal's voltage is low or missing, move the test point to the next closer point to the voltage source.
5. Continue the process in Step 4. above until the source of the low or missing signal is found.

C. Measuring the Resistance of Trip, Close, or Other Control-Circuit Paths

Abnormal circuit resistance can cause poor control-circuit performance.

1. Take resistance readings on suspect circuits for troubleshooting purposes.
2. Use the elementary and connection diagrams as a reference when testing the controls.
3. Compare these readings to any previously recorded readings, to the information in the manufacturer's instructions, or to readings from similar circuits.
4. Measure the resistance of the circuit's individual components until discovering the source of any abnormal resistance.

D. Performing Minimum-to-Trip and Minimum-to-Close Tests

1. General Information



CAUTION

Ensure that electronic relays are not operating in **any** circuits that are being tested with reduced, direct current (dc) voltages.



CAUTION

Thoroughly research the appropriate diagrams and wiring before making any test connections. Ensure that the trip and close circuits being tested are isolated and that there is **no** interference or involvement with **any** other trip or close circuits.

Section 3, Subsection IV.D.1.a.

- a. Use the elementary and connection diagrams as a reference when testing any controls.
- b. Operating reliability is assured when circuit breakers are able to trip and close consistently throughout their nameplate operating-voltage range. However, a large majority of latch-operated circuit breakers will consistently operate at substantially lower voltages when their mechanisms are in prime working order.
- c. Latch-type circuit breaker mechanisms may be subject to slow tripping or closing and possible operating coil burn-out when one or more of the following conditions exist.
 - Inadequate lubrication of the latch and latch roller
 - Incorrect latch adjustment
 - Incorrect latch armature setting
 - Incorrect latch plunger gap

**CAUTION**

Absolute-minimum operating-voltage testing **only** applies to circuit-breaker mechanisms that use a coil or coils to directly operate the trip and close latches using a plunger or armature.

- d. The absolute-minimum amount of voltage required to release the latch is an effective measure of the four factors listed in Subsection IV.D.1.c., making this test an excellent predictor of operating reliability. When absolute-minimum operating voltage values are compared over time, an increasing trend indicates trouble. Performed correctly, the absolute-minimum operating voltage test gives a timely warning, providing the opportunity to perform the maintenance needed to prevent failures.
- e. Other mechanism designs can be damaged or made inoperable by performing absolute-minimum operating-voltage testing. Do not attempt to use absolute-minimum operating voltage testing in any of the following circumstances.
 - Closing circuits operated by alternating current (ac) or rectified ac-to-dc.
 - ABB types R-Mag and AMVAC.
 - Solenoid-close breakers (where the solenoid directly drives the operating mechanism). Closing solenoids on these units draws high current that may damage test equipment.

Section 3, Subsection IV.D.1.e., continued

- Hydraulic and pneumatic operators. These often feature change-over valves. Performing absolute-minimum operating-voltage testing on these units poses the danger that the change-over valve will fail to complete its full travel and become stuck in mid-position. This condition is difficult to detect and correct, so avoid it.
 - Any other circuit breaker type that does not use a coil or coils to directly drive the latch, but instead uses a plunger or armature to initiate tripping or closing.
- f. Test circuit breakers that are not suitable for absolute-minimum operating-voltage testing by verifying that they operate at the lowest voltage of the operating range, as listed on the nameplate.
- g. Refer to Section 9, “Vacuum Circuit Breakers,” Subsection X, Item F., “Minimum to Trip and Close,” for minimum-to-trip and minimum-to-close tests on circuit breakers having an electronic circuit board and no trip or close coils (e.g., ABB-type RMAG and AMVAC).

2. Testing Requirement

Perform minimum-to-trip and minimum-to-close testing on **all** circuit breakers with a DC operated trip latch or close latch.

Test the circuit breakers when any of the following situations occur.

- a. When performing a mechanism service.
- b. When testing is triggered by Utility Standard TD-3322S, [Attachment 7](#).
- c. Any time the circuit breaker fails to operate normally.

3. Methods for Performing Operating-Voltage Tests

There are two methods of performing minimum-operating voltage tests. However, the most accurate comparisons between tests are obtained by consistently using the same test method. Use the remarks field on the appropriate “Mechanism Service” form to note which method is used.

- a. **Preferred Method:** The primary test equipment, when available, is the Vanguard CBCT programmable DC power supply. Video guidance for this procedure can be found on the [PG&E Video Portal](#), using the search term “minimum vanguard.”
- b. The secondary test equipment is the Barrington Model PS-C Power Supply. This test method provides a reasonably stable power source, and the accuracy is acceptable. The advantage of this method is the convenience of performing the operating voltage test in the immediate vicinity of the circuit breaker being tested. Video guidance for this procedure can be found on the [PG&E Video Portal](#), using the search term “minimum barrington.”

Section 3, Subsection IV.D.3.c.

- c. **Alternate Method** (use only as last resort): Tapping the station battery is an alternate method of performing an operating voltage test. The advantage of this method is that it provides a highly stable voltage source. However, a disadvantage is the risk of inadvertently causing a dc short circuit in the immediate vicinity of the station battery

4. Testing Absolute-Minimum Operating Voltage

Use the following procedure when testing absolute-minimum operating voltage.

**CAUTION**

Absolute-minimum operating-voltage testing **only** applies to circuit-breaker mechanisms that use a coil or coils to directly operate the trip and close latches using a plunger or armature.

Thoroughly research the appropriate diagrams and wiring before making any test connections. Ensure that the trip and close circuits being tested are isolated and that there is **no** interference or involvement with **any** other trip or close circuits.

Note: To test the close circuit, start with the circuit breaker open. To test the trip circuit, start with the circuit breaker closed.

- a. Use a test lead to connect the voltage source to a multi-breaker and the multi-breaker to the circuit that connects to the circuit breaker's operating (trip or close) terminal.
- b. Start at 30% of the circuit breaker's nominal battery voltage. When using the Barrington, use the multi-breaker in a keying motion and apply voltage to the operating terminal of the circuit breaker for ½ second. The Vanguard CBCT will only output in ½ second pulses. If the circuit breaker fails to operate at 30%, raise the test voltage in 4.4 V increments (i.e., equivalent of two cells) until the circuit breaker operates.
- c. If the circuit breaker operates at 30%, repeat the test, lowering the test voltage in 4.4 V increments (i.e., equivalent of two cells) until it does not operate.
- d. Record the lowest voltage that caused the circuit breaker to operate by entering it in the Maintenance Program and noting it in the "notes/comments" field on the appropriate maintenance form for the type of circuit breaker being tested.

Section 3, Subsection IV.D.5.

5. Determining When a Mechanism Service Is Required

The information in this subsection describes how to determine when a circuit breaker fails the minimum-to-operate test and when a mechanism service is required.

Perform a mechanism service when:

- a. The minimum-to-operate is 25% or more than base line data. Use the common formula for percentage variation as shown in Section 3, Subsection IV.N.6.I.
- b. The minimum-to-operate is more than the lowest voltage in the operating range as listed on the nameplate (used only when baseline data has not been established).

For new circuit breakers, establish baseline data by recording the minimum-to-operate values on [Form TD-3322M-F10, "Installation Form for New Distribution Circuit Breakers,"](#) or [Form TD-3322M-F26, "Installation Form for New Transmission Circuit Breakers."](#)

For in-service units that have been in service for more than one mechanism service interval and where no baseline data exists, establish baseline data by recording the as-left test data on the appropriate "Circuit Breaker Mechanism Service" form after:

- Disassembling, cleaning, and re-lubricating trip latch bearings/bushings and the trip latch roller.
- Verifying correct adjustment of the trip latch wipe and the latch armature setting/latch plunger gap.

E. Performing Insulation Testing on Bushings, Lift Rods, and Rotating Elements

Perform these tests, using a 2,500 V megger, when a condition or trouble indicates possible insulation system problems or when triggered by the Utility Standard TD-3322S, [Attachment 7](#) maintenance template. The test helps determine the condition of the insulation system. Perform the following steps:

1. Check that all the bushings are clean and dry before testing. Clean them, if necessary. Follow the cleaning instructions in *SMCM*, ["Arrestors, Bushings, and Insulators,"](#) Subsection II.
2. With the circuit breaker closed, connect the megger leads from a bushing cap to ground and megger until the reading stabilizes.
 - a. Repeat the test for each of the other two phases.
 - b. Record the results and compare them to the previous test results.

Section 3, Subsection IV.E.3.

3. If there are any poles with low megger readings (i.e., less than 10 megohms per line-to-line kV), **open** the circuit breaker and perform the following tests.
 - a. Megger each one of the poles from the bushing caps to ground. If the low readings are no longer present on either pole, then the lift rods or rotating elements are most likely causing the problem.
 - b. Open the circuit-breaker compartment, and megger the low-reading poles' lift rods or rotating elements to ground.
 - (1) The rotating-element contacts on units 115 kV and above should test at a minimum of 10,000 megohms to ground.
 - (2) The rotor elements on units less than 115 kV should test at a minimum of 2,000 megohms to ground.
 - c. If low readings are still present at the bushings with the circuit breaker in the open position, disconnect the conductor leads at the top of the bushings and megger from the disconnected leads to ground.
 - (1) A low reading indicates disconnect insulator problems.
 - (2) If the disconnected lead's readings are acceptable, then megger from the bushing cap(s) to ground. A low reading shows which pole has insulation-resistance problems.

F. Testing Insulation Resistance of Control Wiring, Current Transformer (CT) Blocks, Etc.

Power circuit-breaker reliability depends on good mechanism health. Recent root-cause investigations have identified opportunities to enhance the way PG&E assesses mechanism health and the way impending trouble is detected.

1. Control-Circuit Insulation Assessment



CAUTION

Thoroughly research the appropriate diagrams and wiring before making any test connections. Disconnect components in the control circuit that are not designed or rated to withstand the 500 V dc insulation-resistance test. Ensure there is no interference or involvement with any other trip or close circuits. Ensure all components are reconnected to the control circuit before returning it to service.

2. Use a 500 V dc megger to assess the electrical insulation of the trip, close the DC power supply (if possible without de-energizing other equipment), wiring, the terminal blocks, and connected components associated with the circuit breaker controls when:

Section 3, Subsection IV.F.2.a.

- a. Installing circuit breakers.
- b. Performing the circuit-breaker mechanism service.
- c. Suspecting there is trouble with the circuit breaker control's electrical insulation.

Note: The minimum acceptable resistance is 2 megohms.

G. Power-Factor Tests

1. Description of Power-Factor Tests

- a. All insulation systems have minor leakage paths that permit a small current flow.
 - (1) If the insulation systems were perfect, there would be no current leakage at all and the power-factor reading would be 0%.
 - (2) If all the input power were lost through leakage in the insulation system, then the power-factor reading would be 100%.
- b. With lower insulation-system impedance, there is greater leakage current, more power lost through leakage in the insulation system, and higher power-factor readings.
- c. Refer to the power-factor tester's instructions for the proper testing methods and the expected results. Current and wattage readings are recorded for each of the tests and the power factors are calculated.

2. Overall Bushing Power-Factor Test

This test determines the dielectric condition of a bushing. It can be conducted with the circuit breaker either open or closed. With the circuit breaker closed, the lift rods or rotating elements and their guides also are included in the test.

- a. Disconnect the bus and line conductor leads, and any auxiliary devices, to ensure the greatest accuracy. The results may indicate whether to replace or rebuild a bushing.
- b. With lower bushing impedance, there is greater leakage current, more power lost through leakage, and higher power-factor readings.
- c. When bushings are installed in a circuit breaker, the overall tests always are supplemented by separate C1 and C2 tests and by analyzing the oil with either a power-factor or laboratory test.
- d. Refer to the power-factor tester's instructions for the proper testing methods and expected results.

Section 3, Subsection IV.G.3.**3. C1 and C2 Bushing Tests**

- a. The C1 test is a power-factor test from the bushing's center conductor to the potential tap.
- b. The C2 test is a power-factor test from the potential tap to ground.
- c. Refer to the power-factor tester's instructions for the proper testing methods and the expected results.

4. Tank-Loss Test and Index

- a. The tank-loss test determines the dielectric condition of the tank's insulating medium. The circuit breaker's lift rods or rotor elements and their guides also are included in the test since they are not connected to the bushings during an open circuit-breaker, power-factor test.
- b. The index is calculated by subtracting the sum of the two open circuit-breaker bushing losses from the closed circuit-breaker losses on the same tank.
- c. Refer to the power-factor tester's instructions for the proper testing methods and the expected results.

H. Mechanical Measurements and Tolerances

Take mechanical measurements of the circuit-breaker mechanism when triggered by the Utility Standard TD-3322S [Attachment 7](#) maintenance template, or as necessary, to troubleshoot or correct an operating malfunction. Check for incorrect tolerances.

1. Clear the circuit breaker and make it safe for maintenance before performing any of these checks.
2. To troubleshoot circuit-breaker malfunctions that are not lubrication-related, or to verify proper mechanism, linkage, and spring set-up and operation, compare the measurements and tolerances to those provided by the manufacturer.
3. Refer to the manufacturer's instructions for specific safety information and for the proper pressures, angles, and measurements.

I. Pneumatic- or Hydraulic-System Operation

Typically, air systems should not operate more than 50 times a month and hydraulic systems 5 times or 0.2 hours a month. However, some hydraulic systems may have up to 20 pump starts in a 24 hour period. Refer to the applicable manufacturer's instructions for acceptable limits. Compare current compressor/pump counter readings with previous station read data and the manufacturer's limits.

Section 3, Subsection IV.I.1.

1. Bleed the pneumatic or hydraulic system until its air compressor or hydraulic pump starts, or to the point where it is supposed to start. Confirm that the system increases to the proper pressure and then shuts off.
2. If the compressor or pump motor does not start, perform the following actions.
 - a. Check the motor's source fuse or circuit breaker for voltage.
 - b. Ensure that the pressure-switch contacts are closed and in good condition. If they are not closed, adjust the contacts, as necessary. Refer to the pressure-switch manufacturer's instructions when making any adjustments.
 - c. Check for voltage at the output of the pressure switch.
 - d. Check for voltage at the input to the compressor or pump motor.
 - e. Ensure that the motor circuit is complete on the ground or neutral side.
 - f. Ensure that any compressor-motor or pump-motor thermal overloads are reset.
3. If the compressor or pump motor starts, but the pressure does not increase, perform the following actions.
 - a. Ensure that the gauges are reading accurately.
 - b. Ensure that the valves are properly open or closed.
 - c. Ensure that there are no leaking valves, lines, connections, or bypasses; or malfunctioning unloaders.
 - d. If the motor is running, but the compressor or pump is not, take the following steps.
 - (1) Ensure that the belts or couplings are intact and tightened properly.
 - (2) Check for loose or slipping pulleys and couplings.
 - (3) Cut out the compressor power, remove the belt or disconnect the coupling, and then check the compressor or pump shaft for binding.
4. If a leak is suspected in either a pneumatic or hydraulic system, using an ultrasonic detection tool may help locate the leak.
5. If the problem still is not found, dismantle the compressor or pump and repair or replace any worn, loose, or damaged parts. Replace the whole compressor or pump, if necessary.
6. Record any service work on the appropriate compressor-service form, found in Section 13, "Forms."

Section 3, Subsection IV.J.**J. Hydraulic Pre-Charge Pressure**

The hydraulic accumulator is pre-charged with nitrogen gas. The pre-charge pressure is set to meet the operating requirements of the particular circuit-breaker type. The operating mechanism's nameplate or instructions list the proper pre-charge pressure. Use the following general procedure to check the pre-charge pressure, but always refer to the manufacturer's instructions, as well.

1. Open or cut out the pump control circuit.
2. Bleed the hydraulic system to discharge the oil pressure.
3. Operate the hand pump or momentarily energize the pump motor.
 - a. At first, the oil-pressure gauge should indicate a marked increase in the oil pressure.
 - b. Note the gauge reading when the rapid-pressure increase suddenly stops. This reading is the pre-charge pressure.
4. If the temperature-compensated pre-charge pressure at the measured ambient temperature is not within 50 psig of the value listed on the mechanism's nameplate, it should be corrected.
 - a. Refer to the manufacturer's instructions.
 - b. Replace the accumulator if it cannot hold a pre-charge.

K. Pressure-Switch Rundown Testing

Note: These instructions describe how to adjust pressure switches and test pneumatic and hydraulic operators according to pressure measurements. Some newer hydraulic systems are adjusted according to disc-spring-travel dimensions. Follow the manufacturer's instructions for setting and adjusting these newer systems.

1. Set or check the compressor cutoff at the rated operating pressure. Refer to manufacturer's instructions or the nameplate information for the proper cutoff pressure.
2. To set the alarm pressure, perform the following actions.
 - a. Bleed the storage tank to the listed "compressor cut-in" pressure with the compressor's power turned off.
 - b. Perform one close-open operation on the circuit breaker.
 - c. After this operation, verify that the low-pressure alarm comes in, or set it to come in, **just below** the existing pressure.
 - d. When starting with a full-tank pressure, the alarm should come in on the third operation; however, coming in on the fourth operation is acceptable.

Section 3, Subsection IV.K.2.d., continued

Note: To facilitate adjusting the pressure switches, record the operating pressure after each operation. This allows the pressure to be obtained again without repeatedly operating the circuit breaker.

3. To set the lockout pressure, perform the following actions.
 - a. With the storage tank at the alarm pressure and the compressor power turned off, perform one close-open operation on the circuit breaker.
 - b. Set the lockout switch just below the pressure that exists after this operation.
 - c. Set the lockout switch so that, when starting with a full storage tank, no more than five close-open operations are allowed.
4. If the alarm and lockout switches are on the same pressure device and have no differential adjustment between them, set the lockout switch as specified in Step 3. Record the alarm switch's operating pressure and indicate that it cannot be adjusted separately.
5. For circuit-breaker mechanisms designed to have only four or five good close-open operations, ensure that the compressor cut-in controls are set at the lowest point at which they can still come in on the first close-open operation.
 - a. Refer to the manufacturer's instructions.
 - b. Set the alarm to come in on the second close-open operation.
 - c. Set the lockout to come in after the third close-open operation.
6. Record the rundown-test results on Company [Form TD-3322M-F24, "Compressor Rundown,"](#) found in Section 13, "Forms."

L. Contact Pressures

While inspecting the circuit-breaker main and arcing contacts, check for unequal or uneven wear, coke build-up, heavy pitting, or grooves. Any of these may indicate incorrect contact pressure.

1. Use a digital load-cell or spring scale to verify the existing contact pressures if any of these conditions are found.
2. Compare these contact pressures to those specified by the manufacturer.
3. Adjust the pressure accordingly.

Section 3, Subsection IV.M.**M. Testing Contact Resistance****1. Test Triggers**

Test the contact resistance when triggered by the Utility Standard TD-3322S [Attachment 7](#) maintenance template, or if a condition or trouble indicates a possible load-path problem.

- a. Wide variations in resistance usually indicate a faulty condition of the current-carrying components. If this is indicated by diagnostic testing, schedule an early overhaul of the circuit breaker.
- b. Verify that the source of any high reading is not external, such as from leads or connections, before performing internal inspections or work.

2. Contact-Resistance Test Procedure

- a. Take contact-resistance readings with a micro-ohmmeter across each pole of the closed circuit breaker including the incoming leads, connectors, and bushing caps. Always power-close the circuit breaker before taking contact-resistance readings. Slow-closing does not give reliable results.
- b. Compare the readings to the other poles, previous readings, the typical readings listed in Table 2. and the specifications, if any, in the manufacturer's instructions. The difference in contact resistance between any of the three poles should not exceed 25% of the lowest value taken.
- c. If any pole readings are higher than expected, take contact-resistance readings across the individual load-path components to isolate the source of the high resistance. Test from the lead to the lead connector at the bushing, from this connector to the bushing pad, and across any other connections and contacts in the load-carrying path.

Note: Testing the contact resistance on some circuit breakers requires using a 100-ampere (A) tester. Refer to the manufacturer's requirements.

3. Circuit-Breaker Contact-Resistance Readings

See the following Table 2. for circuit-breaker contact-resistance readings. Also, refer to the contact-resistance specifications in the manufacturers' instructions. The listed ranges represent the minimum and maximum resistance reported.

- a. The readings represent trends to expect on various types of circuit breakers. This list is not necessarily complete and does not always represent the absolute maximum range of any given circuit breaker.

Section 3, Subsection IV.M.3.b.

- b. Any readings found to be outside this range, and any showing a more than 25% difference of the lowest reading between phases or heads, are abnormal. They indicate a problem that should be corrected or referred to the local substation field specialist.
- c. Air, vacuum, and SF₆ gas circuit breakers usually have the lowest contact-resistance values. OCBs with wiping-type contacts have higher resistance values. The highest are found on circuit breakers with butt-type contacts where the resistance values may vary significantly.

Section 3, Subsection IV.M.3.c., continued

Table 2. Circuit-Breaker Contact-Resistance Readings

Circuit-Breaker Manufacturer and Type	Current Rating in A	Voltage Rating in kV	Resistance Range in Micro-Ohms ($\mu\Omega$)
Asea (now Asea Brown Boveri [ABB])			
A2Q5141	3,150	72.5/550	0–43
Brown Boveri (Gould, ITE, Kelman)			
F-1	400	7.5	600–1,700
F-2	400	15	600–1,100
F-6	300	15	0–1,100
KM-115	1,600	115	150–200
14.4-KS-500-120	1,200	15	70–200
14.4-TK-500-600	600	14.4	180–200
15-HK-500	2,000	15	20–4
23-KS-500-120	1,200	25	70–200
69-KS-1500-12	1,200	69	150–275
69-RA6-F	600	69	1,050–1,700
69-KSB3500-20	2,000	69	140–160
115-RA6-J	800	115	500–800
115-KM-315-12C	1,200	115	170–205
115-RA6B-K12	1,200	115	500–1,500
121-KM-6320-C	2,000	115	200–240
230-RA6B-L-3500	1,200	230	500–1,000
230-GA20-30-20000	3,000	230	0–15
240-GA20-20-50000	2,000	242	120–130
242-GA50-20C	2,000	230	150–300
242-KM-63-25C	2,500	230	200–270
242-KM-6330-C	3,000	230	200–240
550-GA-50	3,000	550	0–20
General Electric			
AM-2-4-416-100-150	1,200	4.16	15–4
AM-5-50	1,200	4	15–5
AM-13.8	2,500	13.8	20–4
AM-15-250	1,200	15	20–4
AM-15-250-1	1,200	15	20–4
AM-15-500	1,200	15	15–3
FG-230-10000	1,000	230	500–1,000
FGK-230-5000	1,200	230	300–600
FKG-230-10000	1,600	230	0–31
FGK-230-10000-3Y	1,600	230	390–440

Continued on the next page...

Section 3, Subsection IV.M.3.c., continued

Table 2. Circuit-Breaker Contact-Resistance Readings, continued

Circuit-Breaker Manufacturer and Type	Current Rating in A	Voltage Rating in kV	Resistance Range in Micro-Ohms ($\mu\Omega$)
General Electric			
FGK-230-10000-4	1,600	230	200–340
FHKD-36-23B-F2	400	115	400–3,200
FGK-230-15000-2	1,600	230	200–340
FHKD-239-24B-D25A	600	23	700–800
FK-12	1,500	2.5	60–120
FK-143	600	7.5	60–70
FK-14.4-100-1	600	14.4	230–310
FK-69-2500-4	1,200	69	300–380
FK-69-3500-12	1,200	69	150–300
FK-115-5000	1,200	115	600–2,000
FK-115-10000-2	1,600	115	340–550
FK-121-43000	1,600	115	350–525
FK-255	1,200	13.8	270–280
FK-339-115-3500	800	115	550–900
FK-339-1000	1,200	15	35–45
FK-439-115-3500	1,200	115	550–900
FK-339-1000	3,000	15	30–50
FK-339-2,500	800	230	640–760
FK-439-23-250	600	23	150–170
FK-439-23-250	1,200	23	150–200
FK-439-2500	800	230	790–2,500
FK-439-115-2500	1,200	115	0–460
FK-439-115-5000	1,200	115	600–2,000
FKC-2	200	15	1,000–3,500
FKD	600	14.4	150–250
FKD	1,200	15	85–175
FKO-36-9AS	400	73	0–200
FKO-37	600	15	100–130
FKR-132-B	400	15	500–1,100
FKR-132-B	800	15	340–360
FKR-155-20	1,200	15	90–100
FLO-1R	600	15	0–100
VIB	1,200	21	70–200
VIB 15.5	600	12	85–200
VIB 15.5	2,000	15	45–50
VIBC-21-14000	2,000	21	40–100

Continued on the next page...

Section 3, Subsection IV.M.3.c., continued

Table 2. Circuit-Breaker Contact-Resistance Readings, continued

Circuit-Breaker Manufacturer and Type	Current Rating in A	Voltage Rating in kV	Resistance Range in Micro-Ohms ($\mu\Omega$)
McGraw Edison (FPE, Penn, PEM)			
AD-28	600	14.4	75–200
AD-28	1,200	14.4	45–150
AF-36-69	1,500	69	150–300
AHE-48	1,200	115	50–230
AKE-25	600	7.2	100–165
AKE-40	600	14.4	250–1,200
ALP-60	2,000	115	110–150
J-30-D	600	34.5	180–660
JB-45	600	69	690–900
JBE-45	600	69	1,500–2,200
JCE-17-B	600	14.4	100–600
JC-17	600	12	180–2,150
JCE-17-A	600	15	0–220
JCE-22	600	23	100–600
JCE-22-C	600	23	75–280
JCE-22-C	600	14.4	130–310
JCE-22-C	1,200	14.4	100–200
JE-30	600	23	180–460
FE-30-D	600	23	180–320
JE-42-E	600	69	300–745
JE-42-F	1,200	69	250–510
R-45	400	69	200–3,400
RDE-48	600	69	620–1,200
RHE	1,200	230	600–675
RHE	1,600	230	500–575
RHE-64H	1,200	115	610–1,000
RHE-64I	1,200	115	400–1,200
RHE-84	1,200	230	525–750
RHE-84I	800	230	600
RHE-84K	1,600	230	630–650
RHE-90, 6 shoe contact	*	230	300–650
RHE-90, 8 shoe contact	*	230	300–425
RHE-90, 10 shoe contact	*	230	200–300
RW-64	600	115	2,400
RWE-58G	800	115	800–1,500

Continued on the next page...

Section 3, Subsection IV.M.3.c., continued

Table 2. Circuit-Breaker Contact-Resistance Readings, continued

Circuit-Breaker Manufacturer and Type	Current Rating in A	Voltage Rating in kV	Resistance Range in Micro-Ohms ($\mu\Omega$)
McGraw Edison (FPE, Penn, PEM), continued			
RWE-64	600	115	750–1,250
RWE-64A	600	115	1,000–1,200
RWE-64H	800	115	900–1,000
Vac-00	1,200	15.5	50–115
Siemens-Allis (Allis-Chalmers)			
AM-100A	600	5	100–300
BZO-10000	1,200	115	250–400
BZO-10000	2,000	115	200–400
BZO-10000-4 & -7	1,600	115	250–400
BZO-10000-2, -3 and -6	1,600	115	200–400
BZO-115-5000-4	1,200	115	250–400
BZO-15000	1,600	230	200–300
BZO-242-50-3	2,000	242	250–450
BZO-242-50-3	3,000	242	300–400
D-22	600	15	150–450
D-22	800	15	100–450
SDO-15-250	600	14.4	150–200
SDO-15-500	1,200	23	200–250
SDO-23-500	1,200	23	100–200
Y-Z	3,000	2.5	20–50
Westinghouse			
B-13	2,000	7.5	0–30
B-20-B	1,200	15	300–500
B-20-R	600	15	20–380
E-124	600	7.5	50–90
F-3	500	13.2	50–130
G-11	600	73	0–1,000
G-22	400	73	0–4,000
GC-100	600	14.4	10–100
GC-250	600	14.4	50–200
GM-3A	800	230	420–580

Continued on the next page...

Section 3, Subsection IV.M.3.c., continued

Table 2. Circuit-Breaker Contact-Resistance Readings, continued

Circuit-Breaker Manufacturer and Type	Current Rating in A	Voltage Rating in kV	Resistance Range in Micro-Ohms ($\mu\Omega$)
Westinghouse, continued			
GM-4	800	*	300–700
GM-5	1,200	115	500–700
GM-5A	1,200	115	275–490
GM-6	1,200	115	530–700
GO-1B	600	23	170–490
GO-5	4,000	14.4	0–25
GC-2	600	23	90–150
GO-3B	600	69	150–180
O-221	600	25	150–300
14.4G-250	600	14.4	100–200
14.4G-1500	3,000	14.4	2–14
50-DH-100	600	4.33	0–30
50-DH-100	600	5	45–60
50-DH-150	1,200	4.16	15–30
50-DH-150	1,200	5	40–45
50-DH-250	1,200	5	15–25
69-OG-1500	1,200	69	120–140
150-DH-250	1,200	15	20–30
150-DH-500	1,200	15	20–50
150-DH-P500	2,000	13.8	15–30
150-CA-1000	1,200	15	10–40
150-CA-1000	3,000	15	10–40
242-GMS-63	2,000	230	240–300
550-LWEC	3,000	69/550	50–80
1150-GM-5000	1,200	115	100–315
1150-GM-10000	1,600	121	180–375
1150-GM-10000	2,000	121	180–200
2300-GW-5000	1,200	230	230–550
2300-GW-15000	1,600	230	200–475

Continued on the next page...

Section 3, Subsection IV.M.3.c., continued

Table 2. Circuit-Breaker Contact-Resistance Readings, continued

Circuit-Breaker Manufacturer and Type	Current Rating in A	Voltage Rating in kV	Resistance Range in Micro-Ohms ($\mu\Omega$)
Westinghouse, continued			
R1	600	15.5	50–200
R1	1,200	21	50–200
R3	1,200	15.5	50–200
R4	1,200	15.5	50–200
R4	2,000	15.5	50–200
SA-3	600	15	18–37
RCT-95	1,200	13.8	15–40
SAF-2	600	4.16	30–60
V-250	600	14.4	50–200
PG&E			
Type W EXP	400	60	200–350
Type W KINIFE	400	60	0–900
McGraw Edison and Westinghouse			
R	400	12	1,000–2,000
RE/RVE	400	12/21	350–500
3H	*	12	6,000–10,000
6H	*	12	4,000–10,000
RXE	*	*	365–370

* The information is not listed in the source document. Contact the manufacturer, if necessary. For McGraw Edison RHE-90 circuit breakers, the ampacity depends on the contact configuration.

Notes:

1. Take the readings from bushing lead to bushing lead with the circuit breaker closed. This also tests the bushing-lead connectors.
2. Investigate the readings if they are higher than those listed or differ by more than 25% of the lowest value.

N. Testing Circuit Breakers for Functional Performance

Functional-performance tests help evaluate the existing condition of a circuit-breaker mechanism. After a circuit breaker has been in one position, either open or closed, for a period of at least 2 weeks, the mechanism's moving parts and lubrication take a "set." When the **first** operation after the "set" occurs is compared to successive operations, a variation in the operating times indicates that the mechanism needs to be serviced.

1. Using Functional-Performance Test Instruments

- a. Functional-performance test instruments are used **both** for conducting functional-performance tests **and** for measuring the close and open operating times of a circuit breaker during installation and maintenance.

Section 3, Subsection IV.N.1.b

- b. A benchmark test of the operating times is essential for trending and comparison.
- c. Set up the test instrument to capture open-coil and close-coil current profiles and auxiliary contact (Acon) times for dc-operated circuit breakers and a dc-voltage operating profile. As applicable, compare present voltage and current profiles to previous test results to help detect abnormal operating conditions.
- d. Sometimes the lack of a local control switch makes it impractical for one person to conduct a functional-performance test. In these cases, install a permanent, online performance monitor.
- e. The FPT data to be captured on [TD-3322M-F13, "Distribution Circuit Breaker Functional Performance Test Form,"](#) includes:
 - Duration in milliseconds (ms) of the operating coil current.
 - Operating coil current profiles and Acon times.
 - The greatest DC voltage drop for trip and/or close operations.

2. Using Online Circuit-Breaker Performance Monitors**a. Description**

- (1) Some circuit-breakers are equipped with on-line performance monitors.
 - (a) Online monitors measure the tripping times as they occur during switching and fault operations.
 - (b) The monitor alarm activates when the operating time slows down.

b. Checking for Circuit-Breaker Operation

When online performance monitors are installed permanently on a circuit breaker, the only functional-performance task is to ensure that the circuit breaker operates during the required time interval. Any time the circuit breaker operates, it causes the monitor to measure and analyze the operating time.

- (1) An alarm indicates the need for a mechanism service. (On the Star 10,000, the operating alarm is indicated by an exclamation point (!) at the far right side of its display.) When an alarm is received:
 - (a) Document the alarm on Company [Form TD-3322M-F13, "Distribution Circuit Breaker Functional Performance Test Form,"](#) found in Section 13, "Forms."

Section 3, Subsection IV.N.2.b.(1)(b)

- (b) Reset the alarm, contact the local field specialist, and immediately schedule a mechanism service.
- (2) Check for alarms, and reset the Star 10,000 monitors monthly, if there have been any circuit-breaker operations.
- (3) Ensure that non-CAISO (California Independent System Operator) distribution-class circuit breakers operate on a schedule according to the Utility Standard TD-3322S [Attachment 7](#) maintenance template.
- (4) Transmission-class circuit breakers, both CAISO and non-CAISO, should operate within the time period triggered by the Utility Standard TD-3322S [Attachment 7](#) maintenance template.
- (5) Contact the local substation field specialist if there are any questions concerning online circuit-breaker performance monitors.

c. Retrofit of Star 10,000 Monitors

Star 10,000 units purchased before October 2000 occasionally may display a flashing “9999.” This problem may be corrected easily by installing a zener diode supplied by the manufacturer (Barrington). Contact the local substation field specialist for repair and ordering information.

Note: Visit www.Barringtoninc.com for Barrington product information.

3. Functional-Performance and Exercise Test Triggers

A functional-performance test is required for the following circuit breakers that **do not** have online performance monitors:

- a. For all non-CAISO-controlled, distribution-class circuit breakers:
 - (1) Perform the test, as triggered by the Utility Standard TD-3322S [Attachment 7](#) maintenance template.
 - (2) Document the results on a [“Distribution Circuit Breaker Functional Performance Test Form”](#) found in Section 13, “Forms.”

Note: Unit substation circuit breakers with current-trip coils cannot be tested with a functional-performance test. See the Utility Standard TD-3322S [Attachment 7](#) maintenance template for the time-based mechanism service trigger.

- (3) Functional performance testing on RMag and AMVAC breakers will consist only of a capacitor test (rapid open-close-open) in lieu of timing the operating coil duration. See Section 9, Subsection X.E.

Section 3, Subsection IV.N.3.b.

- b. For all transmission-class circuit breakers, no routine Functional-Performance Test is required.
- c. An Exercise is required for the following circuit breakers:

For transmission-class circuit breakers applied to 60 kV and above, perform a routine **Exercise** in accordance with the Utility Standard TD-3322S [Attachment 7](#) maintenance template.

 - (1) CAISO-controlled circuit breakers must be exercised when triggered by the Utility Standard TD-3322S [Attachment 7](#) maintenance template, if they do not operate by unrelated switching or relay action.
- d. **Exception:** If the operating conditions for non-CAISO circuit breakers require extensive switching involving more than 4 total hours of switching and testing time and/or overtime work, then contact the local substation field specialist to discuss possible options.
 - (1) Omit the exercise and the test, if necessary.
 - (2) Enter the reason for the exception in the Maintenance Program every time the test is scheduled and then canceled.
 - (3) If this is likely to occur, installing an online performance monitor is recommended.
 - (4) In rare cases where conditions do not permit an Exercise and these circuit breakers do not have an online monitor, transmission class circuit breakers receive a routine 4-year mechanism service. Refer to the Time Based Triggers “Mechanism Service” item in the Utility Standard TD-3322S [Attachment 7](#) maintenance template.
- e. **Procedure to Perform the Exercise:**
 - (1) In the month when the Exercise order is known, the maintenance supervisor submits an Application for Work (AFW) with a date and time to the Control Center having jurisdiction requesting that the circuit breaker be exercised via SCADA, if possible. However, the Control Center requests that all Circuit Breakers classified as Critical be field exercised. All AFW lead times should be followed so that engineering reviews and normal processing between PG&E and the CAISO can occur. The Control Center reviews the AFW.
 - (2) The Grid Control Center conducts the Exercise when scheduled and via SCADA, if possible. The Grid Control Center will notify the Maintenance Supervisor when the Exercise is completed.

Section 3, Subsection IV.N.3.e.(3)

- (3) If the Control Center determines that the circuit breaker cannot be exercised remotely, they will notify the maintenance supervisor that the circuit breaker will need to be field exercised. The Grid Control Center determines when the field Exercise can be performed and provides the switch log to the maintenance supervisor for the Exercise. The circuit breaker field Exercise can now take place under the direction of the Control Center.
- (4) To expedite repairs, the Grid Control Center will notify the appropriate personnel when there is a problem with the circuit breaker Exercise. The Control Center will notify the Maintenance Supervisor (the on-call supervisor after hours) when a circuit breaker fails to operate during the SCADA Exercise.
- (5) Transmission class circuit breakers that fail to operate during the annual Exercise receive corrective actions as specified in Utility Standard TD-3322S, [Attachment 7](#), Table 2.
- (6) When the Exercise has been completed, make a notation in the Long Text field of the order indicating how the Exercise was completed. This documents compliance with our CAISO Filed Maintenance Practice and other regulatory requirements. Use the most appropriate of the following three phrases:
 - Switching, Maintenance, or Relay Action
 - Remote Exercise Via SCADA
 - Field Exercise Via Switching
- (7) Close the Exercise order using established procedures in [Utility Procedure TD-3320P-12, "Substation SAP Work Management System \(WMS\) Process."](#)

4. Functional-Performance Tests on Energized Circuit Breakers

Note: Do not perform "close" tests on circuit breakers that have AC closing voltage.

The functional-performance test can be performed with the circuit breaker still energized, but only if it is in parallel with another circuit breaker, if it is bypassed so that it can be operated without interrupting its load, or if it is in the process of being cleared.

- a. Before operating a circuit breaker, connect the functional-performance test set to the control circuits to evaluate the "as-found" operating profile.

Section 3, Subsection IV.N.4.b.

- b. The data recorded with the functional-performance test set includes the duration in milliseconds (ms) of the main contact “part” time on opening and the “make” time on closing, the open-coil and close-coil current profiles for dc-operated circuit breakers, and the dc-voltage operating profile.
- c. Set the analyzer to record three open **and** three close operations for DC trip and DC close breakers.

5. Approved Performance-Test Instruments

At this time, only the Kelvatek/Camlin “Profile P3” portable circuit-breaker timer is approved for conducting circuit-breaker performance testing.

6. Procedure for Functional-Performance Testing

Use the following procedure to perform functional-performance testing.

- a. Properly complete and submit the appropriate “Clearance Request” form. (Hard-copy “Clearance Request” forms are available in the headquarters and may be available online.)
- b. Perform a thorough, visual condition assessment of the circuit breaker.
- c. Thoroughly check the hook-up of the hand-held circuit-breaker analyzer to the circuit breaker before performing any switching.
- d. Program all the station data into the hand-held circuit-breaker analyzer **before** setting up for the functional-performance test.
- e. Use an approved switching tag when preparing the circuit breaker for the test. Do not plan to report on the circuit breaker unless it fails to operate. The intent is to not report on unless necessary.
- f. While in parallel or bypassed, hook up the hand-held circuit-breaker analyzer to the circuit breaker. The analyzer **must** be connected and ready to capture the operating times **before** the circuit breaker is operated. This captures the “as-found” operating profile.

**WARNING**

Do not connect functional performance test tools or any other portable timing devices to an energized high-voltage conductor.

Failure to follow this warning exposes persons in close proximity of the test equipment or test leads to hazardous levels of electrical energy. This may result in severe electric shock or arc flash, leading to serious injury or death.

Section 3, Subsection IV.N.6.g.

- g. Perform the functional-performance test.

Note: Do not perform “close” tests on circuit breakers that have ac closing voltage, since doing so does not provide useful data.

- (1) Manually trip and close the circuit breaker three times successively.
 - (2) To reduce exposure, perform the test as efficiently as safety allows. It should take approximately 10 to 15 minutes to complete the test.
 - (3) When setting up the Kelvatek P3 circuit breaker test set, insert the DC test current probe electrically adjacent to the coil being tested to avoid the influence of inrush current from other parts of the operating scheme.
- h. Perform three open and three close operations. Record the Acon times on [Form TD-3322M-F13](#) and electronically via the test equipment.
- i. If previous coil duration times are not available, use the following criteria to determine if the coil duration is acceptable and that the circuit breaker is suitable for service:
- Verify that all three open times are within 15% of one another.
 - Verify that all three close times are within 25% of one another.
 - Verify that DC voltage does not drop more than 10% for 125 vdc or 20% for 24 and 48 vdc circuits during the time the operating coil is energized.



Figure 4. P3 Connection Points

- j. Setting up the Kelvatek P3: Plug the voltage monitoring leads into the P3 DC voltage plugs. Connect the voltage leads (clip end) to the DC positive and negative power supply of the breaker. Refer to Figure 4.

Note: Use the test block terminal strip provided in newer breakers for test connections.

Section 3, Subsection IV.N.6.k.

k. Plug the DC probe into the P3 DC probe socket. Refer to Figure 5.

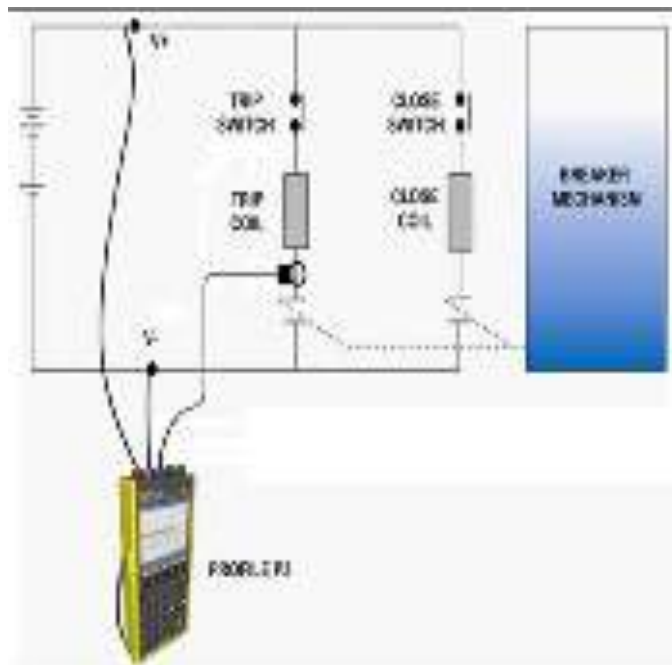


Figure 5. Diagram of Connections to Test TRIP

- (1) Connect the DC probe (sometimes called the DC current probe) to the negative side of the open or close coil being tested. Refer to Figure 5.
 - (2) Place this connection as close as possible to the open or close coil. This helps prevent introducing current from adjacent DC circuits into the trip or close profile.
 - (3) Move the DC probe back and forth between the open and close coils to perform the full set of tests. Refer to the following Figure 6.
- l. Turn on the P3 unit, and enter the tests details for the breaker being tested.
 - m. Set the P3 up for single shot mode. (The multi-shot mode is not recommended because of the need to move the DC probe between shots.)

Section 3, Subsection IV.N.6.m., continued

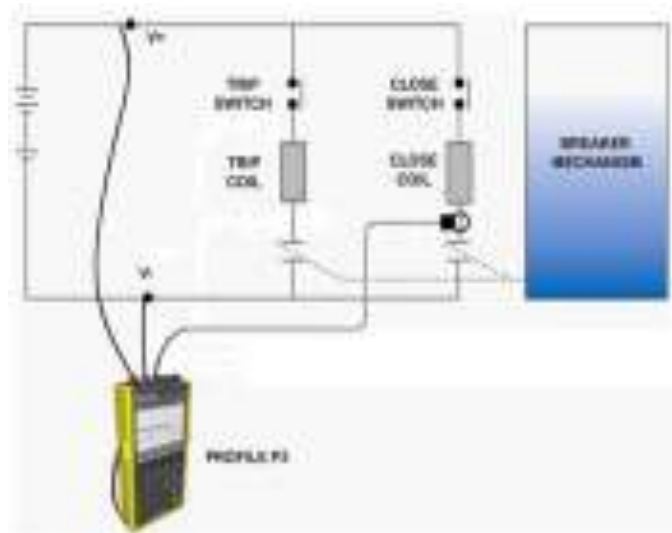


Figure 6. Diagram of Connections to Test CLOSE

- n. Operate the breaker; save after each shot, and continue until testing is complete.
- o. If the circuit breaker fails to operate, immediately contact the operations center having jurisdiction and request to clear and report on the circuit breaker for a mechanism service.
- p. Return the circuit breaker to service unless it fails to operate.
- q. Analyze and compare the trip and close times in ms. A circuit breaker that operates faster after the first operation may have a possible lubrication-related problem. Investigate further if there is abnormal data.
- r. Analyze the open-coil and close-coil current profiles for dc-operated circuit breakers and the dc-voltage operating profile. To check for abnormal patterns, compare these profiles to those provided by previous tests or on similar units. Investigate further if there are any abnormal patterns.
- s. **Performing Mechanism Service Triggered by Functional Performance Tests (FPT)**

Schedule the circuit breaker for a mechanism service in **any** of the circumstances listed in the following Step (1) through Step (4).

- (1) When there is a variation of $\pm 15\%$ or more between the longest and shortest **trip** times from a **present** functional performance test.
- (2) When there is a variation of $\pm 25\%$ or more between the longest and shortest **close** times from a **present** functional performance test.

Section 3, Subsection IV.N.6.s.(2), continued

The common formula for percentage variation is:

$$\frac{\text{Longest Test Time} - \text{Shortest Test Time}}{\text{Shortest Test Time}} \times 100$$

Table 3. Example: Present FPT Results

First Trip	Second Trip	Third Trip
In Milliseconds		
24.34	22.35	20.50

Using the common formula, the percentage variation is 18.7%, which means the circuit breaker fails the functional performance test.

- (3) When there is a variation of +/-15% or more between the longest and shortest **trip** times between **the initial and present** functional performance tests.
- (4) When there is a variation of +/-25% or more between the longest and shortest **close** times between **the initial and present** functional performance tests.

Table 4. Example: Initial and Present FPT Results

	First Trip	Second Trip	Third Trip
In Milliseconds			
Present Functional Performance Test	25.03	23.34	22.47
Previous Functional Performance Test	23.04	21.35	20.50

Using the common formula for the present test, the percentage variation is 11.4%, which implies the circuit breaker passes.

However, when we use the common formula to trend the present FPT with the previous one, the percentage variation between the longest trip time in the table and the shortest is 21.1%, which indicates the circuit breaker is slowing down over time. The breaker **fails** the FPT trend, so a mechanism service is due.

t. **Investigate if an Abnormal Current or DC Voltage Profile Exists**

See Table 4., "Causes of Abnormal Conditions," for possible causes of abnormal conditions. To help detect abnormal trends, also compare the test results to the previous test results and the charted curve shapes.

If it is difficult to capture close times or abnormal results are found during closing, it may be necessary to review the circuit breaker prints to determine if the charging motor is the cause of the abnormal results.

Section 3, Subsection IV.N.6.u., continued

- u. [Form TD-3322M-13, “Distribution Circuit Breaker Functional Performance Test Form,”](#) supplies the formula to calculate the actual percentage variance. (See Section 13, “Forms.”)

Table 5. Causes of Abnormal Conditions

Abnormal Condition	Possible Causes
High main-contact close or open time, or increasing trend	- Poor or incorrect lubrication - Corrosion - Mechanical wear or incorrect mechanical adjustments - Friction in the trip-latch release mechanism Note: Also, slow operating speed can cause premature wear and failure of the main contacts and interrupters.
High peak current differential	
High steady current differential	
High A/B contact time	
High off-latch time	
Low normal dc-voltage supply	- High-impedance battery cell - Bad wiring, corrosion, or connections - Dc ground, partial or hard ground
Low minimum dc voltage during a circuit-breaker operation	
Abnormal trip-coil current-profile curve	- Partially burned-out trip coil. This may be caused by the trip coil being energized for an abnormally long time (slow to trip or the “A” contact out of adjustment). - Poor trip-circuit continuity caused by loose wire

- v. Keep the completed [“Distribution Circuit Breaker Functional Performance Test Form”](#) in the local headquarters’ history files. (See Section 13, “Forms.”)

O. Main-Contact Operating Times

- In addition to performing a functional-performance test, periodically test the opening and closing times of the circuit breaker’s main contacts to verify that the circuit breaker is performing within the specifications given in the manufacturer’s instructions.
- The operating times vary according to the circuit breaker’s type, manufacturer, rating, and operating coil voltage. Investigate and correct all operating times that are outside of the manufacturer’s tolerances.
- The following conditions may cause incorrect operating times.
 - Degraded lubrication
 - Corrosion
 - Improper mechanical adjustments
 - Damaged trip and close coils
 - Dirty auxiliary switches
 - Loose connections in the control circuits or contactors
 - Battery or voltage problems
 - Out-of-adjustment mechanism

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Section 4

Gas Insulated Substations (GIS)

I. Purpose

This section provides information on procedures and tests that are unique to GIS systems. Because of its design and physical construction, many of the components look much different than their more familiar air-insulated counterparts, even though they both perform the same basic function.

Gas insulated switchgear is relatively new to PG&E. GIS consists of an enclosed system, utilizing SF₆ gas as the electrical insulating medium. GIS incorporates all major elements of a substation, except transformers. GIS equipment includes circuit breakers, disconnect switches, potential devices, current transformers, and interconnecting bus. PG&E only has high voltage (60 kV and above) GIS equipment at the present time.

II. Safety Precautions and References

In addition to typical safety rules and procedures followed when working on electrical equipment, the following job aids and procedures focusing on GIS systems must be reviewed and followed in order to safely perform work.

- [Utility Bulletin TD-1403B-004, "Establishing Clearances at Gas Insulated Substations"](#)
- [Job Aid TD-3320P-18-JA05, "Disable and Lock an ABB GIS Disconnect"](#)
- [Job Aid TD-3320P-18-JA06, "Disable and Lock an ABB GIS High-Speed Ground"](#)
- [Job Aid TD-3320-18-JA19, "Operation of 115kV MEPP8 GIS 3-Way Switch"](#)

III. Testing Hybrid Density Monitors

Verifying the proper operation of the hybrid gas density monitor is essential to system operation. This procedure provides guidance in the testing of the pressure points that initiate contact switching. Document the operating pressures of the density monitors on the [TD-3322M-F81, "Hybrid Density Monitor Testing."](#) If any density monitors operate outside the manufacturers recommended tolerances, they must be replaced.

Section 4, Subsection III., continued

**CAUTION**

Cut out tripping associated with the hybrid density monitor being tested before performing any maintenance, removing a hybrid density monitor, or operating any valves associated with the hybrid density monitor.

Some equipment may not have cut-outs for tripping. In those situations, retrofit the equipment as outlined in TD-3322M, “Circuit Breakers,” Section 7, Subsection III.C, “Retrofitting Feature Switches.”

NOTE

Before cutting in the tripping after testing the monitor, test the circuit to ensure that the hybrid density monitor contacts are open. Verify there is no voltage present on the FCO, and verify the annunciator has been reset or will reset.

A. Prior to Testing

1. Contact the Control Center having jurisdiction of the equipment being tested, and notify them of the work that is going to be performed.
2. Place the Feature Cut-Out (FCO) switch for the density monitor to be tested in the “cut-out - blocks tripping on low SF₆ gas pressure” position (Figure 7).



Figure 7. FCO, Lock Out Light and Reset Button

3. Place a **Caution Tag** on the FCO per [Utility Procedure TD-1403P-04, “Tags.”](#)

Section 4, Subsection III.B.

B. Density Monitor Types

PG&E currently purchases GIS equipment from two suppliers: ABB and Mitsubishi. ABB uses Trafag density monitors, and Mitsubishi uses Hyoda density monitors. Due to their designs, they need to be connected to the test equipment differently.

C. Preparing to Test a Trafag Density Monitor (ABB)

1. Remove hybrid SF₆ density monitor by loosening the Malmquist fitting that attaches it to the GIS unit. The Malmquist fitting provided on the ABB installation is designed to not allow gas to escape when the hybrid density monitor is removed (Figure 8).



Figure 8. Trafag Density Monitor with Malmquist Fitting

2. Once the density monitor is removed, attach it to the square flange of the test equipment, and secure it in place with the clamping plate (see Figure 9).

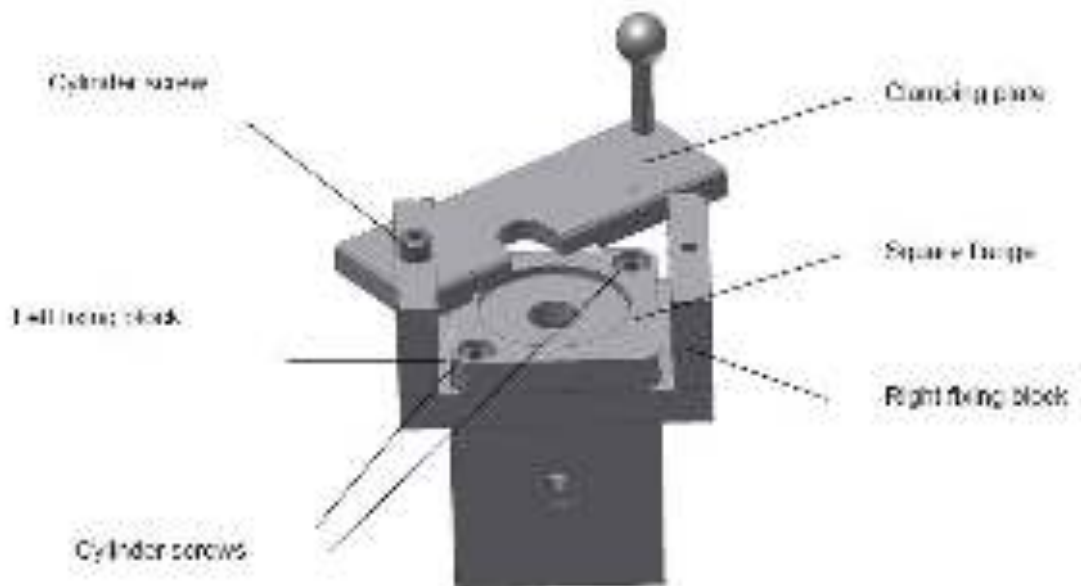


Figure 9. DensiControl DA Square Flange

Section 4, Subsection III.C.3.

3. When testing the Trafag density monitor, use the supplied connector to connect it to the test equipment (Figure 10).

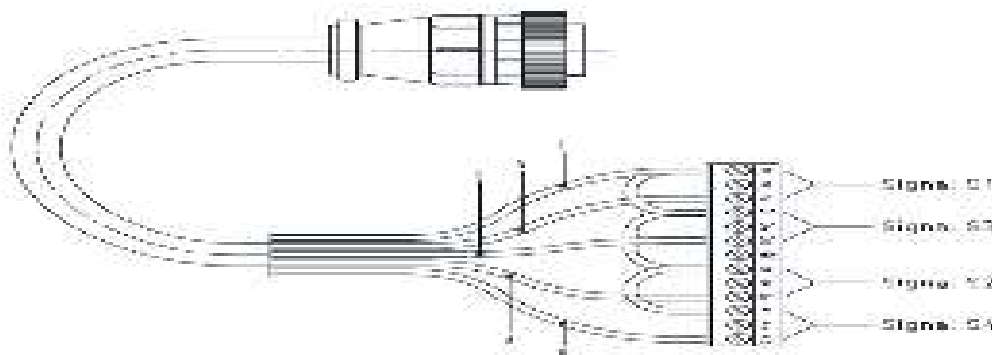


Figure 10. Supplied Connector for Trafag Monitors

D. Preparing to Test a Hyoda Density Monitor (Mitsubishi)

1. Mitsubishi installations with Hyoda density monitors do not require the removal of the density monitor for testing. Close Valve (1) and open Valve (2); then connect the supplied measuring hose (Figure 12) to the Dilo D20 fill port (Figure 11).



Figure 11. Hyoda Density Monitor with Dilo D20 Fill Port

Section 4, Subsection III.D.1. continued



Figure 12. DensiControl IN Measuring Hose and Supplied Electrical Cable

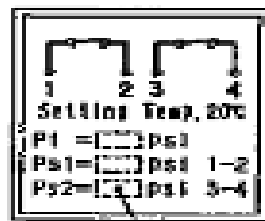
2. With Hyoda density monitors it will be necessary to connect a multi-meter to read DC voltage. Connect it to the alarm and tripping contacts to capture what pressure they operate at.

E. Testing

1. Power on the DensiControl DA/IN test equipment, and follow the on screen instructions. (The instructions can be found on the Substation Maintenance SharePoint: [DensiControl DA/IN Manuals](#))
2. Once the automatic testing process is started, an integrated compressor generates a pressure inside the test tank which corresponds to the stored filling pressure or just higher. The pressure in the test tank is released by a solenoid valve until the last switching contact has triggered. Switching pressure is on the nameplate of the density monitor

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Terminal nameplate is state
when Ps1 and Ps2 of the
density monitor switch
are contact.

Pt: Filling pressure
Ps1, Ps2: Switching pressure

Figure 13. Nameplate for Hyoda Monitor

Section 4, Subsection III.E.3

3. Document the hybrid density monitor number, alarm pressure point and tripping pressure point on [Form TD-3322M-81, "Hybrid Density Monitor Testing."](#)
4. Hybrid density monitors that operate outside manufacturer's specifications must be replaced.

F. Returning to Service

1. After testing is satisfactorily completed, remount the hybrid density monitor to the gas compartment, if it was removed.
2. Return any valves to their original position.
3. Reset any alarms generated by the testing.
4. Reset any lock out generated by the testing.
5. Verify with a voltmeter that no trip signal is coming to the FCO.
6. Return the FCO to the normal position, and remove the caution tag.

IV. Accessing GIS Load Path for Electrical Testing**A. General**

1. With GIS equipment, the high voltage bus work, conductors, switches, and circuit breaker interrupters are within the tank of the GIS. Due to their design, it is necessary to electrically access the internal components through the ground/test bushings.
2. The ground/test bushings are connected to the GIS circuit breaker primary contacts through a three position grounding switch. To access the primary contacts of a circuit breaker, the three position switches that are adjacent to the circuit breaker to be tested must be in the grounded position.
3. It is necessary to use "dual ground" test equipment for this procedure because both sides of the circuit breaker will be grounded when accessing the primary contacts. Dual ground test equipment is designed to perform its measurements while the equipment under test remains grounded. Figure 14 illustrates the typical test connections using the three position switches.

Section 4, Subsection IV.A., continued

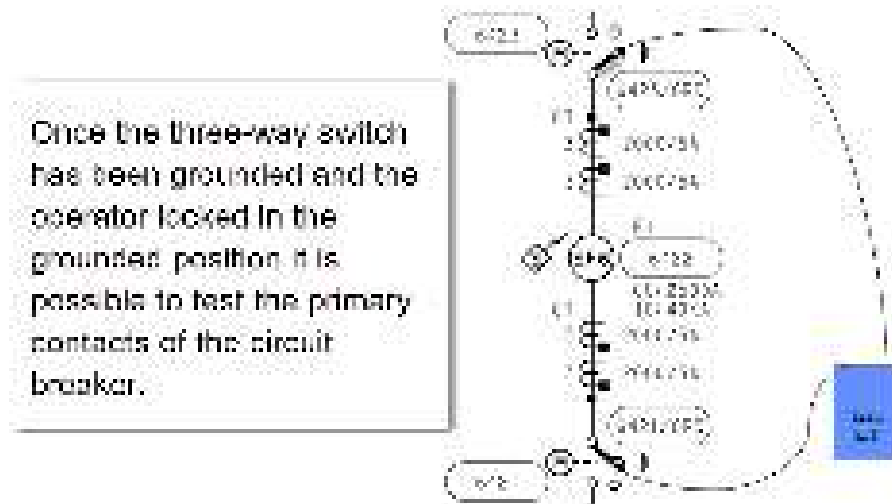


Figure 14. Typical Test Connection

B. Test Equipment

1. The Vanguard DMOM-200 S3 or Auto-ohm 200 S3 are the only approved dual ground micro-ohmmeters approved for use.

Dual ground micro-ohmmeter test equipment can measure circuit breaker contact resistance with both sides of the breaker grounded. For resistance testing, clamp-on probes are placed on the ground connections, and the portion of current going to ground is measured and removed from the total test current. The test equipment then calculates the circuit breakers contact resistance based on the magnitude of the current going through the contacts.

2. The Vanguard CT-7000 S3 is the only dual ground circuit breaker timer approved for use.

Dual ground circuit breaker timers can time a circuit breaker while grounds are applied to both sides of the breaker. This is done using a supplied clamp-on probe to one side of the circuit breakers ground straps, and an AC signal is induced onto the ground. A sensor on the probe detects a change in the induced AC signal when the circuit breaker contact is opened or closed.

C. ABB GIS

1. After the circuit breaker to be tested is cleared and grounded, remove the covers on the ground switches that are adjacent to the circuit breaker that is being tested. (Item 22 on Figure 15)

Section 4, Subsection IV.C.1., continued

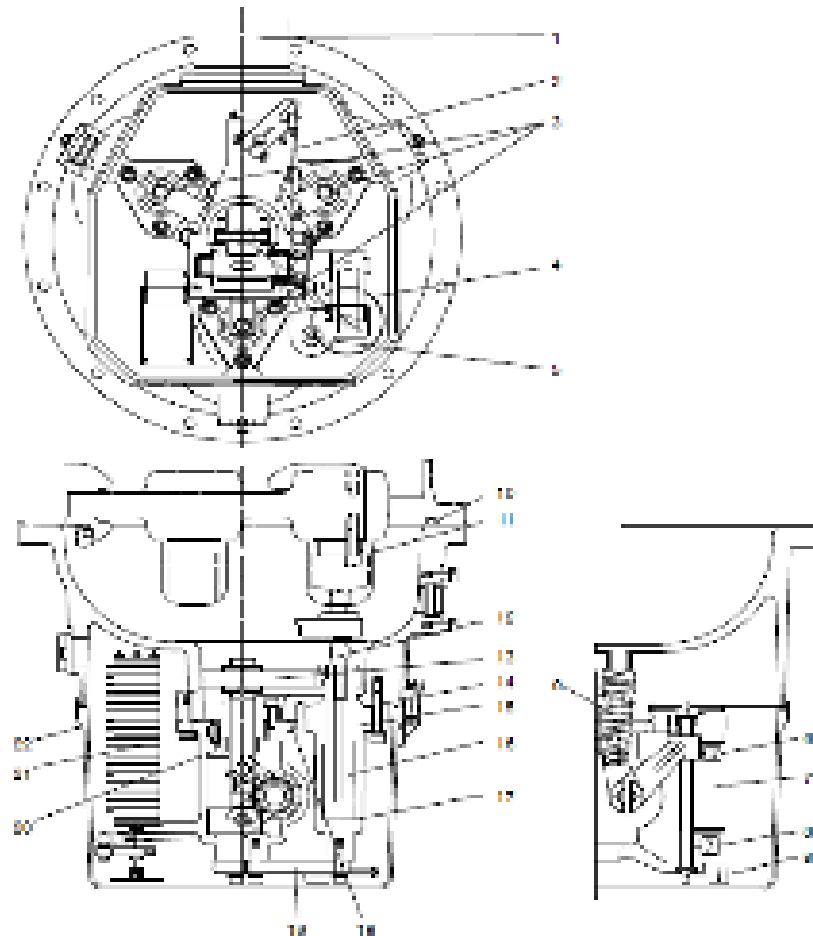


Figure 15. ABB Switch Arrangement

2. Connect the test equipment probes to the “test bushings/grounding contacts.” (Figure 16)
3. Connect the clamp-on probes around the “connector /earthing bridge.” (Figure 16)

Section 4, Subsection IV.C.3., continued

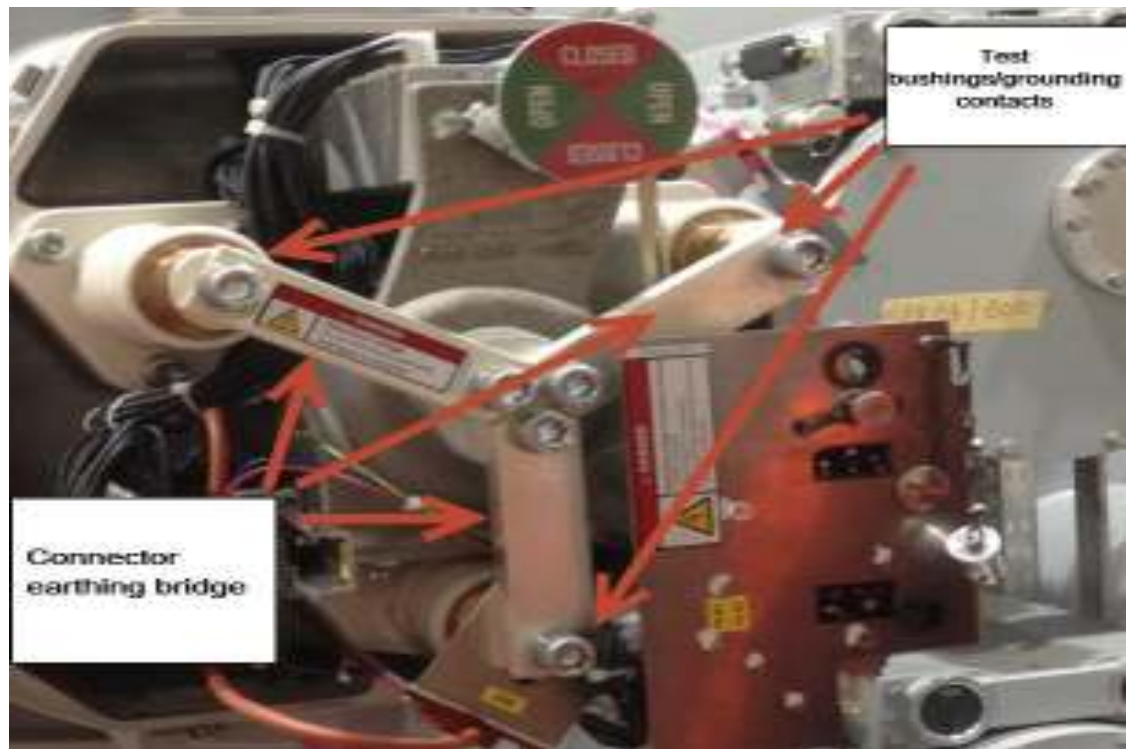


Figure 16. ABB Test Connection Points

4. Refer to Figure 17 for an example of test lead placement on ABB GIS equipment.

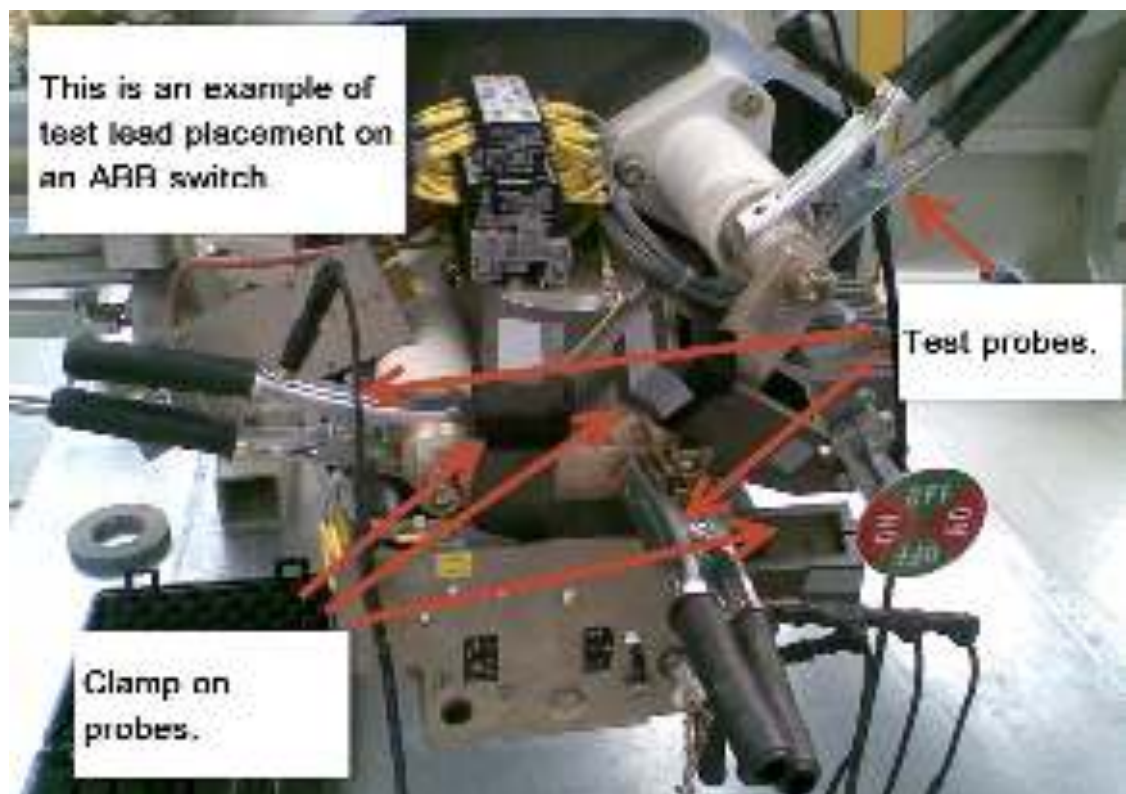


Figure 17. ABB Test Lead Placement

Section 4, Subsection IV.C.5.

5. After the test leads are in place, follow the test equipment manufacturer's instructions to conduct the required testing.

D. Mitsubishi (MEPPI) GIS

1. Once the equipment is cleared and the ground switches for the equipment to be tested are in the grounded position, remove the cover of the ground/test bushing enclosure. (Item 2 in Figure 18).
2. It is not possible to measure individual contact time or resistance with the MEPPI GIS. All three phases are grounded through one point, and it is not possible to isolate the individual ground/test bushings. (Item 1 in Figure 18).
3. Connect the test probe to the ground link. (Item 1 in Figure 18)



Figure 18. MEPPI Switch Arrangement

4. Connect the test equipment clamp-on probe to the bonding strap (Item 1 in Figure 19).
5. After the test leads are in place, follow the test equipment manufacturer's instructions to conduct the required testing.

Section 4, Subsection IV.D.5., continued



Figure 19. MEPPI Bonding Strap Arrangement

E. Returning the GIS to the As-Found Condition

If no issues were found during testing, remove the test probes and clamp-on probes. Install the covers that were removed for testing, and return the equipment to the as-found condition.

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Section 5

Metalclad Switchgear

I. Purpose

This section applies to inspecting, troubleshooting, servicing, and overhauling all oil, air, SF₆, and vacuum metalclad switchgear and enclosures. Refer also to Section 3 for general information, inspection, recordkeeping, and diagnostic procedures that are common to all types of circuit breakers. **Always** use the manufacturers' instructions as a reference for more detailed information, including safety precautions, when performing maintenance work.

Note: Some substations have low-voltage metalclad switchgear in the 480 volts alternating current (Vac) range. Treat this switchgear and its protection equipment in the same way as higher-voltage metalclad switchgear.

II. Safety Precautions

A. Personal Protective Equipment (PPE)

1. As required in the [Code of Safe Practices](#), **always** wear the following PPE when working in a potentially unsafe condition.
 - Flame resistant (FR) clothing
 - Hood
 - Smock
 - Hand protection
 - Eye protection
 - Hard hat
2. Potentially unsafe situations are described in the [Code of Safe Practices](#).
 - a. All employees in the vicinity of the operations listed in Subsection 5.I., above, who could be exposed to a high-voltage arc also are required to use the PPE listed above.

B. Minimum Safe Working Distance

1. Some enclosures contain energized, high-voltage equipment within easy reach.
 - a. Access enclosures with energized, high-voltage equipment for visual inspection **only**.
 - b. Maintain a **minimum safe working distance** from energized equipment as specified in the [Code of Safe Practices](#), Section 809, "Approach and Working Distance."

Section 5, Subsection II.B.c.

- c. Before unlocking and opening any compartments, treat all equipment in such compartments as energized, unless and until the equipment has been cleared, high-voltage tested while de-energized, and properly grounded.

C. Using Remote Racking Equipment

1. Remote racking devices allow the removal and insertion of metalclad breakers from an energized bus while the equipment operator is outside of the arc-flash boundary. Remote racking equipment varies as does metalclad switchgear, so it is critical to understand the specific characteristics of each. Refer to manufacturer's instructions prior to using remote racking equipment. Manufacturer's instructions can be found on the [Maintenance SharePoint](#).
2. Video guidance on the use of remote racking equipment can be found on the [PG&E Video Portal](#), using the search term "racking."

**CAUTION**

Placing the remote racking device on a cell with a closed breaker can lead to inadvertent tripping of the breaker and damage to the equipment.

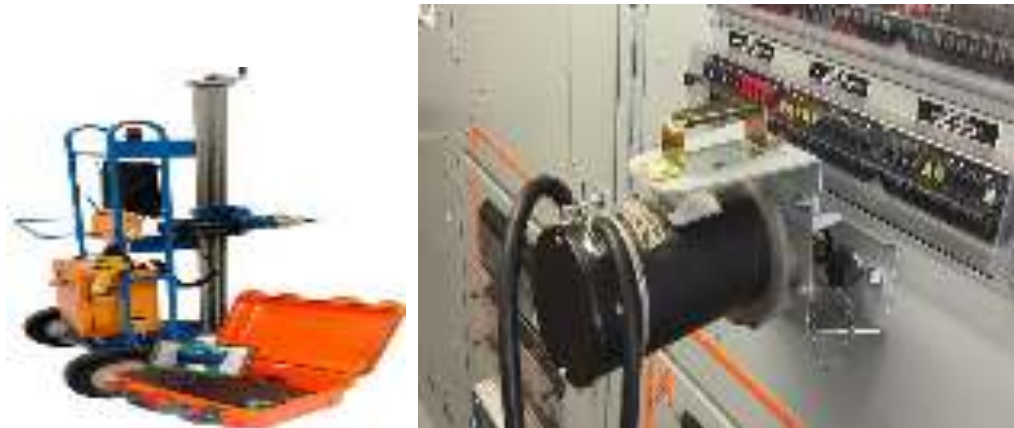


Figure 20. Remote Racking Devices

Section 5, Subsection II.D.

D. Using the Maintenance Slow-Closing Device

Do not use the maintenance slow-closing device to manually close any circuit breaker energized at its primary voltage. The slow-closing device has insufficient force and speed to ensure safe and proper operation.

E. Precautions for Vacuum Metalclad Switchgear

Although the maintenance procedures for vacuum metalclad switchgear are similar to those used for other electrical devices, there are two areas that require extra caution.

1. Charged Electrical Parts



WARNING

Wear high-voltage rubber gloves and safety glasses when working around vacuum metalclad switchgear.

- a. During both normal operation and high-pot tests, the main shield inside an interrupter, as well as other high-voltage parts, can acquire electrical charges. The shield is attached to the external midband ring of the insulating bottle.

Note: These charges usually remain after the high voltage is removed.

- b. Remove the charge before touching the interrupter, connections, circuit breaker studs, or bushings by grounding the bushings and grounding the midband ring with a clip jumper.

2. X-Ray Radiation

- a. High voltage applied across an open gap in a vacuum can produce x-ray radiation.
- b. The interrupter bottle's internal shield and the circuit breaker's metal panels provide a degree of protection.
- c. During high-pot testing, take one of the following safety precautions to provide sufficient protection from radiation.
 - (1) Ensure that the circuit breaker's metal panels are in place, **or**
 - (2) Ensure that employees maintain a minimum distance of 3 meters (9 feet, 10 inches) from any exposed interrupter under test.

F. Protection from High Voltage

1. Do not rely on the insulation covering the connectors and bus conductors in metalclad equipment to provide high-voltage protection to employees.

Section 5, Subsection II.F.2.

2. **Always** treat high-voltage equipment as energized, unless it has been tested dead and then grounded.

G. Grounding Bus Sections

In some indoor stations, cleared bus sections may span several cubicles or floors.

1. In cubicles or on floors where grounds are not visible, test the equipment de-energized **before** working on or near it.
2. Install grounds as close to the work location as practical.
3. Some situations require multiple ground locations to provide personal protection. Enter the locations of any additional grounds in [TD-2345M-F01, "PG&E Grounding Tailboard/Observer Form."](#) Hard copies of this form are kept in the headquarters and are available online as part of [TD-2345M, "Protective Grounding Manual."](#)
4. Ensure that the grounds have been removed from all locations before reporting off and energizing the equipment.

H. Testing Insulation

Perform and record insulation testing of metalclad buses and associated equipment:

- When they are installed initially.
- After a bus failure.
- After additions are made to a bus.
- When a questionable insulation condition indicates that it is necessary.

1. Metalclad Bus Insulation Test

- a. Isolate the bus by opening all circuit breakers connected to it. If practical, open potential, control-power, and main-power transformer connections, as well.
- b. Test phase-to-phase and phase-to-ground with a 2,500 V megger or with a high-pot tester.
- c. When tested with a megger, the minimum resistance for metalclad bus conductors is 10 megohms per line-to-line kV.

Note: In substations where cables remain connected to the bus, the bus conductors may read below 500 megohms. In these cases, the absolute minimum is 1 megohm per line-to-line kV.

Section 5, Subsection II.H.2.

2. Additional Precautions for High-Pot Testing



CAUTION

For all high-voltage insulation testing, ensure that capacitive charges are drained off the equipment both before and after the tests are performed.

- a. Recommended high-pot test voltages vary between manufacturers and may vary between indoor and outdoor types of circuit breakers. To ensure a safe, reliable test, use the test voltages recommended in the manufacturer's instructions.

I. Ground Knobs

Some metalclad switchgear may require the installation of ground knobs for adequate and convenient grounding. These knobs should maintain adequate clearance phase-to-phase and phase-to-ground.

III. Ground Buggies

Manual-ground-type ground buggies are used in substations.

A. Ground-Buggy Designs

Ground-buggy designs vary by age, manufacturer, and current rating. Verify the proper style and size of the ground buggy before racking it into position.

B. Storing Ground Buggies

Store and maintain ground buggies in a way that maintains their dielectric and mechanical integrity.

C. Inspecting Ground Buggies

Inspect a ground buggy before using it.

1. Ensure that it is free of dust, moisture, and any contamination that would affect its dielectric integrity.
2. Ensure that the electrical and mechanical connections are tight and in good condition.
3. Ensure that the stabs are mounted to the intended line or bus position unless both positions are mounted permanently.
4. Ensure that the correct-sized stabs are installed for the intended cubicle and application.
5. Ensure that the interlocks are in good condition.

Section 5, Subsection III.C.6.

6. Test ground buggies with a 2,500 V megger if a visual inspection indicates any lack of dielectric integrity.
 - a. Test the ground buggy stabs phase-to-ground, phase-to-phase, and from the line stabs to the bus stabs if both stabs are in place.
 - b. The minimum acceptable value is 500 megohms.

D. Grounding Procedure

1. As applicable, configure the buggy for a line or bus application.
2. Rack in the buggy to the bus or line position; ensure that the ground knobs are de-energized, and then apply grounds with the buggy in the fully inserted position.
3. A grounding shoe grounds the buggy frame when the buggy is racked into position.
4. If the ground buggy frame does not have a self-grounding shoe, ground the frame with a personal ground before racking in the buggy.

IV. Flowchart for Periodic Maintenance on Metalclad Circuit Breakers

The maintenance flowchart for metalclad vacuum, SF₆, and most OCBs is similar to those given for other circuit-breaker types less than 43 kV. Be aware that there are metalclad air and oil circuit breakers whose oil cannot be BOA™ tested; for example, GE, live-tank, and Type H circuit breakers.

Exception: Metalclad switchgear using **current-trip coils** in unit substations cannot be tested by the functional-performance test method. These circuit breakers have a time-based periodic mechanism service, as described in Utility Standard TD-3322S, “Substation Equipment Maintenance Requirements,” [Attachment 7, “Circuit Breaker Maintenance Template.”](#)

V. Inspecting Metalclad Switchgear and Cubicles

See *SMCM*, [“Substation Inspections,”](#) for periodic inspection procedures for metalclad switchgear and cubicles.

VI. Job Planning Before Maintenance Work

The success of maintenance work depends on good job planning. Consider the following items when planning maintenance work:

A. Using Manufacturer’s Instructions

Always use the manufacturer’s instructions as a reference when performing any maintenance.

1. Most manufacturers’ instructions contain important safety information. Not all this specific information is contained in the *SMCM*.

Section 5, Subsection VI.A.2.

2. Employees are responsible for understanding the maintenance and safety requirements for each piece of equipment before beginning work.
3. Occasionally, it may be necessary to deviate from some of the manufacturer's requirements in order to safely perform Company maintenance and troubleshooting procedures.

B. Checking Records

Before requesting a clearance, check the circuit breaker's past maintenance records and the monthly station inspection information.

1. Review the circuit breaker's operating history and note any pending repair work or service advisories. This information is necessary for good job planning.
2. Keep **all** the station inspection information, maintenance records, and service advisories accurate, thorough, neat and readily available.

C. Relay Service

Determine when the relays were last tested to determine if they are due for service. Review the [PESTP](#) Manual to find the required test intervals for the relays.

D. Performing Mechanism Service for Metalclad Circuit Breakers

Perform a mechanism service on metalclad circuit breakers that are **not** controlled by CAISO when any of the following occurs:

1. A circuit breaker fails to pass a functional-performance test.
2. An online operational-timing monitor alarm is received.
3. A thorough visual condition assessment indicates that this service is necessary.
4. A circuit breaker does not operate correctly.
5. A time-based trigger is reached for metalclad switchgear with current-trip coils in unit substations.

E. Overhauling Metalclad Circuit Breakers

When triggered by Utility Standard TD-3322S, [Attachment 7](#).

F. Tools and Materials

Ensure that the regular truck stock, safety equipment, PPE, and the following special tools and materials are always available. Take all the applicable items to the jobsite where the maintenance work will be performed.

Section 5, Subsection VI.F.1.**1. Tools and Materials for Performing a Mechanism Service on a Metalclad Circuit Breaker**

A mechanism service for a metalclad circuit breaker includes the following tools and materials.

- a. Circuit-breaker timing gear.
- b. Equipment to test the minimum current-pick-up requirements for circuit breakers with current-trip coils.
- c. A protective hood, smock, and gloves.
- d. Company [Form TD-3322M-F14, "Metalclad Circuit Breaker Mechanism Service."](#) (See Section 13, "Forms.")
- e. Company [Form TD-3322M-F25, "Distribution Class Circuit-Breaker Timing Test Report,"](#) if a timing test is required.
- f. The complete set of lubricants listed in Section 10.
- g. Compartment door-gasket and sealing materials, and adhesives.
- h. Cleaning materials: hoses, pressure regulators, bottled gas (nitrogen or air), low-pressure air guns with siphons or pressurized solvent cans, parts-cleaning brushes, cleaning solvents, and rags.
- i. Relay-test gear (if relay tests are due).
- j. 500 V and 2,500 V meggers.
- k. A contact-resistance tester and leads (if a condition requires their use).
- l. Oil-leak repair materials for metalclad OCBs.
- m. Penetrox™ for greasing the contacts of secondary couplings and Mobilegrease 28 for greasing primary-contact connections.
- n. When servicing a metalclad circuit breaker that uses rectified ac-to-dc control circuits, replace the old copper-oxide rectifiers with a selenium rectifier (Code 340139), if the closing time exceeds the manufacturer's specifications or if the rectifier fails.

2. Tools and Materials for Overhauling a Metalclad Circuit Breaker

Overhauling a metalclad circuit breaker requires the following tools and materials, in addition to the items listed above:

- a. A circuit-breaker contact and interrupter replacement kit, if available.
- b. Scotch-brite™ or similar contact-cleaning materials.
- c. A load cell and spring scales for checking contact pressures.
- d. A torque wrench (in case it is needed).

Section 5, Subsection VI.F.2.e.

- e. Company [Form TD-3322M-F15," Metalclad Circuit Breaker Overhaul."](#)
(See Section 13, "Forms.")

3. Tools and Materials for Metalclad OCBs

For metalclad OCBs, also include the following:

- a. An oil-dielectric tester.
- b. Spare filters for the oil-handling equipment.
- c. The latest BOA™ test results documenting the levels and safe handling limits of any combustible gases.
- d. A BOA™ sample kit and sampling fittings and materials.
- e. Oil-testing laboratory ["Internal Inspection Report"](#) and ["BOA™ Breaker Oil Analysis, Oil Circuit Breaker Sample Data"](#) forms. (See [SMCM, "Insulating Oil," Subsection X., "Forms."](#))
- f. Oil-storage containers.
- g. Oil-absorbent and cleanup materials.
- h. Strip heaters or 200-watt light bulbs (if leaving oil out of the circuit-breaker tanks overnight).

4. Tools and Materials for Metalclad Vacuum and SF₆ Circuit Breakers

For metalclad vacuum and SF₆ circuit breakers, also include the following:

- a. Micrometers, calipers, and feeler gauges to check the percentage of contact wear.
- b. A high-pot tester and leads.

VII. Performing Mechanism Service for All Types of Metalclad Switchgear

A mechanism service for metalclad switchgear includes all the following items and requirements. Thoroughly inspect the entire circuit breaker and mechanism for any loose, missing, worn, cracked, or damaged components. Correct any unsatisfactory conditions.

Note: For metalclad breakers that use rectified ac-to-dc control power, limit the number of testing operations to no more than 10 times in 10 minutes and 20 times in 1 hour. Apply the load to the rectifier for no more than one second at a time. Additional operations or extended testing time may damage the rectifier unit.

Section 5, Subsection VII.A., continued**A. Clearance**

Clear the circuit breaker, and make it safe for maintenance.

B. Fasteners

Check the physical condition of all of the springs, cotter pins, keepers, bolts, and other fasteners.

C. Wire Terminations

Ensure that all the electrical wire terminations are tight and are not corroded.

D. Switches and Relays

Ensure that the latch check switch and all the auxiliary switches, microswitches, X-Y anti-pump relays, and seal stacks have good electrical connections.

1. Check any accessible relay and auxiliary-switch contacts for excessive burning or pitting.
2. Check the mechanical condition of switches and relays, including their operating arms and linkages.
3. Clean and lubricate secondary-control coupling contacts with a very thin film of Penetrox™ contact grease lubricant.

E. Motors

Check the condition of the motor assemblies.

F. Insulation, Insulators, and Bushings

1. Check all of the insulators and bushings for evidence of moisture or other contamination.
2. Carefully inspect organic insulation for signs of “tree tracking” or for a white, powdery deposit in the vicinity of a conductor. This condition indicates a corona discharge that, if allowed to continue, will result in **insulation failure**.
3. The pictures in Figure 21., “Photographs of Corona Activity,” illustrate signs of corona activity. If a white, powdery residue is found on substation-owned equipment, contact the local field specialist for advice on corrective actions. If the substance is found on distribution line equipment within the substation, contact the local distribution compliance supervisor.

Section 5, Subsection VII.F.3., continued



White Powdery Residue



White Powdery Residue



Metalclad Cell with Corona Activity



Metalclad Cell Without Corona

Figure 21.
Photographs of Corona Activity

G. Primary-Coupling Contacts

Check the condition of the primary-coupling contacts on the circuit breaker.

1. Look for evidence of heat, binding, striking, discoloration, or uneven pressures on the cluster fingers. Refer to the manufacturer's instructions for any specific spring-pressure requirements.
2. Check the cluster springs for signs of heat or mechanical damage.
3. Clean the circuit breaker's primary connections and lubricate them with Mobilegrease 28.

H. Shock Absorbers and Dashpots

Ensure that the mechanism shock absorbers and/or dashpots are operating properly. Use the manufacturer's instructions as a reference.

1. Inspect the dashpots for leaks and for the proper oil levels.
2. Clean, repair, and add or replace oil, as necessary.

Section 5, Subsection VII.I.**I. Cleaning and Inspecting Vacuum and SF₆ Interrupter Bottles**

Clean and closely inspect any vacuum or SF₆ interrupter bottles.

1. Clean their high-voltage enclosures.
2. Look for any cracks, including in the area of the metal-to-insulation seals at both ends of the bottles, and at the midband ring.

Note: Because an accurate visual inspection is necessary, ensure that there is good lighting, and use inspection mirrors, if necessary. Also, inspect the interrupter linkages for loose, broken, or missing parts. Check the condition of all the cotter pins, ring fasteners, and keepers.

J. Checks Requiring Manual Closing

Slow-close the circuit breaker with the manual closing device, per the manufacturer's instructions.

1. Check for dragging and binding of the shafts, shock absorbers, and linkage parts.
2. For air circuit breakers, also ensure that the arc-puffer assemblies are working properly.

K. Testing Alarms, Relays, and Reclosers

Take the following steps to test the alarms, relays, and reclosers.

1. Notify the distribution operator before testing the alarms, relays, and reclosers.
2. Use the control circuit's auxiliary connective cords or rack the circuit breaker into the test position; then, run the recloser to lockout by activating the protective relays.
3. Verify that the alarms, relays, and recloser are working properly.
 - a. On circuit breakers with electromechanical relays, test three-phase simultaneous targeting.
 - b. Verify the trip-free operation of the circuit breaker.
4. Reset the recloser by electrically closing the circuit breaker.
5. Record the reclosing and lockout times, and update the recloser relay card.
6. Watch for any circuit-breaker malfunctions that require more extensive troubleshooting for permanent correction.

Section 5, Subsection VII.K.6., continued

Note: Perform and document the necessary troubleshooting tests, if there are any circuit-breaker malfunctions. Check and make any required mechanical adjustments listed in the manufacturer's instructions. To ensure service reliability and safety, immediately correct **any** condition that may cause a circuit breaker to possibly malfunction.

L. Indicators

Verify that the circuit-breaker operations counter, all red and green lights, and the mechanical position semaphore are working properly.

M. Lockout Devices

1. Trip the circuit breaker with the emergency or mechanical-maintenance trip device.
2. Verify that the 69 lockout device prevents further electrical operation.
3. Manually reset the lockout device.

N. Cleaning and Lubricating

Thoroughly clean and lubricate the entire mechanism as described in the procedures found in Section 10.

O. Trip Shafts

Ensure that all of the trip shafts are cleaned and lubricated properly. Inadequate lubrication of the trip shafts commonly causes metalclad circuit breakers to malfunction.

P. Compartments

Ensure that the door seals and compartment filters are in good condition and are keeping the mechanism sufficiently clean and dry. Add, repair, or replace the seals, if necessary. Ensure that the compartment heaters are working.

Q. Contact and Interrupter Wear

Determine the percentage wear of all the contacts and interrupters, including those related to vacuum or SF₆ bottles.

1. Perform a high-pot test, and measure the contact erosion on all vacuum or SF₆ bottles, if recommended by the manufacturer.
2. Replace any contacts or interrupters found with 75% or greater wear.
3. Clean all the accessible contacts.

Section 5, Subsection VII.Q.4.

4. While inspecting the main and arcing contacts, check for unequal or uneven wear, coke build-up, heavy pitting, or grooves, any of which may indicate incorrect contact pressure.
5. If any of these conditions are found, check the contact pressure. (See Section 3.)

R. Performing High-Pot Tests for Metalclad Vacuum and SF₆ Circuit Breakers

With the circuit breaker open, perform high-pot tests on the vacuum bottles and on the SF₆ cylinders, if specified by the manufacturer. The bottles must withstand 1 minute at 35 kVac. Use the test voltage recommended in the manufacturer's instructions.

Note: Some metalclad vacuum circuit breakers may have surge suppressors connected to the vacuum bottles. The surge suppressors must be disconnected before the high-pot test is performed. After high-pot testing is complete, and the midband ring and terminals of the vacuum bottles are safely discharged, reconnect the surge suppressors. Figure 22., "One Type of Metalclad Surge Suppressor," provides an example of a metalclad surge suppressor.



Figure 22.
One Type of Metalclad Surge Suppressor

S. Insulation Resistance Tests

Use a 2,500 V megger to test the insulation resistance on the primary voltage circuits. With the circuit breaker closed, test each phase from phase-to-phase and phase-to-ground. With the circuit breaker open, test each pole-to-ground and test across each phase. The minimum acceptable insulation resistance is 10 megohms per line-to-line kV of the primary-voltage circuit.

Note: For low-voltage circuit breakers in the 480 Vac range, the minimum insulation resistance is 2 megohms.

Section 5, Subsection VII.T.

T. Minimum-to-Trip and Minimum-to-Close Tests

Perform a minimum-to-trip and minimum-to-close test on all dc, battery-operated circuit breakers with trip or close latches:

- During installation.
- Whenever a mechanism service is performed.
- That have questionable operating performance.

Video guidance for this procedure can be found on the [PG&E Video Portal](#), using the search term “minimum to trip.”

1. Refer to Section 3 “Diagnostic Tests,” Subsection IV, Item D., “Performing Minimum-to-Trip and Minimum-to-Close Tests,” for general information and testing methods.
2. Refer to Section 9, “Vacuum Circuit Breakers,” Subsection X, Item F., “Minimum to Trip and Close,” for circuit breakers that have an electronic circuit board and no trip or close coils (e.g., ABB-type AMVAC).
3. If a circuit breaker has a current-trip coil, verify that the circuit breaker will trip with the minimum required current.

U. Anti-Pump Feature

Test the anti-pump feature of the control circuit.

1. Close the circuit breaker electrically with a control switch, and hold the control switch in the close position.
2. Apply a trip signal.
3. The circuit breaker should trip only once while the control switch is continuously held in the close position. It should not try to repeatedly close and open.
4. Video guidance for this procedure can be found on the [KnowledgeKeeper](#) website, using the search term “anti” or on the [P&E Video Portal](#), using the search term “Anti-Pump.”

V. “As-Left” Functional-Performance Test

Perform a functional-performance test to provide a return-to-service benchmark for trending purposes. Record the results on a [“Distribution Circuit Breaker Functional Performance Test Form”](#) (See Section 13, “Forms.”)

Section 5, Subsection VII.W.**W. Main-Contact Operating Times**

Test the opening and closing times of the circuit breaker's main contacts to verify that the circuit breaker is performing within the specifications given in the manufacturer's instructions.

X. Cubicle Maintenance

Perform all the cubicle checks and maintenance items listed in Subsection 5.X.

Y. Operational Checks

Operate the circuit breaker from all the available locations, including from the SCADA system, if applicable.

1. Checks Following Service

- a. Following service work, check normal all items and systems that were altered during maintenance, including annunciators and alarms, local and remote control switches, feature and cutout switches, relays, and wires.
- b. Ensure that all the tools and materials have been removed.

2. Determining Safety and Reliability

- a. Review the inspection data, condition assessments, and the operational and diagnostic test results to determine if the circuit breaker is safe and reliable.
- b. If the circuit breaker is not safe or reliable, record the specific abnormal conditions and any repairs that are required.

VIII. Overhauling Metalclad Switchgear

Note: When performing overhauls on GE Type AM 15 500-2 metalclad circuit breakers, see the additional supplemental maintenance information in Subsection 5.IX.

**CAUTION**

Slow-close the circuit breaker by hand before electrically operating it, if any mechanical adjustment or component disassembly was performed.

Overhauling a metalclad circuit breaker includes the following required tasks.

A. Clearing the Circuit Breaker

Clear the circuit breaker, and make it safe for maintenance.

Section 5, Subsection VIII.B.

B. Performing Mechanism Service

Perform a mechanism service. Replace any parts, if necessary. Use the contact and interrupter replacement kit, if applicable.

C. Filtering and Testing Oil

1. For metalclad OCBs, filter the oil and ensure that it has a dielectric strength of at least 25 kV.
2. On GE, live-tank, Type H OCBs, replace the oil rather than filter it.

D. Testing Contact Resistance

Perform contact-resistance tests on all three phases. Refer to Section 3.

E. Mechanical Measurements

Ensure that any mechanical measurements are within the manufacturer's specified tolerances.

F. Determining Safety and Reliability

1. Review the inspection data, condition assessments, and the operational and diagnostic test results to determine if the circuit breaker is safe and reliable.
2. If the circuit breaker is not safe or reliable, record the specific abnormal conditions and any repairs that are required.

IX. Maintaining GE-Type AM 15-500-2 Circuit Breakers

This subsection covers the maintenance requirements for GE AM 15-500-2 circuit breakers. In addition to understanding the information in this subsection, employees should be familiar with the manufacturer's installation and maintenance instructions. Maintenance instructions are included for the following components:

- Arc chutes
- Trip-latch bearings
- Barriers between the load-side stabs and the upper control rods
- Upper control-rod hinge points
- Control rods
- Contact assembly (complete)
- Arcing contacts
- Contact assembly (primary and intermediate)
- Seal stacks
- Upper blow-out coils

Section 5, Subsection IX.A.**A. Lubricating****1. Hinge Points**

Partial disassembly is necessary to access all hinge points for inspection and lubrication. At a minimum, the following components must be removed:

- a. Arc chutes.
- b. Separators between the load-side stabs (rear bushings) and the operating rods. (See Figure 23.)
- c. The upper cover assembly on the MS 12 model operator assembly.
- d. The lower cover assembly on the MS 12 model operator assembly.



Figure 23.
Load-Side Stabs and Separators

Note: The load-side stabs are the vertical cylindrical assemblies. The separators are the plates behind the load-side stabs.

2. Lubricating Ball Bearings and Pins

Lubricate all ball bearings with Dow 3451 grease, as well as all of the pins that are removed during disassembly. Use DC Moly-Pene-Lube to lubricate pins that are inaccessible and were not removed during disassembly.

B. Disassembling and Servicing

Always ensure that the circuit breaker is in the tripped position before disassembling and/or servicing any part. Disassemble and service parts in the following sequence:

Section 5, Subsection IX.B.1.

1. Arc Chutes



CAUTION

The arc chutes are made from a combination of dark brown, high-density fiber board (“hercolite”) and a light gray, heat-proof material. The light gray parts may contain asbestos. If unsure whether or not the material contains asbestos, send a small fragment to an approved laboratory for analysis. If asbestos is present, use proper precautions.



CAUTION

Even when new, the arc chutes are fragile and they become more so with age. For this reason, **do not** remove or install an arc chute without using the arc-chute lifting device provided by the manufacturer. If an arc-chute lifter is not available; consult with the local substation field specialist before attempting to remove the arc chute.

- a. To remove an arc chute, install the lifting device and adjust it to lift the chute slightly. Remove the lower bolt and the three upper bolts. See Figure 24. and Figure 25. below. Using the lifting device, raise the arc chute approximately $\frac{1}{2}$ inch. Gently pull the chute away from the circuit breaker frame in a straight line, taking care not to apply side-to-side force.



CAUTION

Using side-to-side force while removing an arc chute will damage the upper blow-out coil covers. If the arc chute sticks, loosen the row of fasteners on the top edge to allow the chute to be spread approximately $\frac{1}{4}$ inch. If it still sticks, contact the local substation field specialist before any making any further attempt to remove it.

Section 5, Subsection IX.B.1.a., continued



Figure 24
Top Bolts on an Arc Chute



Figure 25.
Bottom Bolt on an Arc Chute

2. Trip-Latch Bearings

- a. Lubricate and check the adjustment of the trip-latch roller.
- b. If the minimum-to-trip voltage is above 45 V, disassemble the trip latch and service the ball bearings, as follows.
 - (1) Double-shielded type bearings cannot be lubricated and must be replaced.
 - (2) If the bearings are shielded on one side, clean and inspect them. If they are smooth and operate freely, repack them with Dow 3451 grease and reinstall them. Replace any bearings that operate roughly; use only the single-shielded type for replacement. Ensure that replacement bearings are installed with the shields facing the outside of the mechanism housing.
- c. After the new or re-greased bearings are in place and the trip latch is reassembled, lubricate the trip-latch roller shaft, the close roller shaft, and all of the linkage pins, using a can of DC Moly-Pene-Lube with a small applicator tip. Wipe up any excess.
- d. Experience indicates that when the bearings are operating correctly, the latch spring is properly tensioned, and the latch wipe adjustment is within specification, these circuit breakers will trip between 28 and 32 V.

3. Barriers Between the Rear Stabs and the Upper Control Rods

- a. Remove the fasteners from all three barriers, and slide them all to one side. This provides enough room to maneuver the barriers one by one out of the circuit breaker.

Section 5, Subsection IX.B.3.a., continued

Note: Deposits can accumulate on the lower end of the barriers across from the upper bolts that fasten the arc runners to the bottom end of the load-side stabs. The deposits are distributed on the separators in a pattern that makes an image of the bolt heads. See Figure 26. below.

- b. Use a soft rag moistened with denatured alcohol to remove the deposits; then, clean the barriers and set them aside. If the bolt-head images are burned into the separator, contact the local substation field specialist.



Figure 26.
Bolt-Head-Shaped Deposits on Separators

4. Upper Control-Rod Hinge Points

- a. Remove the shaft that couples the upper control rods to the operator mechanism.
- b. Check the shaft for signs of scoring, pitting, and galling at the five bearing points. (Three of these are located where upper ends of the control rods engage the shaft and the other two where the arms of the operating mechanism engage the shaft.) See Figure 27.
- c. Check that the bushings are seated tightly in the eyes of the operating arms.
- d. Check that the eyes in upper ends of the control rods free of scoring, pitting, or galling.
- e. Inspect the control rods for any sign of cracking or de-lamination.

Section 5, Subsection IX.B.4.f.

- f. Replace any parts that are not in good condition.



Figure 27.
Scored Main Shaft

- g. Lubricate the bushings in the operating arms with Dow 3451 grease.
- h. In this portion of the circuit breaker, use DC Moly-Pene-Lube to lubricate all the other bearing points.

5. Control Rods

- a. Check the lower-end eyes for evidence of wear or scoring. See Figure 28. below. If an eye is no longer round, the wear is unacceptable, and the control rod must be replaced.
- b. Visually inspect the operating rod for cracks or splitting. Minor de-laminations (e.g., small cracks that run in a very straight line parallel to the sides of the rod) are acceptable. If concerned about the serviceability of operating rods with splits or larger cracks, contact the local substation field specialist.
- c. Do not lubricate the lower eyes in the operating rods. After all checks are done, lubricate the upper end of the control rods with Dow 4351 grease, and reinstall the rods, along with the spacers, on the shaft.
- d. Temporarily secure the assembly with 3/16-inch hairpin clips. (Later in the procedure, after the contact adjustments are complete, the shaft will be secured by cotter pins.)



Figure 28.
Operating Rod Assembly

Section 5, Subsection IX.B.6.

6. Contact Assemblies

- a. Remove the hinge pin that secures the main contact assemblies. Then, remove the thin metal cover from the booster assembly. See Figure 29. and Figure 30., below.
- b. Rotate the contact assembly approximately 45° and, holding it as a unit, raise it until the booster piston comes out of the booster cylinder. Set the contact assembly aside. See Figure 31. and Figure 32., below.
- c. Clean all grease from the mounting holes, contact assemblies, hinge pins, and booster (puffer) pistons. Set them aside when complete.
- d. Clean the grease from the booster (puffer) cups.



Figure 29.
Installed Contact Assembly



Figure 30.
Hinge Pin and Spacers Removed



Figure 31.
Rotated Contact Assembly



Figure 32.
Lifting the Contact Assembly and Booster Piston

Section 5, Subsection IX.B.7.**7. Arcing Contacts**

Arcing contact assemblies have been manufactured in two styles. The early units, typically made before 1950, have copper-plated steel blades. The later assemblies, typically made after 1950, have brass-colored blades made from chromium copper.

a. Preliminary Inspection and Tests

- (1) Check for corrosion at the riveted joint where the contact carrier meets the blades. (The arcing contact assemblies often corrode at this point.)
- (2) Check that the arcing contact carrier is sandwiched firmly between the blades, held in place by three rivets.
- (3) Perform a micro-ohm test between the contact carrier and each blade. Newly assembled units should perform in a range of 8 to 50 micro-ohms when measured from the contact carrier to each blade. Any unit over 100 micro-ohms needs to be serviced. See Subsection 5.IX.B.7.b. for servicing instructions.
- (4) The newer type of blade tends to crack adjacent to the rivet holes. For an example, see the area outlined in black in Figure 33. below. Inspect for cracks, using a 10X magnifying glass. Replace cracked blades with copper-plated steel blades.

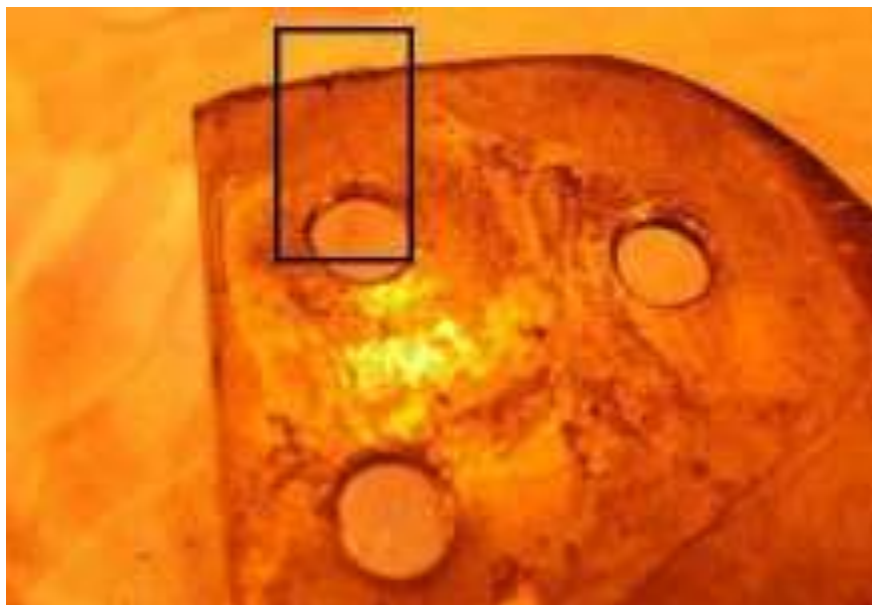


Figure 33. Crack Radiating From a Rivet Hole (Outlined in Black)

Section 5, Subsection IX.B.7.b.

b. Servicing Instructions

- (1) **Disassembly:** Center-punch the rivet head and, using a 7/64 bit, drill to a depth of 1/8 inch. Using a 3/32 pin punch, wobble the rivet head to break it off and then drive the rivet out of the arcing contact carrier. See Figure 34. through Figure 37., below.



Figure 34.
Center Punching



Figure 35.
Drilling



Figure 36.
Breaking Off the Rivet Head



Figure 37.
Driving Out the Rivet

Section 5, Subsection IX.B.7.b.(2)

- (2) **Contact Carrier:** Using a smooth file, “draw-file” the contact-carrier mating surfaces to remove small burrs, high spots, and minor surface imperfections. See Figure 38. and Figure 39. below. Buff the mating surfaces of the contact carrier with smooth Scotch Brite; then, silver-plate them with Cool-Amp silver-plating powder. See Figure 40. and Figure 41. below.

Order Cool-Amp from:

Cool-Amp Conducto-Lube Co. 15934

Upper Boones Ferry Road Lake

Oswego Oregon 97035

Phone: 503-624-6246

Internet: <http://www.cool-amp.com>



Figure 38.
Filing



Figure 39.
High Spot Removed



Figure 40.
Buffing With Scotch Brite



Figure 41.
Silver-Plated Mating Surface

Section 5, Subsection IX.B.7.b.(3)

- (3) **Blades:** Unlike the rest of the blade, the mating surfaces of a copper-plated steel blade are not plated and are likely to corrode. Clean the mating surfaces of the blade with Scotch Brite and paint with SPI Conductive Silver Paint (designed for scanning electron microscopes), available in 1 Troy ounce bottles.

Order SPI Catalog No. 0502 AB from:

Structure Probe, Inc.
SPI Supplies Division
PO Box 342
West Chester, PA 19380
Phone: 215-436-5400
Internet: www.2spi.com

For chromium-copper blades, clean the mating surfaces with Scotch Brite and then silver-plate them with Cool-Amp.

c. Reassembling the Arcing Contact Carrier and Blades

Reassemble the arcing contact carrier and the blades, as follows.

- (1) Prepare 3/16 by 1-1/4 inch countersunk brass rivets. Order these rivets from:

R.J. Leahy Co.
1475 Yosemite Avenue
San Francisco, CA 94124
Phone: 415-861-7161

Note: Longer rivets may be purchased if 1-1/4 inch rivets are not available.

Cut the rivets to the correct length to ensure full mechanical strength and that the newly formed rivet heads will be flush with the surface of the blade after they are pressed. Rivet heads that protrude above the surface of the blade will scrape the inside of the arc chute, resulting in undesirable wear. The required rivet length is between

1 1/8 and 1 1/4 inches, depending on how deep the countersink was made on the blade where the new rivet head is formed. Since this varies, the exact rivet length must be determined by experimentation.

- (2) Once the rivets are cut to the correct length, fit the assembly together with the pre-made rivet heads facing down. Check that the two blades are firmly in contact with the contact carrier and that the assembly is square in the hydraulic press. Verify that the center of the rivet aligns with the center of the ram before pressing.

Section 5, Subsection IX.B.7.c.(3)

- (3) Form the new rivet heads by pressing each rivet individually to 10,000 pounds per square inch. See Figure 42. below.



Figure 42.
Pressing Rivets

Note: Due to the serrated nature of the ram face, the hardened hexagonal piece of steel shown in Figure 42. above was used to provide a flat surface for forming the rivet head.

- (4) Following pressing, check each rivet head flush with the surface of the blade. Take micro-ohm readings at the connections between the contact carrier and each blade. See Figure 43. below.



Figure 43.
Testing the Contact Carrier-to-Blade Micro-Ohms

Section 5, Subsection IX.B.8.

8. Primary and Intermediate Contact Assembly

- a. Inspect the assembly, checking for misalignment and missing or broken parts.
- b. Clean off all lubricant. Lubricate the bronze spacer bushings between the primary contact blade and the arcing contact blade with conductive grease, such as Mobilegrease 28. Do not lubricate the silver contact ring because it is self-lubricating. See Figure 45. below.
- c. Apply a conservative coating of Dow 3451 grease to the hinge pin.
- d. Place the assembly back into the circuit breaker.
- e. Turn the screw in the hinge-pin assembly until the cotter-pin holes line up in the top-hat-shaped nut. This automatically sets the contact pressure at the hinge point. Install the cotter pins.
- f. Connect the lower operating rods to the contact assemblies and install the cotter pins.
- g. Lubricate the metal-to-metal portion of the hinged joint with Dow 3451 grease, but **do not** lubricate the hole in the lower end of the control rod.



Figure 44.
Contact Assemblies



Figure 45.
Bronze Spacer

Note: In Figure 44., the upper assembly is the primary and intermediate contact. The lower assembly is the arcing contact. In Figure 45., the silver ring contact in the bronze spacer is outlined by the box.

- h. Check the contact gaps and adjust the operating rods, as needed. After adjustment, replace the 3/16 hairpin clips with cotter pins (see Subsection 5.IX.B.5.d.).

Section 5, Subsection IX.B.9.**9. Seal Stacks**

- a. The earlier model of AM 15 circuit breakers (manufactured in the late 1940s) features a four-high stack of contact assemblies (“seal stack”) that serves a maximum of six circuits. The upper two contact assemblies employ two mechanically dependent contacts in series to form one contact set. The lower two contact assemblies feature two contacts each that are mechanically and electrically independent, with the contact pair capable of accommodating two circuits.
- b. Later models of AM 15 circuit breakers feature a six-high seal stack designed to provide a maximum of six circuits. The stack design differs from the four-high seal stack by being made up exclusively of contact assemblies employing two mechanically dependent contacts in series to form one contact set. The purpose of this change was to provide more efficient breaks of the lower four circuits by doubling the effective contact gap, resulting in longer contact life.
- c. When servicing four-high seal stacks, it is critical that the two lower contact assemblies are cleaned and burnished adequately.

10. Upper Blow-Out Coils

- a. With the arc chutes removed, take micro-ohm readings between the stationary primary (main) contacts for each pole and each segment of the respective arc runners. Starting from the bottom segment of the runner, the readings will become progressively greater and will fall into the following general ranges:
 - Bottom runner: 260 micro-ohms
 - Middle runner: 2,500 micro-ohms
 - Top runner: 7,400 micro-ohms
- b. These readings should vary no more than 5 percent between poles. To correct higher-than-normal readings or variances greater than 5 percent between poles, remove the two light-gray cover plates and check the torque on the fasteners that secure the connections to the blow-out coils. See Figure 46. Adjust the torque to the correct 60 inch-pounds.
- c. After all connections are checked and adjusted, take new micro-ohm readings and confirm them within the ranges shown above.

Section 5, Subsection IX.B.10.c., continued



Figure 46.
Testing Micro-Ohms From Stationary Primary Contacts to Arc Runners

C. AM 15-500 Supplemental Maintenance Record

This subsection provides instructions for filling out Company Form [TD-3322M-F23, “AM 15-500 Supplemental Maintenance Record.”](#) This form covers the additional maintenance required for AM 15-500 circuit breakers. (See Section 13, “Forms.”) Also, refer to manufacturer’s instructions GEI 23949D, “Instructions, Switchgear, Power Circuit Breakers: Magne-Blast Breakers, Type AM15-500-2, 1200 and 2000 Amperes with MS 12 Mechanism,” located at the maintenance headquarters.

Note: The sequence of the steps in the [“AM 15-500 Supplemental Maintenance Record”](#) are not the same as in the manufacturer’s instructions. Following the sequence in the job aid saves time because measurements are not re-taken after making adjustments.

1. Micro-Ohm Testing on Arcing Contact Assemblies

Table 6., below, illustrates the “Arcing Contact Assembly Micro-Ohms” part of the [“AM 15-500 Supplemental Maintenance Record.”](#) Measure the micro-ohms before and after adjusting the arcing contact assemblies. Record the data as shown below.

Table 6. Arcing Contact Assembly Micro-Ohms

	Pole 1		Pole 2		Pole 3		Initials
	Left	Right	Left	Right	Left	Right	
As Found							
As Left							

Section 5, Subsection IX.C.2.

2. Mechanical Checks

Table 7., “Circuit-Breaker Mechanical Checks,” illustrates the mechanical checks part of [Form TD-3322M-F23, “AM 15-500 Supplemental Maintenance Record.”](#) Review the following items. If the measurements are found to be out-of-tolerance, adjust them accordingly. Refer to GEI 23949D, if needed. Document these measurements and adjustments as shown in Table 7.

Table 7. Circuit-Breaker Mechanical Checks

Step	Manufacturer's Instructions (GEI 23949D)	Task	Tolerance in Inches	Measurement Found OK?	Measurement Left OK?	Initials
1	Instructions on Page 6, illustrated in Figure 5 on Page 9	Check/ Adjust the Trip-Latch Clearance	1/32" to 1/16" (0.031" to 0.063")			
2	Page 6	Check the Plunger Clearance	At Least 1/8" (0.125")			
3	Instructions on Page 6, illustrated in Figure 5 on Page 9	Check the Trip-Latch Wipe	3/16" to 1/4" (0.188" to 0.250")			
4	Instructions on Page 6, illustrated in Figure 5 on Page 9	Check the Prop Clearance	1/32" to 5/64" (0.031" to 0.078")			

3. Measuring the Primary Contact Wipe

Table 8. illustrates the “Primary Contact Wipe Measurements” part of the [“AM 15-500 Supplemental Maintenance Record.”](#) Document these measurements as shown in Table 8.

- a. Use a low-profile hydraulic jack, with a lift range of 1½ inches to 11-1/4 inches, to move the circuit breaker to the fully-closed position.

Note: This jack is available locally from Grainger Industrial Supply at: <http://www.grainger.com/Grainger/www/start.shtml>, Westward Catalog 3ZC57G or equivalent.

**CAUTION**

Before taking the following measurements, block the props and trip latch to prevent tripping of the circuit breaker accidentally.

Section 5, Subsection IX.C.3.b.

- b. Measure the gap between the upper side of the contact rest and the extreme upper end of the notch in the moving contact fingers. (See Figure 1 on Page 5 of the manufacturer's instructions, GEI 23949D.)
- c. After completing the measurements, unblock the props and the trip latch. With all personnel clear of the moving parts, trip the circuit breaker.
- d. Adjust the operating rods, as needed, to attain the required tolerance.

Note: Adjust the operating rods safely by placing the circuit breaker in the open position and the master shaft between the main operating linkage. Remove the three operating rods.

- e. Re-examine the primary contact wipe after making any adjustments.

Table 8. Primary Contact Wipe Measurements

Step	Manufacturer's Instructions (GEI 23949D)	Task	Tolerance in Inches	Measurement Found OK?	Measurement Left OK?	Initials
5	Figure 1 on Page 5	Check the Pole 1 Primary Contact Wipe	3/16" to 9/32" (0.188" to 0.281")			
		Check the Pole 2 Primary Contact Wipe	3/16" to 9/32" (0.188" to 0.281")			
		Check the Pole 3 Primary Contact Wipe	3/16" to 9/32" (0.188" to 0.281")			

4. Measuring the Primary and Intermediate Gaps on Arcing Contacts

Table 9. illustrates the "Primary and Intermediate Gaps on Arcing Contacts" part of [Form TD-3322M-F23 "AM 15-500 Supplemental Maintenance Record."](#) Document these measurements as shown in Table 9.

- a. Verify that the trip latch is blocked and that the circuit breaker is in the tripped position.
- b. Using a 20-ton hydraulic jack with a 5-3/4" stroke, "slow-close" the circuit breaker until the arcing contact for the pole to be measured just begins to "make."

Note: Each arcing contact "makes" at a slightly different time.

Section 5, Subsection IX.C.4.c.

- c. Repeat the measurement on each pole, using the jack to adjust the circuit breaker's position, as needed, for each arcing contact to "make."
- d. Leave the circuit breaker in the partially closed position and measure the primary gaps on the intermediate contacts.

Table 9. Primary and Intermediate Gaps on Arcing Contacts

Step	Manufacturer's Instructions (GEI 23949D)	Task	Tolerance in Inches	Measurement Found OK?	Measurement Left OK?	Initials
6a	Instructions on Page 6, illustrated in Figure 3 on Page 5	Check the Pole 1 Arcing Contact Intermediate Gap	15/32" to 19/32" (0.469" to 0.564")			
		Check the Pole 1 Arcing Contact Primary Gap	Approx. 11/16" to 13/16" (0.688" to 0.813")			
6b	Instructions on Page 6, illustrated in Figure 3 on Page 5	Check the Pole 2 Arcing Contact Intermediate Gap	15/32" to 19/32" (0.469" to 0.564")			
		Check the Pole 2 Arcing Contact Primary Gap	Approx. 11/16" to 13/16" (0.688" to 0.813")			
6c	Instructions on Page 6, illustrated in Figure 3 on Page 5	Check the Pole 3 Arcing Contact Intermediate Gap	15/32" to 19/32" (0.469" to 0.564")			
		Check the Pole 3 Arcing Contact Primary Gap	Approx. 11/16" to 13/16" (0.688" to 0.813")			

5. Measuring the Primary Gaps on Intermediate Contacts

Table 10. illustrates the "Primary Gaps on Intermediate Contacts" part of [Form TD-3322M-F23 "AM 15-500 Supplemental Maintenance Record."](#) Document these measurements as shown in Table 10.

Section 5, Subsection IX.C.5.a

- a. Starting from the partially closed position left after measuring the gaps on the arcing contacts, use the jack to “slow-close” the circuit breaker until the intermediate contact for the pole being measured just begins to “make.”

Note: Each arcing contact “makes” at a slightly different time.

- b. Repeat the measurement on each pole, using the jack to adjust the circuit breaker’s position, as needed, for each intermediate contact to “make.”
- c. After the measurements are recorded, relax the jack, release the breaker to the fully open position, and unblock the trip-latch assembly.

Table 10. Primary Gaps on Intermediate Contacts

Step	Manufacturer’s Instructions (GEI 23949D)	Task	Tolerance in Inches	Measurement Found OK?	Measurement Left OK?	Initials
7	Figure 2 on Page 9	Check the Pole 1 Primary Gap	5/16” to 7/16” (0.313” to 0.412”)			
		Check the Pole 2 Primary Gap	5/16” to 7/16” (0.313” to 0.412”)			
		Check the Pole 3 Primary Gap	5/16” to 7/16” (0.313” to 0.412”)			

6. Measuring the Primary Contact Gap

Table 11. below illustrates the “Primary Contact Gap” part of [Form TD-3322M-F23 “AM 15-500 Supplemental Maintenance Record.”](#) With the circuit breaker in the fully open position, check the primary contact gap. Record the measurement found and the measurement left, as shown in Table 11.

Table 11. Primary Contact Gap

Step	Manufacturer’s Instructions (GEI 23949D)	Task	Tolerance in Inches	Measurement Found OK?	Measurement Left OK?	Initials
8	Figure 2 on Page 9	Check the Open Primary Contact Gap	Greater Than 4”			

Section 5, Subsection IX.C.7.

7. Micro-Ohm Testing on Upper Blow-Out Coils

Table 12. below illustrates the “Upper Blow-Out Coil Micro-Ohms” part of [Form TD-3322M-F23 “AM 15-500 Supplemental Maintenance Record.”](#) Measure the micro-ohms before and after adjusting the upper blow-out coils, as needed. Record the data as shown in Table 11.

Table 12. Upper Blow-Out Coil Micro-Ohms

	Pole 1		Pole 2		Pole 3		Initials
	As Found	As Left	As Found	As Left	As Found	As Left	
Bottom							
Middle							
Top							

8. Performing Circuit-Breaker Cell-Fit Tests

Table 13. illustrates the “Circuit-Breaker Cell-Fit Testing” part of [Form TD-3322M-F23, “AM 15-500 Supplemental Maintenance Record.”](#)

Note: If installing a different circuit breaker salvaged from another station in the cell...or if reinstalling an overhauled circuit breaker...verify that the circuit breaker will fit properly in the cell. If there is any doubt about the fit, perform the steps described in the following subparagraphs.

Document the performance of this procedure as shown in Table 13.

- a. Apply a thin coat of Mobilegrease 28 to the primary coupling connections (i.e., stab tips).
- b. Perform the following steps before racking the circuit breaker into position.
 - Hook up the test umbilical leads.
 - Close and trip the circuit breaker from the control switch.
 - Verify that the breaker and its red and green indicating lights are operating properly.
 - Leave the breaker in the closed position.
- c. Disconnect the test umbilical leads and rack the circuit breaker into the “connected” position.
- d. Verify that the circuit breaker trips before the interlock roller on the right side of the breaker reaches the end of the diagonal portion of the interlock cam ramp.
- e. With the circuit breaker racked fully into the connected position, verify that the secondary disconnects and the mechanically operated control (MOC)/auxiliary seal stack operator are aligned correctly.

Section 5, Subsection IX.C.8.f.

- f. Close and open the circuit breaker from the control switch. Verify that the breaker operates correctly and that the MOC/auxiliary seal stack operator changes status (in the cell).
- g. Close the circuit breaker. Using the elevator switch, lower the breaker and verify that it trips electrically as soon as the control handle is operated.
- h. Rack the circuit breaker back into the fully connected position. Close the breaker and remove the trip fuses.
- i. Using the elevator control switch, lower the circuit breaker and verify that the breaker trips mechanically before the interlock roller reaches the end of the diagonal portion of the interlock cam ramp.
- j. Reinstall the trip fuses.
- k. Verify that the wipe on the primary couplings is acceptable by viewing the pattern made in the grease on the stab tips.
- l. Place all the control switches back to their normal positions.

Table 13. Circuit-Breaker Cell-Fit Testing

Date	Circuit-Breaker Serial Number	Circuit-Breaker Number	Cell Fit and Test OK?	Initials

X. Maintaining Cubicles



WARNING

Do not perform maintenance on ungrounded, high-voltage equipment.

When performing maintenance on cubicles, look for the following conditions.

A. Moisture in Cubicles

Check the cubicle for signs of moisture or leaks from rain water.

B. Dirty Cubicles

1. Remove dust and debris.
2. Wipe up any oil or grease.

Section 5, Subsection X.C.**C. Racking Mechanism, Gears, and Chains**

Inspect and service the racking mechanism to ensure smooth operation.

1. Check the condition of the gears, chains, and mechanical components for signs of wear or damage.
2. Repair or replace them, as necessary.

D. Shutter and Interlock Mechanisms

Safely ensure that the shutter and interlock mechanisms are operating smoothly. Lubricate them, as necessary.

E. Bushings and Insulation

Check the porcelain bushings in the cubicle for signs of moisture and condensation.

1. Maintain a safe working distance.
2. Visually inspect porcelain bushings for a white, powdery deposit in the vicinity of:
 - Bushings
 - Ducts
 - Throats
 - Potential transformers (PTs)
 - CTs
 - Conductors

Such deposits may indicate a destructive corona discharge. See Figure 4. for important photographs illustrating corona activity.

**WARNING**

Do not perform maintenance unless the bus is de-energized, tested dead, and grounded properly.

F. Bus Conductors and Connections

Carefully open the cubicle doors. Visually inspect the bus conductors and connections for signs of overheating and deteriorated insulation. In particular, check the primary leads to the PTs. They have failed in the past.

Section 5, Subsection X.G.

G. Rodent Infestation

Check for signs of rodents or other small animals inside any area of the switchgear. If any evidence of animal infestation is present, locate their points of entry and either screen them off or seal them closed to prevent future access.

H. Cable Ducts

1. Ensure that all of the used and unused cable ducts are sealed with Duxseal™.
2. **Do not** perform maintenance unless the cables are de-energized, tested dead, and properly grounded.

I. Cubicle Ventilation

Check the condition of the ventilation screens and filters. Clean or replace them, as necessary.

J. Fire Ducts

1. Ensure that the fire ducts are free from obstructions and protected against rain.
2. All ducts should be screened to prevent foreign material and small animals from entering.

K. Associated Compartments

Safely clean and check the associated compartments containing CTs and PTs, fuses, disconnects, and station service transformers. Look for leaks and signs of overheating.



WARNING

Do not perform maintenance on ungrounded, high-voltage equipment.

L. Automatic Grounding Devices

Ensure that the automatic grounding devices in de-energized, draw-out compartments are operating properly.

M. Control-Coupling Contacts

Check the stationary control-coupling contacts in the cubicle.



WARNING

These contacts may be energized.

Section 5, Subsection X.N.**N. Interlocks**

Ensure that the interlocks are operating properly.

O. Ground-Shoe Connections

Ensure that the ground-shoe connections are tight.

P. Control Contactor, Rectifier, and Solenoid

Check the condition of the control contactor, rectifier, and solenoid, if applicable.

Q. Lights and Plugs

Ensure that the compartment lights and plugs are working.

R. Switches and Wiring

Check the auxiliary switches and compartment wiring.

S. Door Gaskets

Check the condition of the door gaskets.

T. Door Latches

Ensure that the linkage for the enclosure's door-latch mechanism is secure and working properly.

U. Metalclad Circuit Breakers Using Compressed Air

For metalclad circuit breakers using compressed air, follow the Maintenance Program (SAP WMS) guidelines for compressor service.

1. Safely de-energize and service the compressor when maintenance is required.
2. Perform a rundown test (see Section 3).
3. Ensure that the air alarm and pressure switches are operating properly.
4. Check the compressor's oil level.
5. Check the condition of the belts and pulleys.
6. Bleed condensate from the tank. Check for excessive oil in the condensate.
7. Service the air cleaner.
8. Lubricate the motors, as needed.

Section 5, Subsection X.V.

V. Checks Following Maintenance

When maintenance is completed, inspect all the compartments to ensure that all the tools and materials have been removed.

W. Testing Insulation

Test the insulation of metalclad buses and associated equipment:

- When they are installed initially.
 - After additions are made to a bus.
 - After a bus failure.
 - When a questionable insulation condition indicates that it is necessary.
1. Use a 2,500 V megger to test the insulation phase-to-phase and phase-to-ground.
 2. The minimum resistance for bus conductors is 500 megohms.

Note: In substations where cables remain connected to the bus, the bus-conductor resistance may read less than 500 megohms. In these cases, the absolute minimum is 1 megohm per line-to-line kV.

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Section 6

Oil Circuit Breakers

I. Purpose

This section applies to inspecting, troubleshooting, servicing, and overhauling OCBs. Refer also to Section 3 for general information, inspection, recordkeeping, and diagnostic procedures common to all types of circuit breakers. **Always** use the manufacturers' instructions as a reference for more detailed information, including safety precautions, when performing any maintenance.

II. Safety Precautions

A. BZO-Type OCBs

Note: BZO is an Allis-Chalmers and Siemens circuit-breaker model designation, not an acronym.

1. On BZO-type OCBs, measure the contact penetration from the bottom of the stationary arcing contacts.
2. To avoid over-penetration resulting in broken lift rods and eventual catastrophic failure, **never** use an ohmmeter to measure the contact penetration on BZO circuit breakers.

B. Confined Spaces

Before entering any enclosed circuit-breaker tank or any other confined space, employees **must** know, understand, and carry out all the required safe work practices contained in [Utility Procedure TD-3320P-01, "Electric T&D Confined Space Work Procedures."](#)

C. Bushing Mounting Studs

Never tighten the mounting studs on any OCB bushing unless planning to open the tank for inspection. Tightening may result in contact misalignment.

D. Power Close and Open Operations

Whenever oil is removed from OCB tanks, always check the manufacturer's instructions to verify if power close or open operations are safe for the equipment.

III. References

The following references provide additional guidance for certain maintenance tasks.

A. Bushings

1. *SMCM*, ["Arrestors, Bushings, and Insulators,"](#) Subsection II., "High-Voltage Insulation Bushings and Insulators"

Section 6, Subsection III.B.**B. Handling Oil**

1. [Utility Standard TD-3324S, “PCB Management in Substations”](#)
2. [PCB Management in Substations](#)
3. [SMCM, “Insulating Oil”](#)

C. Work-Area Protection

1. [Utility Standard D-S0421, “Fall Protection and Prevention”](#)
2. [Utility Procedure TD-3320P-01, “Electric T&D Confined Space Work Procedures”](#)
3. [Code of Safe Practices](#), Section 1, “General Rules,” Rule 34, and Section 8, “Electric Substations”

IV. Testing and Analyzing Oil

The information previously located in this subsection has moved to *SMCM*, [“Insulating Oil.”](#)

V. Flowcharts for Periodic OCB Maintenance

The flowcharts previously located in this subsection have moved to *SMCM*, [“Insulating Oil.”](#)

VI. Planning the Job Before Performing OCB Maintenance Work

The success of maintenance work depends on good job planning. Consider the following items when planning maintenance work:

A. Using Manufacturer’s Instructions

Always use the manufacturer’s instructions as a reference when performing any maintenance.

1. Most manufacturers’ instructions contain important safety information. Not all of this information is listed in the [SMCM](#).
2. Employees are responsible for understanding the maintenance and safety requirements for each piece of equipment **before** beginning work.
3. Occasionally, it may be necessary to deviate from some of the manufacturer’s requirements in order to safely perform Company maintenance and troubleshooting procedures.

B. Checking Records

Before requesting a clearance, check the circuit breaker’s previous maintenance records and the monthly station-inspection information.

Section 6, Subsection VI.B.1.

1. Review the circuit breaker's operating history and note any pending repair work. This information is necessary for good job planning.
2. Keep **all** station inspection information, maintenance records, and service advisories accurate, thorough, neat, and readily available.

C. Relay Service

Check the last relay-test dates to see if the relays are due for service. Check the [PESTP](#) Manual for the relay-test intervals.

D. OCB Mechanism Service

1. Perform a mechanism service for all CAISO-controlled and transmission-class circuit breakers when triggered by Utility Standard TD-3322S, "Substation Equipment Maintenance Requirements," [Attachment 7, "Circuit Breaker Maintenance Template."](#)
2. For all OCBs with oil-sampling capabilities, perform a BOA™ before or during the mechanism service. As a recommended best practice, perform a BOA™ **before** the mechanism service clearance, allowing sufficient time to plan and schedule an overhaul, and to obtain replacement parts, if the test results indicate that an overhaul is needed.
3. For all distribution-class, non-CAISO-controlled circuit breakers, perform a mechanism service when any of the following occur:
 - a. A circuit breaker fails to pass a functional-performance test.
 - b. An online operational-timing monitor alarm is received.
 - c. A thorough visual condition assessment indicates that this service is necessary.
 - d. A circuit breaker does not operate correctly.
 - e. The time-based default trigger is reached.

E. OCB Overhaul

Schedule an overhaul on an OCB when triggered by receiving a Condition Code 4 or 4* on a BOA™. Perform a dissolved gas analysis (DGA) or a BOA™ within 15 days before the overhaul to verify the oil's safe handling limit (SHL). For more information, see *SMCM*, ["Insulating Oil."](#)

1. On three-tank, transmission-class OCBs, if only one or two tanks receive a Condition Code 4 or 4*, the local headquarters may decide whether to inspect the other tanks if they receive a Condition Code 3 or less.
2. For distribution-class OCBs, inspect all phases if any of the tanks receives a Condition Code 4 or 4*.

Section 6, Subsection VI.E.3.

3. See the Utility Standard TD-3322S [Attachment 7](#) maintenance template and the OCB maintenance flowcharts in *SMCM*, [“Insulating Oil,”](#) to determine the maintenance requirements. After an overhaul, ensure that none of the components inside a circuit breaker have more than 75% wear.
4. Periodic BOA™ tests are not performed on oil reclosers in substations or on OCBs without oil-sampling capabilities. Their overhauls are based on a 100% ACC count.

F. Routine Inspection Items

1. When performing station inspections and circuit-breaker maintenance work, **always** ensure that all the compartment heaters are working and that the compartment doors and openings are sealed properly against rain, dust, and insect contaminants.
2. Clean or replace the ventilation filters and door seals to prevent dust, moisture, or insects from contaminating the mechanism. Install new filters or seals, if necessary.
3. Maintain a clean, dry mechanism. This increases the reliability of the circuit breaker. Also, it makes lubrication more effective and reduces future cleaning needs and maintenance time.

G. Testing and Maintaining Bushings

See *SMCM*, [“Arrestors, Bushings, and Insulators,”](#) Subsection II., for information on testing and maintaining bushings during circuit-breaker maintenance.

H. Preventing Moisture

Place a strip heater or 200-watt light bulb in the tanks to prevent condensation and the absorption of moisture by organic parts, if it is necessary to leave the oil out of a circuit breaker overnight or longer.

I. Tools and Materials

Ensure that all the regular truck stock, the safety equipment, the PPE, and the following special tools and materials are always available. Take all the applicable items to the jobsite where the maintenance work will be performed.

1. Tools and Materials For Performing an OCB Mechanism Service

An OCB mechanism service includes the following tools and materials:

- a. Company [Form TD-3322M-F13, “Distribution Circuit Breaker Functional Performance Test Form,”](#) and a test set or other timing gear if a test set is unavailable. (See Section 13, “Forms.”)
- b. Test equipment for measuring the open and close times of the main contacts.

Section 6, Subsection VI.I.1.c.

- c. Oil-leak repair materials.
- d. Company [Form TD-3322M-F16, “OCB Mechanism Service.”](#) (See Section 13, “Forms.”)
- e. A BOA™ sample kit, sampling fittings, and materials, if a BOA™ was not performed within the last 6 months.
- f. The complete set of lubricants listed in Section 10.
- g. Ventilation-filter materials for the mechanism compartments.
- h. Door-gasket and sealing materials, and adhesives.
- i. Dashpot oil.
- j. Hydraulic or compressor oil, as applicable.
- k. Cleaning materials: hoses, pressure regulators, bottled gas (nitrogen or air), low-pressure air guns with siphons or pressurized solvent cans, parts-cleaning brushes, cleaning solvents, and rags.
- l. Relay-test gear (if relay tests are due).
- m. A contact-resistance tester and leads (in case a condition requires their use).

2. Tools and Materials for an OCB Overhaul

An OCB overhaul requires the following items in addition to the items listed for a mechanism service:

- a. A circuit-breaker contact and interrupter replacement kit, if available.
- b. Torque wrenches.
- c. Impact wrenches and associated sockets and extensions.
- d. Oil-tank door-gasket materials and adhesives.
- e. Lock wire for bolts (if needed).
- f. The latest BOA™ test results documenting the level of any combustible gases and their safe handling limits.
- g. A BOA™ sample kit, sampling fittings, and materials for a “return-to-service” BOA™ test.
- h. Scotch-brite™ or similar contact-cleaning materials.
- i. A circuit-breaker analyzer with a transducer (in case adjustments are made or parts replaced that could affect the circuit breaker’s performance).
- j. An oil-dielectric tester.
- k. 500 V and/or 2,500 V meggers, as applicable.

Section 6, Subsection VI.I.2.I.

- l. Confined-space-entry tools (if applicable): a calibrated, tested, and working four-gas tester with four spare “C” batteries and Company [Form TD-3320P-01-F01, “Permit-Required Confined Space \(PRCS\) Entry Permit”](#) (Use [Utility Procedure TD-3320P-01](#) as a reference for this work, as well as a source for the [“Entry Permit”](#) form. Copies of the [“Entry Permit”](#) are available at headquarters.)
- m. Fall-protection equipment, as required. [Use Utility Standard D-S0421, “Fall Protection and Prevention,”](#) as a reference.
- n. A load cell or spring scales for checking contact pressures, if needed.
- o. Spare filters for the oil-filtering equipment.
- p. Company [Form TD-3322M-F17, “OCB Overhaul”](#) (see Section 13, “Forms,” an oil-testing laboratory [“Internal Inspection Report”](#) form; and a [“BOA™ Breaker Oil Analysis, Oil Circuit Breaker Sample Data”](#) form (see *SMCM*, [“Insulating Oil,”](#) Subsection X., “Forms”).
- q. Extra oil-storage containers (depending on the quantity of oil in the circuit breaker).
- r. Oil-absorbent and cleanup materials.
- s. Strip heaters or 200-watt light bulbs (if leaving oil out of the circuit-breaker tanks overnight).
- t. A Tag 330 high-voltage detector, either 60 to 115 kV or 230 to 500 kV, if available.

VII. Performing an OCB Mechanism Service

An OCB mechanism service includes the following items and requirements. Thoroughly check the entire circuit breaker and mechanism for any loose, missing, worn, cracked, or damaged components. Correct any unsatisfactory conditions.

A. Clearance

Clear the circuit breaker and make it safe for maintenance.

B. Fasteners

Check the physical condition of all the springs, cotter pins, keepers, bolts, and other fasteners.

C. Electrical Wire Terminations

Ensure that all of the electrical wire terminations are tight and are not corroded.

Section 6, Subsection VII.D.

D. Switches and Relays

Ensure that all of the latch-check switches and all of the auxiliary switches, microswitches, X-Y anti-pump relays, and seal stacks have good electrical connections.

1. Check any accessible contacts for excessive burning or pitting.
2. Check the mechanical condition of the switches and relays, including their operating arms and linkages.

E. Checks Requiring Slow Closing

1. Slow-close the circuit breaker according to the manufacturer's instructions.
2. Check for dragging and binding of the shafts, shock absorbers, and linkage parts.

F. Testing Alarms, Relays, and Reclosers

Take the following steps to test the alarms, relays, and reclosers on distribution-class circuit breakers:

1. Notify the distribution operator before testing the alarms, relays, and reclosers.
2. Run the recloser to lockout by activating the protective relays.
3. Verify that the alarms, relays, and recloser are working properly.
4. On circuit breakers with electromechanical relays, test three-phase simultaneous targeting.
5. Reset the recloser by electrically closing the circuit breaker.
6. Record the reclosing and lockout times, and update the recloser-relay card.
7. Watch for any circuit-breaker malfunction that requires more extensive troubleshooting for permanent correction.

Note: Perform and document the necessary troubleshooting tests, if there are any circuit-breaker malfunctions. Check and make any required mechanical adjustments listed in the manufacturer's instructions. To ensure service reliability and safety, immediately correct **any** condition that may cause a malfunction.

G. Indicators

Verify that the circuit-breaker operations counter(s), all red and green lights, and the mechanical position semaphore(s) are working properly.

Section 6, Subsection VII.H.**H. Lockout Devices**

1. Trip the circuit breaker with the mechanical trip device.
2. Verify that the 69 lockout device prevents further electrical operation.
3. Manually reset the lockout device.

I. Cleaning and Lubricating

Thoroughly clean and lubricate the entire mechanism according to the procedures found in Section 10.

J. Compartments

Check that the door seals and compartment filters are in good condition and are keeping the mechanism sufficiently clean and dry. Add, repair, or replace the seals, if necessary. Ensure that the compartment heaters are working.

K. Compressor and Hydraulic Service

Compressor and hydraulic services for distribution-class OCBs are separate maintenance tasks with their own scheduling triggers. Compressor and hydraulic services for the two-stage air compressors used with transmission-class OCBs are performed as part of the mechanism service. See the Utility Standard TD-3322S [Attachment 7](#) maintenance template.

1. Use Company [Form TD-3322M-F12, "Compressor Service,"](#) to document compressor and hydraulic-system service tasks. (See Section 13, "Forms.")
2. See Subsection 1.V.C., "Performing a Compressor Service," for compressor and hydraulic service procedures.

Section 6, Subsection VII.L.

L. Minimum-to-Trip and Minimum-to-Close Tests



CAUTION

With hydraulically and pneumatically tripped circuit breakers, there is a danger that the change-over valve will only partially shift position at a reduced voltage. Avoid this condition because it is difficult to detect and correct.

Do not test the trip circuits on these circuit breakers to the **absolute minimum**. If the manufacturer specifies a minimum-to-trip test voltage, verify that they will operate at minimum tripping control voltage on the nameplate, or 70% of their nominal voltage if a nameplate value is not available.

1. Perform a “minimum-to-trip” and “minimum-to-close” test on all dc-operated circuit breakers with a trip or close latch:
 - Whenever a mechanism service is performed.
 - That have questionable operating performance.
 - Video guidance for this procedure can be found on the [PG&E Video Portal](#), using the search term “minimum to trip.” Refer to Section 3, “Diagnostic Tests,” Subsection IV, Item D., “Performing Minimum-to-Trip and Minimum-to-Close Tests,” for general information and testing methods.
2. Compare the test results with a benchmark and other previous tests.

M. Anti-Pump Feature

Test the anti-pump feature of the control circuit.

1. Close the circuit breaker electrically with a control switch and hold the control switch in the close position.
2. Apply a trip signal.
3. The circuit breaker should trip only once while the control switch is held continuously in the close position. It should not try to close and open repeatedly.
4. Video guidance for this procedure can be found on the [KnowledgeKeeper](#) website, using the search term “anti” or on the [PG&E Video Portal](#), using the search term “minimum to trip.”

Section 6, Subsection VII.N.**N. “As-Left” Functional-Performance Test and Verifying Trip-Free Operation**

1. Perform a functional-performance test to provide a return-to-service benchmark for trending purposes.
2. Record the results on a [“Distribution Circuit Breaker Functional Performance Test Form.”](#) (See Section 13, “Forms.”)
3. Verify the trip-free operation of the circuit breaker.

O. Main-Contact Operating Times

Test the opening and closing times of the circuit breaker’s main contacts to verify that the circuit breaker is performing within the specifications given in the manufacturer’s instructions. See Subsection 3.O., “Main-Contact Operating Times,” for additional information.

P. “As-Left” Speed Shot

1. Use a time-and-distance circuit-breaker analyzer to perform an “as-left” speed shot if:
 - a. Any critical components were replaced, or
 - b. Any measurements were changed that may affect the operational performance of a transmission-class circuit breaker.
2. Analyze the test results for the proper circuit-breaker performance. Use the manufacturer’s instructions as a reference.

Q. BOA™

Take a BOA™ oil sample, if a BOA™ was not performed in the past 6 months.

R. Checks Following Service

1. Following service work, check normal all items and systems that were altered during maintenance, including annunciators and alarms, local and remote control switches, feature and cutout switches, relays, and wires.
2. Ensure that all of the tools and materials have been removed.

S. Determining Safety and Reliability

1. Determine if the circuit breaker is safe and reliable after reviewing the inspection data, condition assessments, and the operational and diagnostic test results.
2. If the circuit breaker is not safe or reliable, record the specific abnormal conditions and any repairs that are required.

Section 6, Subsection VII.T.

T. Operational Checks

Operate the circuit breaker from all the available locations, including from the SCADA system, if applicable.

VIII.Overhauling the OCB

An OCB overhaul includes the following requirements.



CAUTION

Slow-close the circuit breaker by hand **before** electrically operating it if any mechanical adjustments or component disassembly were performed.

A. Functional-Performance Test

1. Perform a functional-performance test before clearing the circuit breaker.
2. Record the test results on a [“Distribution Circuit Breaker Functional Performance Test Form.”](#) (see Section 13, “Forms”).

B. Clearance

Clear the circuit breaker and make it safe for maintenance.

C. Contact-Resistance Readings

Take “before” contact-resistance readings from just above the top bushing-terminal connectors.

1. Analyze these readings to help indicate if any connections, including the bushing-terminal connectors, have a possible high resistance that will need to be corrected during the overhaul.
2. If any readings indicate high resistance, take additional readings across the individual component connections until the high-resistance problem is found and corrected.
3. Refer to Subsection 3.IV.M.2., “Contact-Resistance Test Procedure,” for more information about contact-resistance testing.

D. Cleaning the Tanks

Clean the tanks internally. Use filtered oil removed from the tanks to wash down the tank walls, interrupters, and bushing parts.

1. After this process, use only dry materials to remove any remaining particles and arc byproducts.
2. **Do not** use solvents.

Section 6, Subsection VIII.E.**E. Inspecting Internal Components**

1. Carefully inspect all the internal components, including the lift rods or rotating elements, for discoloration, coking, “tree tracking,” cracks, and loose parts, bolts, nuts, and keepers.
2. Ensure that there is no excessive movement or play in the moving **and** stationary components.

F. Interrupters

Damaged or excessively worn interrupters cannot interrupt a high-magnitude fault successfully, which could result in catastrophic failure of the OCB.

1. Thoroughly inspect the interrupters for wear and warping.
2. Disassemble the interrupters if necessary for a complete inspection.
3. Determine the greatest percentage of wear to any of the interrupters.
4. Record the wear data on Company [Form TD-3322M-F17, “OCB Overhaul,”](#) and the BOA™ test laboratory’s [“Internal Inspection Report”](#) form. (See Section 13, “Forms,” and the *SMCM*, [“Insulating Oil,”](#) Subsection X., “Forms.”)
5. Replace any interrupter components with 75% or greater wear. Use the contact and interrupter replacement kit, if applicable.
6. If the interrupters are equipped with resistors, ensure that the resistance is within the manufacturer’s tolerance. Record the results.

G. Contact Wear

1. Check all the contacts for wear, protruding burrs, or varnish build-up.
 - a. Clean all contacts with Scotch-brite™ or similar pads.
 - b. Carefully file off any burrs.
 - c. Do not remove any silver material from the contacts, and do not file to remove any pits.
2. Determine the contacts’ wear percentages.
3. Record the wear data on the [“OCB Overhaul”](#) form and the BOA™ test laboratory’s [“Internal Inspection Report”](#) form (See Section 13, “Forms,” and *SMCM*, [“Insulating Oil,”](#) Subsection X., “Forms”.)
4. Replace any components with 75% or greater wear. Use the contact and interrupter replacement kit, if applicable.
5. While inspecting the main and arcing contacts, check for any unequal or uneven wear, coke build-up, heavy pitting, or grooves, any of which may indicate incorrect contact pressure. If any of these conditions are found, check the contact pressure. (Refer to Section 3.)

Section 6, Subsection VIII.H.

H. Checks Requiring Slow Closing

1. Slow-close the circuit breaker after reassembling the interrupters.
2. Ensure that the moving contacts are aligned properly as they enter the stationary components and that no signs of damage or binding exist.

I. Contact Measurements

1. Check the contact-travel and wipe measurements.
2. Compare the measurements with the manufacturer's recommendations and make adjustments, if necessary.
3. Record any adjustments.

J. Oil Indicators and Leaks

1. Check the condition of the oil-level indicators. Make any required repairs to ensure that the indicators are visible and moving freely.
2. Ensure that sight glass' vent holes are open and not blocked by paint or other material.
3. Repair any oil leaks.

K. Shock Absorbers and Dashpots

If there are dashpots and shock absorbers inside the tanks, ensure that they are working properly.

L. Rotating-Contact Elements

On OCBs with rotating-contact elements, test the rotor with a 2,500 V megger.

1. The rotating-contact elements on 115 kV or 230 kV units should test at a minimum of 10,000 megohms to ground.
2. The rotating-contact elements on circuit breakers less than 115 kV should test at a minimum of 2,000 megohms to ground.

M. Checking the Tanks

Following an internal inspection, ensure that all of the tools and materials have been removed before closing an OCB tank.

N. Testing Oil

Test the dielectric strength of the oil after filtering it, but before returning the circuit breaker to service. Used oil must test at a minimum of 25 kV using the ASTM D-877 method.

Section 6, Subsection VIII.O.**O. Pressure-Switch Rundown and Relief-Valve Tests**

1. Perform a pressure-switch rundown test on circuit breakers with air or hydraulic operators.
2. Perform a relief-valve test on compressed air accumulators.
3. Refer to Section 3 for the test procedures.
4. Document the test results on [Form TD-3322M-F12, "Compressor Service,"](#) and [Form TD-3322M-F24, "Compressor Rundown."](#) (See Section 13, "Forms.")
5. Ensure that the compressor operations counter is working properly.

P. "As-Left" Speed Shot

1. Use a circuit-breaker analyzer to perform an "as-left" speed shot, including velocity traces, if any critical components were replaced, or if any measurements were changed that may affect the operational performance of a transmission-class circuit breaker.
2. Analyze the test results for the proper circuit-breaker performance. Use the manufacturer's instructions as a reference.

Q. "As-Left" Contact-Resistance Test

Perform, analyze, and record "as-left" contact-resistance tests. Always power-close a circuit breaker when performing contact-resistance tests.

R. Determining Safety and Reliability

1. Determine if the circuit breaker is safe and reliable after reviewing the inspection data, condition assessments, and the operational and diagnostic test results.
2. If the circuit breaker is not safe or reliable, record the specific abnormal conditions and any repairs that are required.

S. Taking Return-to-Service BOA™ Oil Samples

After the oil has been returned to all the tanks, operate the circuit breaker twice. Take a "return-to-service" BOA™ oil sample after the oil has been in the circuit-breaker tanks for at least 1 hour. The test results from the "return-to-service" BOA™ sample are the benchmark against which all future oil tests are compared.

Note: The circuit breaker may be returned to service before the test results are received from the laboratory.

Section 7

SF6 Circuit Breakers

I. Purpose

This section applies to inspecting, troubleshooting, servicing, and overhauling SF6 circuit breakers. Refer also to Section 3 for general information, inspection, recordkeeping, and diagnostic procedures common to all types of circuit breakers. Also see Section 8, “Handling SF6 Gas.” **Always** use the manufacturer’s instructions as a reference for more detailed information, including safety precautions, when performing any maintenance.

II. Safety Precautions and Important General Information

A. Gas Dielectric Capability

1. **Never** operate an energized SF6 circuit breaker either electrically or mechanically if there is any evidence that its gas dielectric capability has deteriorated. Deterioration is indicated by the following conditions:
 - The gas pressure is at or below the lockout point.
 - Test results show a high moisture content (contact the local field specialist if values in excess of 200 ppm are found.)
2. If the conditions listed in Step 1. above occur, use the applicable load-breaking devices to de-energize the circuit breaker from all of the sources; then, open the disconnect switches.
3. SF6 circuit breakers still may be operated after a low gas-pressure alarm is received, but not following a low gas-pressure lockout alarm.
4. The SF6 gas moisture content and operating-pressure limits vary for each style of circuit breaker. Refer to the manufacturer’s instructions for the acceptable limits.

B. Gas-Sampling Safety



CAUTION

Do not take gas samples from energized circuit breakers.

C. Using and Labeling Manually Operated, Mechanical Opening Devices

The information previously located in this section of the manual now is located in Subsection 1.II.C.).

Section 7, Subsection II.D.**D. Working Above the Top of SF₆ Circuit Breakers With Porcelain Bushings****CAUTION**

Protect porcelain bushings on SF₆ circuit breakers from falling objects whenever any work is performed above them. The bushings are pressurized by the SF₆ gas inside the circuit breaker. Anyone nearby could be injured by flying porcelain if the bushings are cracked or otherwise damaged. Barricade the circuit breakers or shield the bushings from falling objects.

E. SF₆ Leak Repair

1. As a charter member of the United States Environmental Protection Agency (EPA) Voluntary Sulfur Hexafluoride (SF₆) Emission Reduction Partnership, PG&E (via its SF₆ Management Team) is committed to reducing the SF₆ leak rate associated with insulating electrical transmission and distribution equipment. The Company is working through the California Climate Action Registry to certify both actual and avoided SF₆ emissions.

This information is presented in the annual Corporate Responsibility Report. Also, the Company provides technical expertise to the United Nations Intergovernmental Panel on Climate Change's SF₆ Working Group.

2. Note the following information about SF₆ gas leaks and repairs:
 - a. SF₆ is an extremely potent greenhouse gas approximately 22,200 times as potent as carbon dioxide (CO₂).
 - b. All new SF₆ circuit breakers are covered by a 5- to 10-year manufacturer's warranty for the repair of SF₆ leaks.
 - c. Whenever makeup SF₆ gas needs to be added to **any** electrical equipment, leaks must be identified and repaired. Contact the local field specialist for assistance.
 - d. See Subsection 7.X.B. for information about gas-leak monitoring.
 - e. See Section 8 for information about the Company's SF₆ Gas Supply Program.

F. Pilot-Valve Trip-Blocking Device

To prevent personal injury and equipment damage, **always** use the pilot-valve trip-blocking device whenever maintenance or inspection work is performed on a GE/Hitachi high-voltage circuit breaker (HVB). Refer to the manufacturer's instructions for a sketch of the magnetic opening valve.

Section 7, Subsection II.G.

G. Time-Delay-Close Relays

Ensure that time-delay-close relays are installed on ABB 550 PM EHV circuit breakers with AHMA-8 operators. **Do not** remove or bypass them. Review the following information.

Note: AHMA, EHV, LFAA, and PM are model designations, not acronyms.

1. Purpose of Time-Delay Relays

All of the ABB 550 PM EHV circuit breakers with AHMA-8 operators should be equipped with three time-delay-close Agastat relays (Device Nos. 62-1, 62-2, and 62-3).

- a. These relays delay the closing signal for 20 cycles and begin timing as soon as the circuit breaker is opened.
- b. They prevent the circuit breaker from attempting to reclose before the resistor (bypass) switch linkage comes to a full reset position.
- c. If the close signal is applied before the linkage fully resets, severe damage can occur to the resistor linkage and result in a subsequent internal flashover of the interrupter to ground. Also, this damage can occur to newer, Model “B,” modified circuit breakers.

2. Removal and Reinstatement of Time-Delay-Close Relays

The time-delay-close relays (“62” devices) were removed at the same time that LFAA high-speed reclose relays were installed at 500 kV intertie substations. However, severe damage has resulted from circuit breakers being in service without the 62-1, 62-2, and 62-3 devices. Efforts should have been made to reinstate the devices at all of their locations.

3. Damage Caused by Removing Time-Delay-Close Relays

Timing an ABB 550 PM EHV circuit breaker with a circuit-breaker travel analyzer revealed the cause of the damage.

- a. A sustained, 100 ms close signal was applied to a circuit breaker to test its “open-close-open” (trip-free) operation.
- b. The “built-in” delay (the auxiliary make-and-break switch) allowed the circuit breaker to travel fully closed before the trip signal for opening the circuit breaker was recognized. This delay is normally 19 to 21 cycles.
- c. With a 100 ms close signal and no 20-cycle time-delay-close protection, multiple reclose operations occurred. They can keep occurring until the circuit breaker runs out of hydraulic pressure.

Section 7, Subsection II.G.4.**4. Preventing Damage by Checking Time-Delay-Close Relays**

Use the following procedure to ensure that damage does not occur to the resistor-switch linkage and interrupter components.

- a. Ensure that the time-delay-close relays are installed, set for a 20-cycle delay, and are operating properly on all ABB 550 PM circuit breakers on the 500-kV system.
- b. **Never** bypass the time-delay-close relays to perform time-travel analysis or any other test that may close the circuit breaker.
- c. Discuss any exceptions with the local substation field specialist before testing.

5. Applying Close Signals

- a. **Always** apply closing signals from remote devices, such as time-travel analyzers, to the remote-close terminal (typically Terminal 7) on the circuit breaker's terminal board.
- b. Confirm that the time-delay-close relays ("62" devices) are in the circuit before an attempt is made to close the circuit breaker.

6. Applying Trip Signals

Always apply the trip signals from remote devices, such as time-travel analyzers, to the remote-trip terminals (typically Terminals 9-1, 9-2, and 9-3) to apply a trip signal to all three phases at the same time.

H. Temperature Compensation of SF₆ Gas

SF₆ gas pressure cannot be evaluated accurately without compensating for the ambient temperature. Manufacturers of SF₆ circuit breakers may refer to the temperature-compensated gas pressure as the "SF₆ gas density."

1. Refer to the temperature compensation chart posted in the circuit-breaker cabinet or to the manufacturer's instructions if a chart is not present.
2. Lightly tap the circuit breaker's gas-pressure gauge to verify that the indicating needle is operating freely.

Note: Some gauges measure absolute pressure (psia) that measure pressure from a perfect vacuum. This results in a reading that is 14.7 psi greater than measured from atmosphere (psig).

I. Additional Information About SF₆ Gas, Including Transfer Procedures

See Section 8 for information about the health and safety hazards of SF₆ gas, safe working procedures, and procedures for transferring, handling, and storing SF₆ gas.

Section 7, Subsection II.J.

J. Moving or Relocating SF₆ Circuit Breakers



WARNING

Moving or relocating an SF₆ circuit breaker with normal SF₆ operating pressure can result in the release of the SF₆ gas and its bi-products. It is also possible to damage the circuit breaker bushings which could result in bushing shrapnel projected into the work area.

1. SF₆ circuit breakers that are required to be moved need to be cleared, tested de-energized, grounded, and made safe to work on per established work methods in [TD-2345M, Protective Grounding Manual](#), and the [CSP, Section 8, Rule 805](#).
2. After the circuit breaker has been made safe to work on, the SF₆ gas must be evacuated to a level between 5 and 10 lbs of pressure before the breaker is physically moved. All gas handling practices in Section 8 must be followed to ensure the safety of employees and the environment while processing SF₆ gas and its arcing bi-products.

K. Bushing-Mounted Capacitors on SF₆ Circuit Breakers

1. Typically, SF₆ circuit breakers with a 63 kiloamps (kA), short-circuit rating require a certain amount of line-to-ground capacitance when protecting overhead transmission lines. The additional capacitance is provided by either capacitively coupled voltage transformers (CCVT) or a capacitor mounted on the breaker (referred to as bushing-mounted capacitors).
2. The bushing-mounted capacitor is grounded at its base through the mounting bracket, which is attached to the grounded interrupter tanks. Either a CCVT or bushing-mounted capacitor **per phase** on the line-side of the breaker is required.
3. **If the capacitor mounting bracket is attached above the bushing current transformer (BCT), the bushing-mounted capacitor's mounting brackets cannot have a bonding cable to ground, either individually or bonding all three brackets together.** Adding a bonding cable completes a conductive loop around the BCT, consisting of the bonding cable, the capacitor mounting bracket and the interrupter tank. This interferes with the BCT signal and may lead to a false trip.
4. A bonding cable is acceptable from the bushing-capacitor mounting bracket to ground if the bracket is attached to the breaker below the BCT.

Section 7, Subsection II.L.

L. SF₆ Circuit Breakers with Spring-Type Mechanisms in Substations with 48 Volts Direct Current (Vdc) Battery Systems

SF₆ breakers with spring-type energy storage can only perform an open-close-open (OCO) operation cycle before the springs require recharging using the 120 Vac station service.

1. Per specification, the SF₆ breakers in substations with 125 Vdc battery systems use a universal motor and auto-transfer circuit to switch the motor to a dc source when the ac source is lost.
2. Most of the SF₆ breakers in substations with 48 Vdc battery systems do not have this ac-dc transfer feature for the charging motor. **Performing an OCO cycle with loss of ac station service will discharge the springs, requiring either manual charging of the spring or applying an external ac power source to the motor circuit in order to close the breaker.**



CAUTION

Only substation personnel trained in circuit-breaker-mechanism safe-maintenance practices either must manually charge the closing spring or connect auxiliary motor power. Refer to the manufacturer's specific circuit-breaker instructions for the procedure to charge the closing spring manually.

3. The substation maintenance supervisor is responsible for ensuring that the appropriate manual spring charging tool is stored at each 48 Vdc substation for emergency use.
4. The circuit breaker **specification** was updated in 2010 to require an auto-transfer scheme on all future purchases of SF₆ breakers with 48 Vdc controls, similar to the current design for 125 Vdc controls.
5. A systemwide project was initiated in 2010 to convert the motor circuits on ABB and MEPPI breakers to have dc back-up with auto-transfer for loss of ac.

III. Feature Switches for SF₆ Circuit Breakers

A. Feature-Switch Configuration

1. Low SF₆ Pressure Feature

- a. The low SF₆ pressure feature switch may be configured to either initiate or prevent low gas-pressure tripping and to block low SF₆ gas-pressure tripping while gassing in-service circuit breakers.
- b. Automatic tripping or blocking tripping on low SF₆ pressure ensures that a circuit breaker with inadequate gas pressure is not over-stressed by attempting to clear a fault.

Section 7, Subsection III.A.2.

2. Low Mechanism-Operating-Pressure Feature

- a. The low mechanism-operating-pressure feature may be configured to either initiate or prevent tripping from low mechanism-operating pressure on circuit breakers with hydraulic or pneumatic operating mechanisms. This choice is dependent on the circuit breaker's operating configuration.
- b. Tripping at a preset, low operator pressure prevents the possibility of partially opening the circuit breaker, a condition that may occur on some circuit breakers that do not use an opening spring, such as the AHMA and HMB8 types, when their hydraulic pressure is low.

3. Electros witch 101 Cutout Switch

The Electros witch 101, Model No. 10262LN, is a cutout switch for the low SF₆ pressure and low mechanism-operating-pressure features. It is provided on all of the new SF₆ circuit breakers, except 500 kV, as described in [Numbered Document 063122, "Automatic Feature, Relay, Potential Cutout Switches and Nameplates."](#)

B. Feature-Switch Selection Criteria

1. Normally Cut In

The low SF₆ pressure and low mechanism-operating-pressure trip features normally are cut in when:

- a. 500 kV-and-below circuit breakers installed in "breaker-and-a-half" schemes have relays set to activate an alarm and then trip the circuit breaker on low SF₆ gas pressure or low operating pressure. In this configuration, tripping does not cause a system disturbance or a customer interruption.
- b. Circuit breakers protecting nonnuclear, generator step-up transformers have relays set to activate an alarm and then trip on low SF₆ gas pressure and/or low mechanism-operating pressure.

2. Normally Cut Out

The low SF₆ pressure and low mechanism-operating-pressure trip features normally are cut out and the protective-relay trip feature blocked:

- a. On all of the circuit breakers in distribution-owned substations.
- b. When tripping transmission banks or lines will result in the overloading of associated equipment, a system disturbance, or a loss of customers.

Note: All circuit breakers have an alarm that is set to activate on any low-pressure condition regardless of whether the trip features are cut in or out.

Section 7, Subsection III.B.3.

3. Exceptions

Consult with the local system protection engineer and the local transmission operations engineer about feature-switch settings for all other SF₆ circuit breakers. Also contact these employees to determine if any exceptions are needed and whenever there are any other questions concerning proper setup. For distribution-class circuit breakers, consult with the distribution planning engineer.

C. Retrofitting Feature Switches

Some transmission-class SF₆ puffer circuit breakers were supplied to the field with removable jumpers designed to enable or disable low-pressure trip features. These circuit breakers, excluding 500 kV circuit breakers, may be retrofitted with an Electroschwitch 101 installation.

1. Mount and label the new components in a convenient and clearly visible location in the circuit-breaker control cabinet.
2. Order the Electroschwitch 101 (Code 394118) and the red, normally cut-in nameplate (Code 026388), or the green, normally cut-out nameplate (Code 026387), as needed, to conform with the feature selection criteria listed in Subsection 7.III.B.
3. Label the feature-switch installations, per [Numbered Document 027818, "Nameplates for General Use,"](#) as follows:

Use 1-inch x 3½-inch, black lamicoids with white lettering.

See Figure 47., "Label for Low SF₆ Gas-Pressure Feature Switches," and Figure 48., "Label for Low Mechanism-Operating-Pressure Feature Switches," for more information.

Low SF ₆ Gas Pressure:	Cut In – Trips on low SF ₆ gas pressure Cut Out – Blocks tripping on low SF ₆ gas pressure
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Figure 47. Label for Low SF₆ Gas-Pressure Feature Switches

Low Mechanism Operating Pressure:	Cut In – Trips on low mechanism operating pressure Cut Out – Blocks tripping on low mechanism operating pressure
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Figure 48. Label for Low Mechanism-Operating-Pressure Feature Switches

Section 7, Subsection III.C.4.

4. Label existing puffer circuit breakers that are wired to trip but installed without feature switches, as applicable. See Figure 49., “Label for Low SF₆ Gas-Pressure or Low Mechanism-Operating-Pressure Trips Without Feature Switches,” below.

This Breaker Trips on Low SF ₆ Gas Pressure or Low Mechanism Operating Pressure
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Figure 49.
Label for Low SF₆ Gas-Pressure or Low Mechanism-
Operating-Pressure Trips Without Feature Switches

IV. Specific Manufacturer’s Information and Service Advisories

Review the following manufacturer’s service advisories.

A. GE Hitachi 550 kV Circuit Breakers

1. GE Hitachi 550 kV circuit breakers manufactured between 1983 and 1996 can develop a problem with the cement that bonds the upper bushing-cap flange to the bushing porcelain. If the external caulking that seals this cement bond fails, water can penetrate the cement bond. When this happens, the cement can expand and crack the porcelain. This can result in a leak of the circuit breaker’s SF₆ gas. The bolts that join the upper bushing-cap flange halves can also be a source of SF₆ gas leaks if this caulking fails and the cement expands.
2. Inspect the caulking areas of all six bushing caps during every mechanism service for these circuit breakers. If deterioration of the caulking is observed or suspected, apply new, high-quality silicone caulking to the joint formed between the top cap and the top of the porcelain. Also apply new caulking around the top and the bottom of the bolts that secure the top cap. Force the caulking into the joints to ensure a complete seal. Use a caulking color other than gray to provide the greatest visual contrast for the inspection.
3. See Figure 50., “Resealing With Silicone Caulking,” below, to help identify the areas to be inspected and resealed with silicone caulking.

Section 7, Subsection IV.A.3., continued

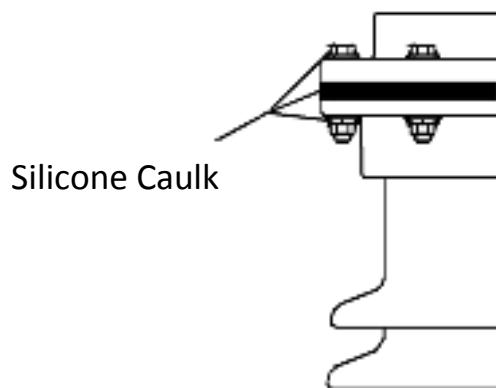


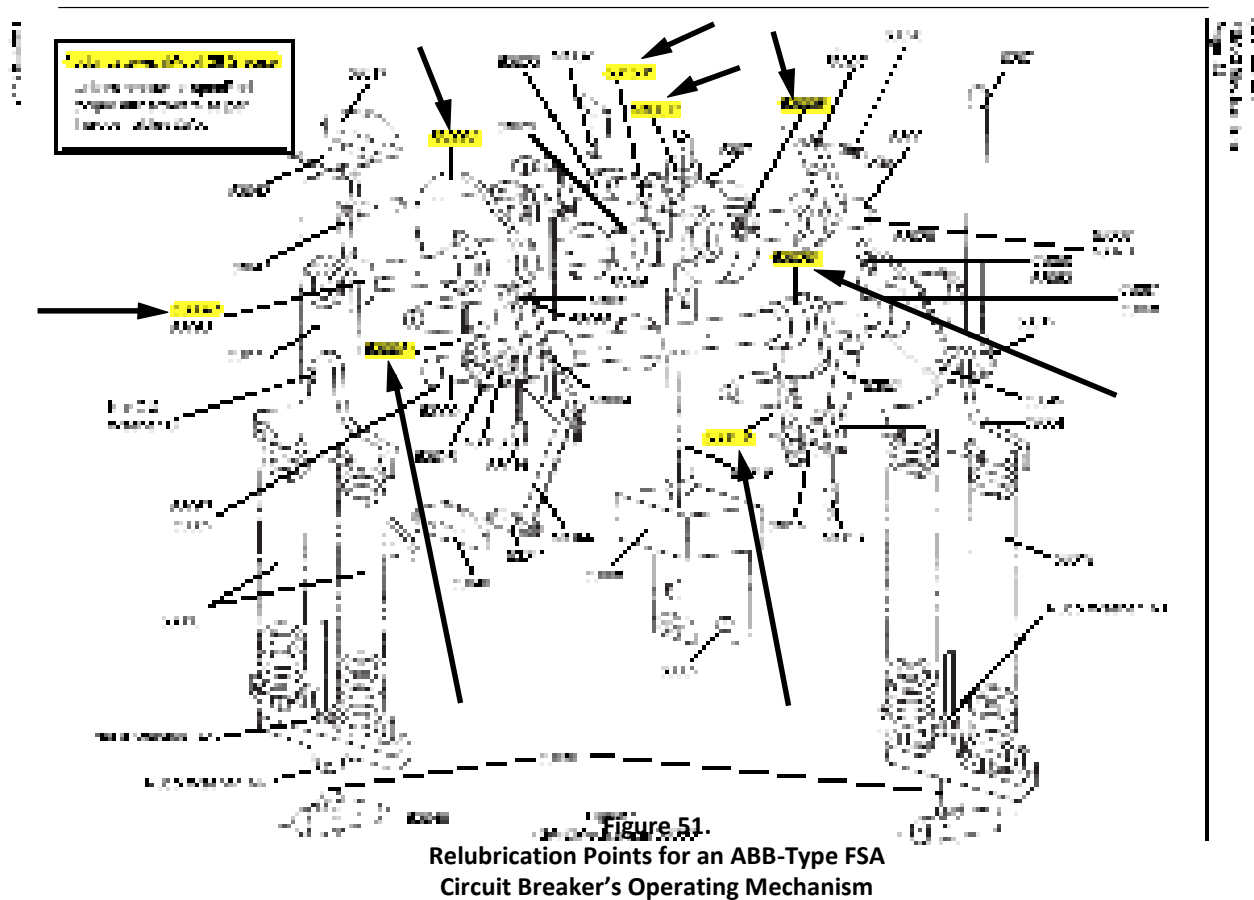
Figure 50. Resealing With Silicone Caulking
Resealing With Silicone Caulking

B. ABB Circuit Breaker, Type FSA Operating Mechanisms**CAUTION**

DO NOT use Dow 321 or 3451 lubricants. They will accelerate the operating mechanism's failure.

1. ABB has identified a problem with the transfer roller assembly on the original Type FSA mechanism which may cause a failure to close and trip. These issues have been addressed. Should you need any information regarding this, contact the local field specialist.
2. ABB advises using **only** Mobilegrease 28 synthetic lubricant to re-lubricate specific parts of the operating mechanisms of ABB Type FSA circuit breakers. Apply the lubricant to the **eight** points highlighted with arrows pointing to them in Figure 51., "Relubrication Points for an ABB-Type FSA Circuit Breaker's Operating Mechanism." (For ordering information, see Table 21., "Order Codes for Lubricating and Cleaning Products.")

Section 7, Subsection IV.B.2., continued



Note: The above drawing is from the ABB Instruction Book #641P007-07, Page 24.

C. ABB Circuit Breaker, Type FSA Mechanisms: Relaxed Trip-and-Close Operating Springs

1. Relaxed Spring Problem

ABB has identified a problem with the closing and tripping springs that maintain the Type FSA mechanism's stored energy. Over time, both of these springs may "relax," which may cause a failure to close and/or trip. Due to the complex design and precision requirements of the Type FSA mechanism, there is no permanent repair to eliminate this problem.

2. Identifying the Relaxed Spring Problem

Perform travel trace velocity testing during every mechanism service to identify which springs may be relaxing and failing. Timing alone cannot identify the problem because a timing test does not measure the entire stroke of travel during the tripping operation. If necessary, see the Vanguard CT-7000 job aid on the T/SM&C SharePoint or contact the local area field specialist.

Section 7, Subsection IV.C.2.a.

- a. To identify which mechanisms may be failing, perform a velocity trace and a timing test. Follow the steps in the ABB instruction manuals “72 PM Timing” and “121 PM Timing.”
- b. For the timing and velocity specifications, see the ABB “Timing Checklist Bulletin.”
- c. If the opening or closing velocities do not meet the required specifications, refer to the “Adjusting the Opening and Closing Velocities” section of the ABB “Instructions for the FSA (-1 or -2) Mechanism.”

3. Verification of Velocity Requirement

Indicate on Company [Form TD-3322M-F18, “SF6 Circuit Breaker Mechanism Service,”](#) that the velocity trace was performed. On Company [Form TD-3322M-F11, “Transmission Class Circuit-Breaker Timing Test Report,”](#) record the open and close velocities as found, if any adjustments were made, and the velocities after any adjustments. (See Section 13, “Forms,” for these forms.) Attach a copy of the travel trace test to the form.

D. ABB PM/I and PMR/I Circuit-Breaker Operating Mechanisms

ABB recommends that all 72 PM/I, 145 PM/I, and 242 PMR/I circuit breakers with exposed ball-joint rod ends manufactured with plated steel should be cleaned and relubricated at **every mechanism service**, if the circuit breakers are exposed to highly corrosive conditions, such as in the switch yards at Diablo Canyon Power Plant (DCPP) and the San Mateo Substation. At DCPP, one of these rods broke during an attempt to close Circuit Breaker 384 because corrosion had weakened the rod. ABB is replacing the existing plated-steel rods with stainless steel for all Company circuit breakers installed in corrosive areas. On these circuit breakers, perform a mechanism service **every 4 years** until the rods are replaced with stainless steel.

E. ABB HMB Spring/Hydraulic Operating Mechanism: Maintenance Alert

ABB HMB spring/hydraulic operators equipped with a low-hydraulic-pressure interlock may be damaged during maintenance, if the following events and conditions occur:

- The spring plug has not been removed.
- The hydraulic pump and trip controls have been disconnected from a power source.
- Depending on the extent of internal hydraulic leaks, the low-hydraulic-pressure interlock could be reached in 1 to 24 hours.
- Power is restored to the trip circuits and hydraulic pump

Section 7, Subsection IV.E.1.

1. If the hydraulic pressure has drained below the low-pressure interlock, an automatic trip will be initiated due to low SF₆/hydraulic pressure. The trip coil(s) will pick up by auto trip, and the pump will start. Since the force to move the ram is less than the force to compress the springs, the ram will move in the open position before the low-pressure interlock's linkage, causing damage to the interlock linkage and, possibly, scoring the ram and breaking the operator/interrupter coupling.
2. To prevent the problem above, always remove the spring plug during maintenance work, as shown in Figure 52., "Spring Plug and Warning Decal" (note the Warning decal). Reinstall the spring plug before returning the circuit breaker to service.

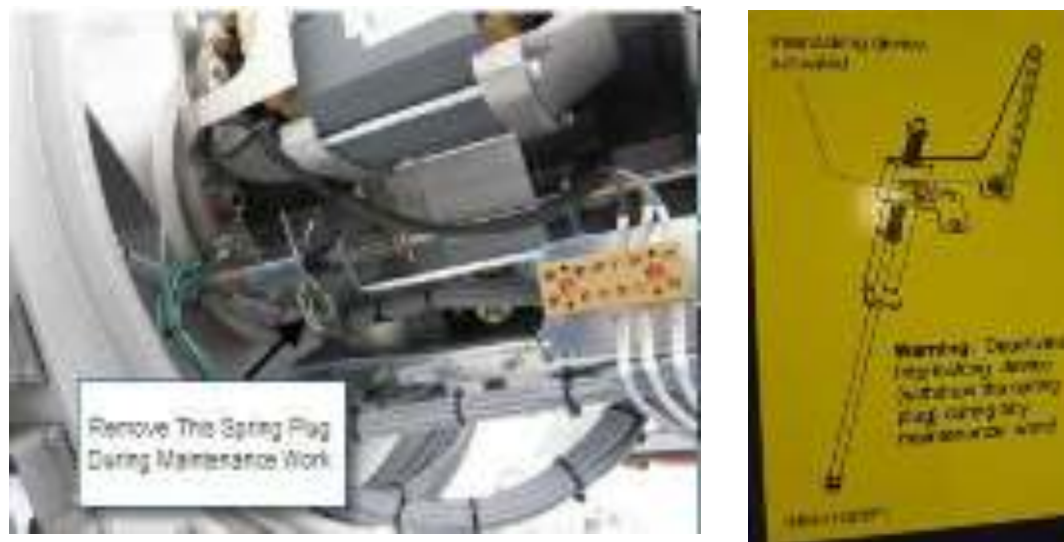


Figure 52.
Spring Plug and Warning Decal

F. ABB 550PM Circuit Breaker – Pole Disagreement Lockout

ABB 550PM circuit breakers may fail to close if the trip-coil plungers are sticky and do not reset after having been energized by a tripping operation. ABB 550PM circuit breakers have six trip coils (two per phase). A pole with a trip coil that failed to reset will not close on a subsequent close command, resulting in the circuit breaker having both closed and open poles. When this happens, a “pole disagreement” or “pole discrepancy” lockout and alarm will occur. In some instances, the lockout has been reset, and attempts to close the circuit breaker have repeated the problem.

1. When a “pole disagreement” or “pole discrepancy” lockout and alarm are received, **do not** reset the lockout and **do not** attempt to reclose the circuit breaker until it has been inspected by substation maintenance personnel.

Section 7, Subsection IV.F.2.

2. When an ABB 550PM circuit breaker has experienced a “pole disagreement” or “pole discrepancy” lockout or has any other unexplained operating malfunction, clear the circuit breaker, remove the black covers from the ends of the trip coils, and inspect the six trip-coil plungers. Compare the movement and reset action of the plungers to help identify which one is slow or sticking. A trip-coil plunger moves approximately $\frac{1}{4}$ inch only. If a sticky or slow-to-reset trip-coil plunger is found, keep the circuit breaker cleared and replace the trip coil.
3. Occasionally, the lockout alarm may not pick up before the line protective relays operate to de-energize the line. To help identify this possibility, verify the proper number of counter operations for each phase. If the problem is present, the number of counter operations will not be equal between phases.

**CAUTION**

When inspecting trip-coil plungers, ensure that the hydraulic pressure from the mechanism is equalized. Refer to the manufacturer's instructions for the procedure. If the hydraulic pressure is not equalized, the circuit breaker may operate when the plungers are depressed. Ensure that the circuit breaker is in the open position before equalizing the pressure. If not, severe damage to the mechanism may occur.



Figure 53.
Trip Coil With Cover Removed

G. Siemens SP72 Circuit Breakers

During every mechanism service, the control and pilot valves on Siemens SP72 circuit breakers must be rebuilt. These valves tend to fail during the closing operation because of moisture contamination in the air system, and the failure leads to extended outages.

Section 7, Subsection IV.G.1.

1. To rebuild the valves, order the following kits:
 - Control valve service kit–Code 340443
 - Pilot valve service kit–Code 340446
2. If necessary, replace the valves. Return the old valves to the Company repair facility in Emeryville to be rebuilt and returned to stock for credit. Order the new valves, as follows:
 - Control Valve–Code 340442
 - Pilot Valve–Code 340444

H. Siemens TCP SF6 Circuit Breaker – Hydraulic Relief-Valve Problem

1. A “dart”-type hydraulic relief valve was used on TCP circuit breakers built before January 1992. The dart and anvil seat were sensitive to foreign material, sometimes causing the valve to leak from the high-pressure to the low-pressure side and to not reseal. When this happened, the pump motor ran continuously, causing damage to the circuit-breaker mechanism.
2. This type of valve was changed in January 1992 to another style. The newer valve is of the direct-acting ball type and fits directly into the cavity of the earlier valve. The new valve uses crushable copper washers as a means of sealing to atmosphere and does not have the same problem with leaks.

Replace the washers whenever the cover is removed and/or the valve is adjusted. Carefully torque the locknut to 13 ft/lbs.

3. If the older type of hydraulic relief valve is found on a TCP circuit breaker, replace it at the next mechanism service. Order the newer type of relief valve directly from Siemens (Part No. W43840801). If the hydraulic motor relay contactor has been damaged, order a new one (Siemens Part No. W551106). Contact Siemens, as follows:

Siemens Energy, Inc.

7000 Siemens Road

Wendell, NC 27591

Kelvin.king@siemens.com

Telephone: 601-936-9135; Fax: 601-936-9151

I. MEPPi BH-3 Trip-and-Close Prevention Service Advisory

Mitsubishi Electric Power Products, Inc. (MEPPi) has issued a service advisory stating that new, factory-supplied clips must be used to prevent inadvertent operation of BH-3 and BH-3.1 circuit-breaker mechanisms during installation and maintenance. Use these clips **in addition to** the trip and close prevention pins.

Section 7, Subsection IV.I.1.

1. The clips come supplied with a caution tag that states, “Solenoid clip must be installed when trip/close prevention pins are inserted.” Newer mechanisms are shipped with the clips, but they were not provided with older circuit breakers. However, MEPPi has shipped the new clips to the affected substation headquarters.
2. The MEPPi advisory states that, when a worker pressed against a trip plunger unintentionally while assembling a gas circuit breaker at the MEPPi factory, the mechanism operated unexpectedly, even though the trip-prevention pin was installed. Without the additional clip, the circuit breaker could operate inadvertently, creating a safety hazard for employees performing inspections or making adjustments during installation or maintenance.
3. **All** MEPPi gas circuit breakers with BH-3 and BH-3.1 mechanisms require a clip and trip **and** close prevention pins. All affected mechanisms assembled at the factory after July 2005 are supplied with the new clips.
4. See Figure 54., “Protective Clip for MEPPi H-3 and BH-3.1 Circuit Breakers,” below, for an illustration of the clip.

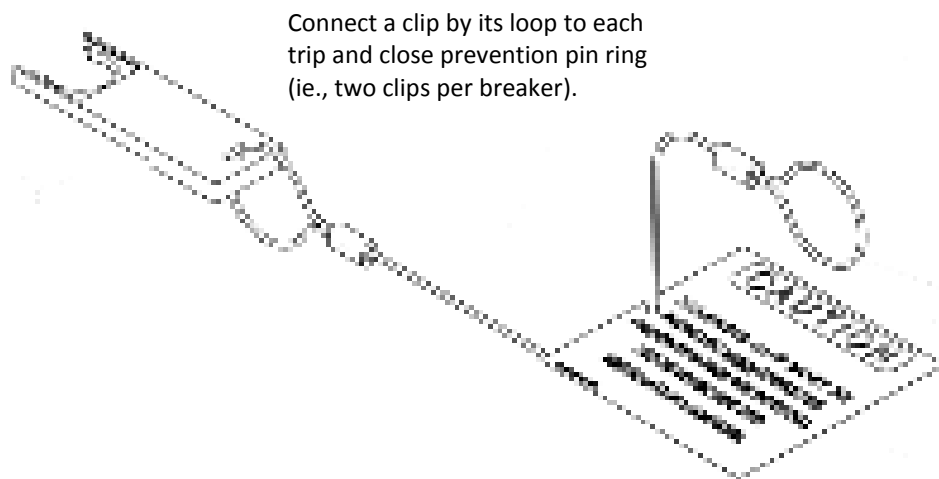


Figure 54.
Protective Clip for MEPPi H-3 and BH-3.1 Circuit Breakers

J. MEPPi 500 kV Circuit Breakers – Air Orifice Setting

Mitsubishi (MEPPi) 500 kV breakers have mechanisms that use compressed air storage to operate the breaker. There is one compressor per breaker and an air system that routes compressed air to all three poles. MEPPi recommends that the air compressor operate approximately 2 hours a month to maintain proper lubrication. Small air leaks in the system trigger the compressor’s operation, as well as removing the air orifice caps inside the mechanism cabinet of each pole.

Section 7, Subsection IV.J.1.

1. Check the compressor run time counter over a 1-month period with no breaker operations. If the counter shows between 2 and 4 hours operating time, do nothing.
2. If the counter shows less than 2 hours operating time for the month, remove the 3 air-bleed orifice caps. The caps are located in each pole cabinet. Use two wrenches to remove or install the caps (one to hold the orifice and one for the cap). Save the caps for possible re-installation in the future. See Figure 55., "Location of Air Bleed Orifice on MEPPi 500 kV Breakers," for an illustration of the air bleed orifice.



Figure 55.
Location of Air Bleed Orifice on MEPPi 500 kV Breakers



CAUTION

The air orifice is not located near any moving parts; therefore, the breaker can remain in service while removing or installing the air orifice caps. **DO NOT** bang or hit the mounting panel when working on the orifice caps. Air and SF₆ pressure switches are mounted to this same panel and a sharp vibration could activate one of these switches.

Section 7, Subsection IV.J.3.

3. The compressor run times should be monitored for one month (30 days) without any breaker operations. Without any breaker operations, the compressor should run about 2 hours per month from air leakage including the design leakage from the three air orifice caps removed. If it is less than 2 hours with the three caps removed, that is acceptable.
4. If the compressors runs more than 4 hours per month without any breaker operations, install the 3 air orifice caps and recheck. If run time is still more than 4 hours, remove the breaker from service and repair any air system leaks. Return the breaker to service and start over at Subsection IV.J.1.

K. SF₆ Gauges on Mitsubishi Circuit Breakers**CAUTION**

Mitsubishi (MEPPI) SF₆ breakers (72 kV and above) manufactured from March 2007 through August 2009 may have faulty SF₆ pressure gauges where the gauge needle can stick. This gives a false indication of SF₆ pressure!

1. MEPPI identified 250 breakers delivered to PG&E with this faulty gauge. MEPPI shipped new gauges, mounting blocks, and tubing for each breaker to affected maintenance headquarters on December 31, 2011. Install the new gauge following the instructions included with each MEPPI shipment.
2. Faulty gauges can create safety and operating hazards as described in the following two examples.
 - Personnel **not** adding gas to under-pressurized breakers.
 - Personnel over-pressurizing breakers when adding gas.

The affected gauges have a white plastic housing with a metal rim as shown in Figure 56., “Faulty SF₆ Gauge with White Plastic Housing,” below.

Section 7, Subsection IV.K.2., continued



Figure 56.
Faulty SF₆ Gauge with White Plastic Housing



CAUTION

Refer to the circuit breaker gas-transfer procedures in this manual for filling procedures. Specifically, follow the instructions for properly regulating the pressure setting of the SF₆ regulator. **DO NOT** rely solely on the circuit breaker SF₆ pressure gauge as an accurate indicator of pressure. **Over pressurizing can cause the rupture disks to operate while they are filling and the gas temperature increases, or when there is arc interruption by the main contacts.** Lightly tapping on the gauge should free the needle if it is stuck. As another check of the true pressure in the breaker, attach a portable SF₆ gauge to the “Gas Accessory Port” on the circuit breaker gas panel.

3. If you suspect a faulty SF₆ gauge, report it to your supervisor. Place an Information Tag on the gauge stating that gauge needle may stick. Replace the gauge as soon as practical with a replacement gauge from MEPMI.

L. MEPMI SF₆ Circuit Breakers: Bushing Terminal Hardware Corrosion

MEPMI circuit breakers manufactured from January 2001 until May 2003 were assembled with bushing top terminals using bolts, washers, and nuts that may not have met specification for galvanizing. Surface corrosion ranging from light white oxidation to red rust has been reported. Although not likely to result in failure of the bolted joints, the corrosion could eventually make

servicing a bushing difficult.

Section 7, Subsection IV.L.1.

1. Standing on the ground, examine the underside hardware of the bushing's top terminal. Figure 57, "Possible Corrosion on Top Bushing Cap Hardware for Certain MEPPI SF₆ Breakers," illustrates what may be visible.



Figure 57.
Possible Corrosion on Top Bushing Cap
Hardware for Certain MEPPI SF₆ Breakers

2. If surface corrosion is visible, turn in a Notification to clear and ground the high voltage terminals at the next mechanism service for the purpose of sealing the hardware.
3. After the breaker is cleared and grounded, remove loose powder from the bolt and nut and immediate surrounding area with a soft-bristled brush.
4. Using rubber gloves, apply a liberal amount of Dow Corning 737 clear, neutral-cure silicone sealant to the nut, bolt, and surrounding area of the bushing terminal casting. (See Figure 58, "Correct Application of Silicone Sealant to Hardware on MEPPI Breakers," below.) Spread the sealant into the space between the nut and the casting with a finger, completely coating the nut and exposed threads and sealing the nut to the casting. All exposed bolt and nut surfaces must be covered completely with sealant for the treatment to be effective. Checking the top end of the fastening hardware is not necessary because it is treated with silicone sealant at the factory.
5. The sealant takes about 24 hours to cure, but the breaker may be put back into service immediately after completing the sealing operation.

Section 7, Subsection IV.L.5., continued



Figure 58. Correct Application of Silicone Sealant to Hardware on MEPPi Breakers

M. Test Requirements for Specific MEPPi Circuit Breakers

MEPPi has provided the following test requirements and measurements for the circuit breakers listed in Table 14., “Test Requirements for MEPPi Circuit Breakers.”

1. It is not necessary to perform a trip-free timing test.
2. Take mechanical measurements from the linkage for the interrupter stroke and contact wipe; do not rely on measurements from the transducer, since these are calculated by the timing equipment.
3. It is not necessary to take over-travel or bounce-back measurements.
4. Routine measurement of the velocity of dead-tank SF₆ MEPPi circuit breakers is not necessary. If performed, the “average velocity” requirement is + 10%. Perform a velocity test if the contact operating times indicate a possible problem. Follow the manufacturer’s instructions for the test procedures.

Section 7, Subsection IV.M.4., continued

Table 14. Test Requirements for MEPPI Circuit Breakers

Measurement Specifications	70-SFMT-32F	100-SFMT-40E	100-SFMT-63F	100-SFMT-63J	100-SFMT-40SE
Interrupter Stroke (Minimum)*	116 mm	145 mm	195 mm	118 mm	145 mm
Interrupter Stroke (Maximum)*	122 mm	152 mm	202 mm	122 mm	152 mm
Interrupter Wipe (Minimum)*	25 mm	25 mm	37 mm	25 mm	25 mm
Interrupter Wipe (Maximum)*	29 mm	29 mm	41 mm	29 mm	29 mm
Closing Operation (Time)	≤ 75 ms	≤ 150 ms	≤ 110 ms	≤ 80 ms	≤ 69 ms
Closing Operation (Average Velocity)	2.5 m/s	2.3 m/s	3.6 m/s	2.0 m/s	4.2 m/s
Opening Operation (Time) (3-Cycle Breakers)	≤ 26 ms	≤ 28 ms	≤ 28 ms	≤ 28 ms	≤ 32.5 ms
Opening Operation (Average Velocity)	4.7 m/s	5.0 m/s	7.6 m/s	4.5 m/s	5.7 m/s
Opening Operation (Time) (2-Cycle Breakers)	–	–	≤ 19 ms	–	–
Measurement Specifications	200-SFMT-40E	200-SFMT-50SE	200-SFMT-63F	500-SFMT-50E	
Interrupter Stroke (Minimum)*	195 mm	195 mm	195 mm	267 mm	
Interrupter Stroke (Maximum)*	202 mm	202 mm	202 mm	271 mm	
Interrupter Wipe (Minimum)*	37 mm	37 mm	37 mm	35.5 mm	
Interrupter Wipe (Maximum)*	41 mm	41 mm	41 mm	38.5 mm	
Closing Operation (Time)	≤ 110 ms	≤ 100 ms	≤ 110 ms	≤ 100 ms	
Closing Operation (Average Velocity)	3.6 m/s	3.4 m/s	3.6 m/s	4.6 m/s	
Opening Operation (Time) (3-Cycle Breakers)	≤ 25 ms	≤ 28 ms	≤ 28 ms	–	
Opening Operation (Average Velocity)	7.6 m/s	6.5 m/s	7.6 m/s	13.5 m/s	
Opening Operation (Time) (2-Cycle Breakers)	–	–	≤ 19 ms	≤ 18 ms	

ms = milliseconds, m/s = meters per second

Section 7, Subsection V.

V. Flowcharts for Periodically Testing and Maintaining SF₆ Circuit Breakers

A. Non-CAISO-Controlled, Distribution-Class SF₆ Circuit Breakers

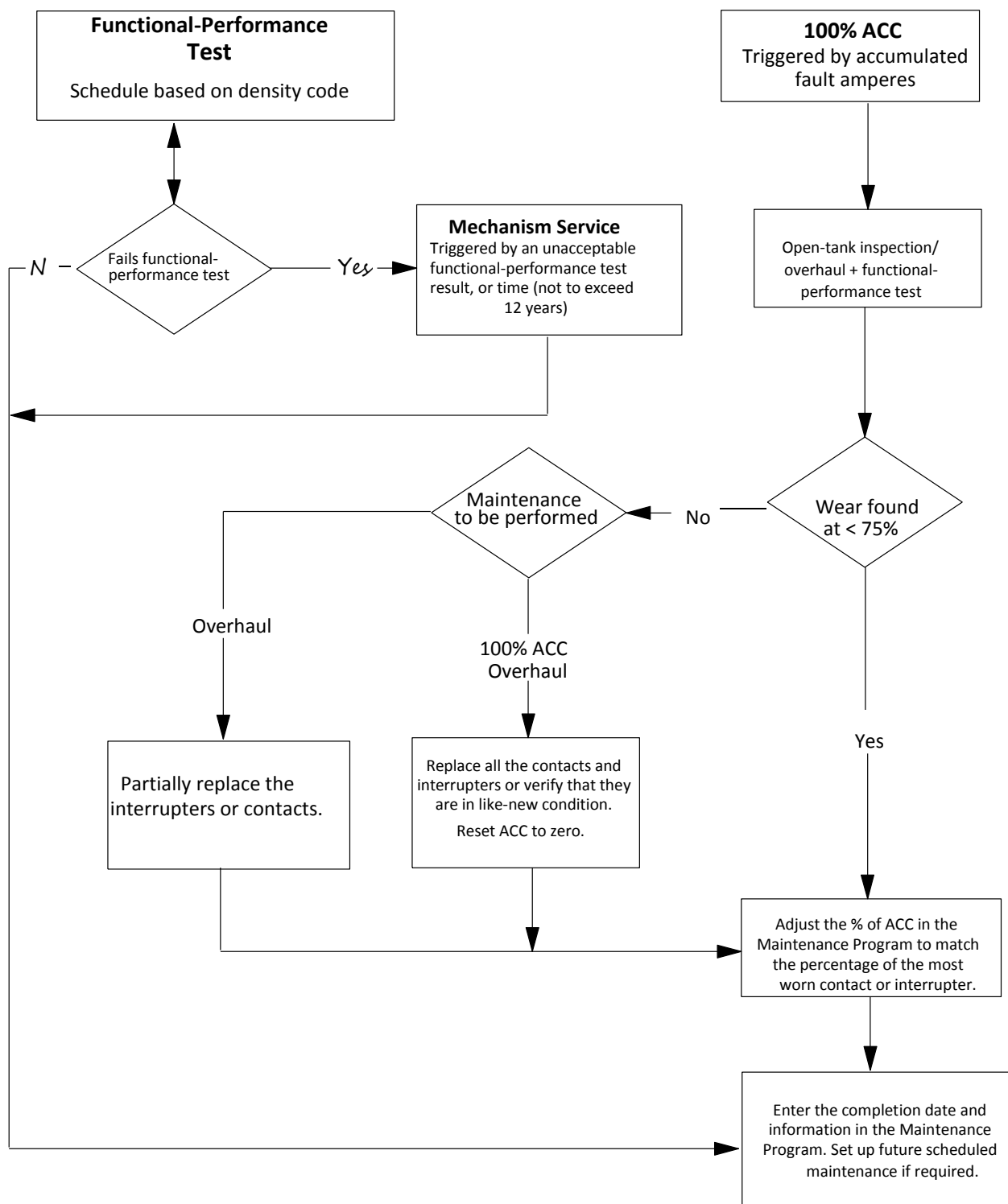


Figure 59.
Flowchart for Non-CAISO-Controlled, Distribution-Class, SF₆ Circuit Breakers

Section 7, Subsection V.B.

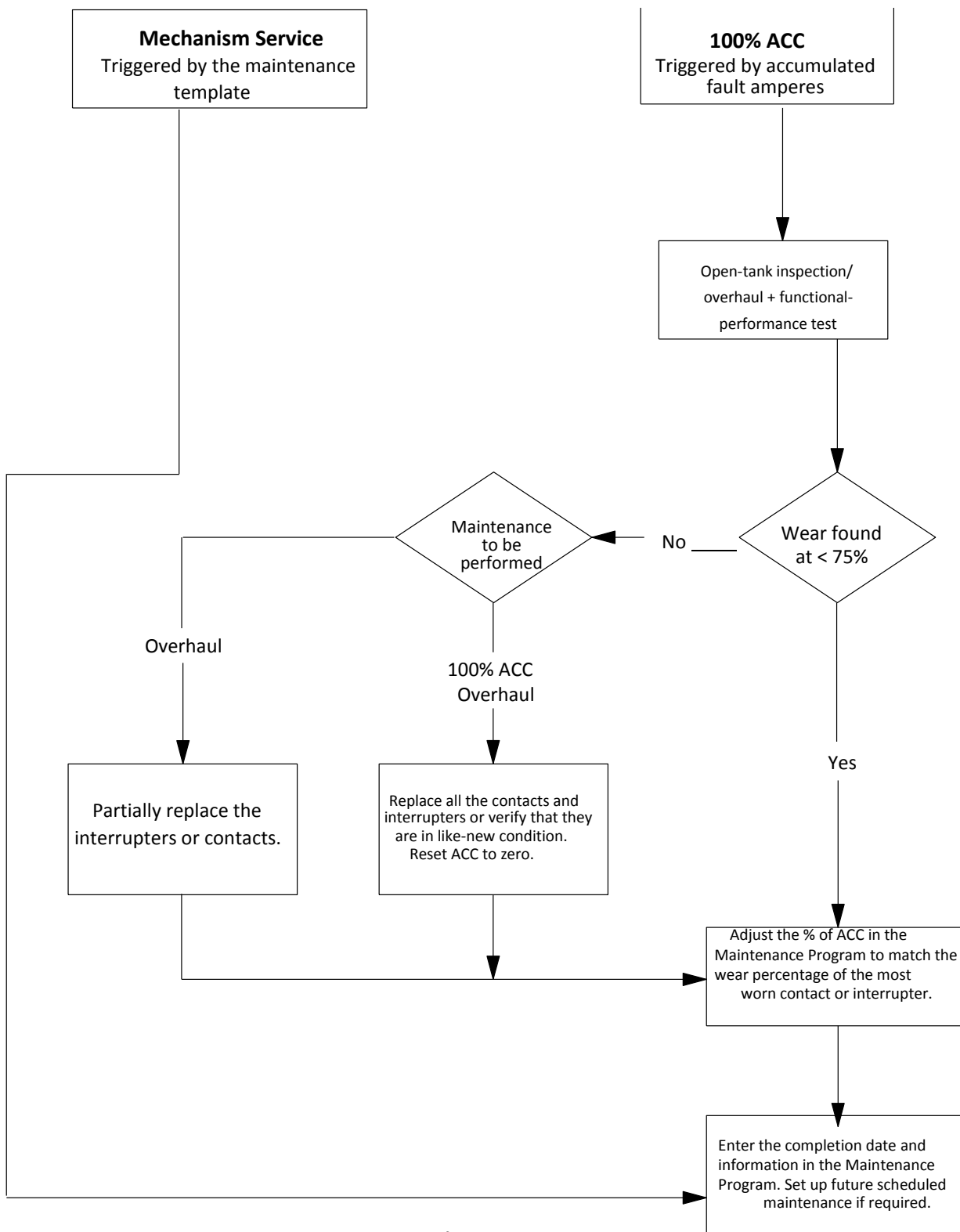
B. CAISO-Controlled and Transmission-Class SF₆ Circuit Breakers

Figure 60.
Flowchart for All CAISO-Controlled and Transmission-Class SF₆ Circuit Breakers

Section 7, Subsection VI.

VI. Inspecting SF₆ Circuit Breakers

See *SMCM*, [“Substation Inspections,”](#) for the procedures for periodic inspections of SF₆ circuit breakers.

VII. Planning a Job Before Performing Maintenance Work on SF₆ Circuit Breakers

The success of maintenance work depends on good job planning. Consider the following items when planning maintenance work.

A. Using Manufacturer’s Instructions and Service Advisories

Always use the manufacturer’s instructions as a reference when performing any maintenance.

1. Most manufacturers’ instructions contain important safety information. Not all of this information is listed in the *SMCM*.
2. Employees are responsible for understanding the maintenance and safety requirements for each piece of equipment **before** beginning work.
3. Occasionally, it may be necessary to deviate from some of the manufacturer’s requirements in order to safely perform Company maintenance and troubleshooting procedures.
4. For manufacturers’ service advisories, see Subsection 7.IV.

B. Additional Information About SF₆ Gas, Including Transfer Procedures

1. See Section 8 for information about the health and safety hazards of SF₆ gas, safe working procedures, and procedures for transferring, handling, and storing SF₆ gas.
2. Before moving or relocating an SF₆ breaker, the gas pressure must be lowered for safe handling. Refer to Section 7.0.



CAUTION

Moving or relocating a SF₆ circuit breaker with normal SF₆ operating pressure can result in the release of the SF₆ gas and its bi-products. It is also possible to damage the circuit breaker bushings which could result in bushing shrapnel projected into the work area exposing employees to a hazard.

C. Checking Records, Service Advisories, and Information Bulletins

Before requesting a clearance, check the circuit breaker’s previous maintenance records and the monthly station-inspection information.

Section 7, Subsection VII.C.1.

1. Review the circuit breaker's operating history and note any pending repair work. This information is necessary for good job planning.
2. Keep **all** of the station inspection information, maintenance records, and service advisories accurate, thorough, neat, and readily available.
3. Check Subsection 7.IV. for additional service work required for specific types of SF₆ circuit breakers.
4. Check for any applicable information bulletins.

D. Testing and Maintaining Bushings

See *SMCM*, [“Arrestors, Bushings, and Insulators,”](#) Subsection II., for information on testing and maintaining bushings during circuit-breaker maintenance.

E. Servicing Relays

Check the last relay-test dates to see if the relays are due for service. Check the [PESTP](#) Manual for the relay-test intervals.

F. Servicing Mechanisms on SF₆ Circuit Breakers

Perform a mechanism service on the following SF₆ circuit breakers:

1. All transmission-class and CAISO-controlled circuit breakers. Perform as triggered by Utility Standard TD-3322S, “Substation Equipment Maintenance Requirements,” [Attachment 7, “Circuit Breaker Maintenance Template.”](#)
2. All non-CAISO-controlled, distribution-class circuit breakers. Perform a mechanism service whenever:
 - a. The circuit breaker fails to pass a functional-performance test.
 - b. An online operational-timing monitor alarm is received.
 - c. A thorough visual condition assessment indicates that this service is necessary.
 - d. The circuit breaker does not operate correctly.
 - e. The time-based default trigger is reached.

G. Overhauling SF₆ Circuit Breakers

Perform an overhaul on an SF₆ circuit breaker when it reaches 100% ACC or when a condition exists that warrants an internal inspection.

H. Preventing Moisture

1. If it is necessary to leave the SF₆ gas out of a circuit breaker overnight or longer, perform the following steps.

Section 7, Subsection VII.H.1.a.

- a. Seal the circuit breaker's tanks.
 - b. Pull a slight vacuum on the tanks.
 - c. Apply a positive pressure of dry, bottled air or nitrogen gas.
2. The desiccant in the tanks helps absorb any moisture, and the pressure seals the tanks against contamination.
 3. If the bushings have been removed, seal the tanks with bushing-flange shipping covers, if available, or temporary bushing flanges made out of plywood or a similar material that allows sealing.

I. Replacing Seals

1. Certain SF₆ seals must be replaced during an overhaul according to the manufacturer's requirements. Refer to the manufacturer's instructions.
2. Obtain the replacement seals before requesting a clearance.

J. Tools and Materials

Ensure that all of the regular truck stock, safety equipment, PPE, and the following special tools and materials are always available. Take all of the applicable items to the jobsite where the maintenance work will be performed.

Note: Some distribution-class SF₆ circuit breakers are designed similarly to transmission-class circuit breakers. Ensure that the equipment taken to the jobsite is specific to the type of circuit breaker.

1. Tools and Materials for Performing a Mechanism Service on an SF₆ Circuit Breaker

A mechanism service on an SF₆ circuit breaker requires the following tools and materials:

- a. Company [Form TD-3322M-F13, "Distribution Circuit Breaker Functional Performance Test Form,"](#) and a test set, or other timing gear if this is unavailable. (See Section 13, "Forms.")
- b. Tools and equipment for measuring the open and close operating times of the main contacts.
- c. Company [Form "SF₆ Circuit Breaker Mechanism Service."](#) (See Section 13, "Forms.")
- d. SF₆ gas-leak-repair materials.
- e. The complete set of lubricants listed in Section 10.
- f. Ventilation-filter materials for the mechanism compartments.

Section 7, Subsection VII.J.1.g.

- g. Door-gasket and sealing materials, and adhesives.
- h. Dashpot oil.
- i. Hydraulic or compressor oil, as applicable.
- j. Cleaning materials: hoses, pressure regulators, bottled gas (nitrogen or air), low-pressure air guns with siphons or pressurized solvent cans, parts-cleaning brushes, cleaning solvents, and rags.
- k. Relay-test gear (if applicable).
- l. Micrometers, calipers, and/or feeler gauges to determine the wear percentage. (May be necessary for SF₆ gas cylinders used in some distribution-class circuit breakers.)
- m. A 100 A contact-resistance tester and leads (in case a condition or maintenance trigger requires their use). Manufacturers of SF₆ circuit breakers require using a 100 A contact-resistance tester.
- n. A high-pot tester for distribution circuit breakers with sealed SF₆ gas cylinders if the manufacturer requires high-pot testing.
- o. High-quality silicone caulking for use on GE Hitachi 550 kV circuit breakers manufactured from 1983 to 1996. (See Subsection 7.IV.A.)
- p. Mobilegrease 28 lubricant for the operating mechanisms of ABB Type FSA circuit breakers. (See the manufacturer's service advisory, Subsection 7.IV.B.).
- q. For all Siemens SP72 circuit breakers, kits for rebuilding the mechanism control valve (Code 340443) and the pilot valve (Code 340446). For more information, see Subsection 7.IV.H.
- r. For all ABB Type FSA mechanisms on 72 PM and 121 PM circuit breakers, a **circuit breaker analyzer with a transducer** to perform velocity traces and timing tests. For more information, see Subsection 7.IV.C. If necessary, see the Vanguard CT-7000 job aid on the T/SM&C SharePoint website (request access to the website, if needed). To locate the job aid, select "Quality Control Program," then "Original Documents."
- s. An SF₆ Breaker Gas Analysis (BGA)[™] sample kit, sampling fittings and materials, testing laboratory ["Internal Inspection Report"](#) (see *SMCM*, ["Insulating Oil,"](#) Subsection X., "Forms"), and [TD-3322M-F22, "BGA[™] Breaker Gas Analysis Sulfur Hexafluoride \(SF₆\) Data Sheet"](#) (for circuit breakers without sealed gas cylinders). (See Section 13, "Forms." Copies of these forms also are kept at headquarters.)

2. Tools and Materials for Overhauling an SF₆ Circuit Breaker

Overhauling an SF₆ circuit breaker requires the following items in addition to those listed for the mechanism service.

Section 7, Subsection VII.J.2.a.

- a. A circuit-breaker contact and interrupter replacement kit, if available.

Note: These kits are not always readily available for SF₆ circuit breakers.

- b. An SF₆ gas moisture detector.
- c. Torque wrenches.
- d. Impact, Allen, and other wrenches, and their associated sockets and extensions.

Note: Many SF₆ circuit breakers require **metric tools**. Refer to the manufacturer's instructions for specific tool requirements.

- e. SF₆ seals and desiccant, if required to replace during an overhaul.
- f. An SF₆ gas-handling cart with prefilters (for circuit breakers without sealed gas cylinders).
- g. SF₆ tank door-gasket material and adhesives.
- h. Lock wire or Locktite™ for bolts.
- i. Denatured alcohol.
- j. Lint-free rags.
- k. An SF₆ BGA™ sample kit, sampling fittings and materials, testing laboratory [“Internal Inspection Report”](#) (see *SMCM*, [“Insulating Oil,”](#) Subsection X., “Forms”), and a [“BGA™ Breaker Gas Analysis Sulfur Hexafluoride \(SF₆\) Data Sheet”](#) form (for circuit breakers without sealed gas cylinders). (See Section 13, “Forms.”) Copies of these forms also are kept at headquarters.)
- l. Scotch-brite™ or similar contact-cleaning materials.
- m. A circuit-breaker analyzer with a transducer (for transmission-class circuit breakers).
- n. A 500 V megger.
- o. A load cell for checking contact pressures (for circuit breakers without sealed gas cylinders).
- p. Spare filters for handling SF₆ gas (for circuit breakers without sealed gas cylinders). Change a filter when the differential pressure across it reaches 4 psig.
- q. Company [Form TD-3322M-F19, “SF₆ Circuit Breaker Overhaul.”](#) (See Section 13, “Forms.”)
- r. Flange-sealing materials, if bushings are removed.

Section 7, Subsection VII.J.2.s.

- s. A Tag 330 high-voltage detector, if available, either 60 to 115 kV or 230 to 500 kV (for transmission-class circuit breakers).
- t. Dry, bottled air and a pressure regulator (to break the vacuum after removing the SF₆ gas).
- u. A calibrated and tested four-gas tester with four spare “C” batteries (for confined-space testing, if applicable).
- v. Confined-space entry tools (if required for the specific circuit breaker) and [“Entry Permit”](#) forms. (See [Utility Procedure TD-3320P-01, “Electric T&D Confined Space Work Procedures,”](#) for transmission-class SF₆ circuit breakers. This procedure includes Company [Form TD-3320P-01-F01, “Permit-Required Confined Space \(PRCS\) Entry Permit.”](#) Copies of the form also are kept at headquarters.)
- w. PPE for entering a possibly hazardous environment containing SF₆ by-products.
- x. An air blower or fan to purge the SF₆ tanks.
- y. An ABB, SF₆ gas-density, mini-monitor tool for SF₆ circuit breakers manufactured by ABB.
- z. “Alvania EP Grease 2 (PB)” is required during an overhaul for lubrication **inside** the SF₆ tanks on ABB SF₆ circuit breakers. (This grease is available from ABB.)

VIII. Servicing Mechanisms on SF₆ Circuit Breakers

A mechanism service on an SF₆ circuit breaker includes the following items and requirements. Thoroughly inspect the entire circuit breaker and mechanism, including all of the gears and cams, for any loose, missing, worn, cracked, or damaged components. Correct any unsatisfactory conditions.

A. Clearance

Clear the circuit breaker and make it safe for maintenance.

B. Fasteners

Check the physical condition of all of the springs, cotter pins, keepers, bolts, and other fasteners.

C. Electrical Wire Terminations

Ensure that all of the electrical wire terminations are tight and are not corroded.

Section 7, Subsection VIII.D.

D. Switches and Relays

Ensure that the latch-check switch and all of the auxiliary switches, microswitches, X-Y anti-pump relays, and seal stacks have good electrical connections.

1. Check any accessible contacts for excessive burning or pitting.
2. Check the mechanical condition of the switches and relays, including their operating arms and linkages.

E. Shock Absorbers and Dashpots

Ensure that the mechanism shock absorbers and/or dashpots are operating properly. Use the manufacturer's instructions as a reference.

1. Inspect the dashpots for leaks and for the proper oil levels.
2. Clean, repair, and add or replace oil, as necessary.

F. Interrupter Bottles

Carefully inspect the interrupter bottles on sealed-gas-bottle-type circuit breakers. Look for any cracks, including in the area of the metal-to-insulation seals.

G. Testing Alarms, Relays, and Reclosers

Take the following steps to test the alarms, relays, and reclosers on distribution-class circuit breakers.

1. Notify the distribution operator before testing the alarms, relays, and reclosers.
2. Run the recloser to lockout by activating the protective relays.
3. Verify that the alarms, relays, and recloser are working properly.
4. On circuit breakers with electromechanical relays, test three-phase simultaneous targeting.
5. Reset the recloser by electrically closing the circuit breaker.
6. Record the reclosing and lockout times, and update the recloser-relay card.
7. Watch for any circuit-breaker malfunctions that require more extensive troubleshooting for permanent correction.

Note: Perform and document the necessary troubleshooting tests if there are any circuit-breaker malfunctions. Check and make any required mechanical adjustments listed in the manufacturer's instructions. To ensure service reliability and safety, immediately correct **any** condition that may cause a malfunction.

Section 7, Subsection VIII.H.**H. Indicators**

Verify that the circuit-breaker operations counter(s), all of the red and green lights, and the mechanical position semaphore(s) are working properly.

I. Lockout Devices

1. Trip the circuit breaker with the mechanical-maintenance trip device, if applicable.
2. Verify that the 69 lockout device prevents further electrical operation.
3. Manually reset the lockout device.

J. Cleaning and Lubricating

1. Thoroughly clean and lubricate the entire mechanism according to the procedures in Section 10.

**CAUTION**

Check the manufacturer's instructions to verify the lubrication requirements. Some newer SF₆ circuit-breaker mechanisms do not require relubrication.

2. Clean the entire high-voltage compartment on sealed-bottle-type circuit breakers.

K. Cylinder-Erosion Measurements

1. Check the SF₆ gas cylinder-erosion measurements on sealed-bottle-type circuit breakers.
2. Record the percentage wear of each phase.

L. High-Pot Testing

Perform a high-pot test on the cylinders of sealed-bottle-type circuit breakers, if recommended by the manufacturer.

M. Compressor and Hydraulic Service

Compressor and hydraulic services for distribution-class SF₆ circuit breakers are separate maintenance tasks with their own scheduling triggers. Compressor and hydraulic services for air compressors used with transmission-class SF₆ circuit breakers are performed as part of the mechanism service. See the Utility Standard TD-3322S [Attachment 7](#) maintenance template.

Section 7, Subsection VIII.M.1.

1. Use Company [Form TD-3322M-F12, "Compressor Service,"](#) found in Section 13, "Forms," to document compressor and hydraulic-system service tasks.
2. See Subsection 1.V.C. for compressor and hydraulic service procedures.

N. Minimum-to-Trip and Minimum-to-Close Tests



CAUTION

The change-over valve on hydraulically and pneumatically tripped circuit breakers may fail to shift position fully at a reduced voltage. This condition is difficult to detect and correct. To avoid this hazard, **do not** test the trip circuits on these types of circuit breakers to the absolute minimum, unless the manufacturer specifies a minimum-to-trip voltage. It is only necessary to verify that these circuit breakers will trip at 70% of their nominal voltage rating or the minimum tripping control voltage on the nameplate, whichever is lower.

1. Except for the circuit breakers stated in the Caution note above, perform a "minimum-to-trip" and "minimum-to-close" test on all the dc-operated circuit breakers with a trip or close latch:
 - Whenever a mechanism service is performed.
 - That have questionable operating performance.
2. Video guidance for this procedure can be found on the [PG&E Video Portal](#), using the search term "minimum to trip."
3. Refer to Section 3 "Diagnostic Tests", Subsection IV.D., for general information and testing methods.

O. Anti-Pump Feature

Test the anti-pump feature of the control circuit.

1. Close the circuit breaker electrically with a control switch and hold the control switch in the close position.
2. Apply a trip signal.
3. The circuit breaker should trip only once while the control switch is held continuously in the close position. It should not try to close and open repeatedly.
4. Video guidance for this procedure can be found on the [KnowledgeKeeper](#) website, using the search term "anti" or on the [PG&E Video Portal](#), using the search term "Anti-Pump."

Section 7, Subsection VIII.P.**P. “As-Left” Functional-Performance Test and Verifying Trip-Free Operation**

Perform a functional-performance test to provide a return-to-service benchmark for trending purposes. Record the results on a [“Distribution Circuit Breaker Functional Performance Test Form.”](#) (See Section 13, “Forms.”) Verify the trip-free operation of the circuit breaker.

Q. Main-Contact Operating Times

Test the opening and closing times of the circuit breaker’s main contacts to verify that the circuit breaker is performing within the specifications given in the manufacturer’s instructions. See Subsection 3.O. for additional information.

R. “As-Left” Speed Shot

1. Use a time-and-distance circuit-breaker analyzer to perform an “as-left” speed shot, if any critical components were replaced or if any measurements were changed that may affect the operational performance of a transmission-class circuit breaker.

Note: This test is **required for all ABB FSA mechanisms**. For more information, see Subsection 7.IV.C.

2. Analyze the test results for the proper circuit-breaker performance. Use the manufacturer’s instructions as a reference.

S. BGA™ Gas Sample

Take a BGA™ gas sample for laboratory analysis. Moisture levels for in-service equipment must not exceed the limits given in the specific manufacturer’s instructions. Refer to Section 8 for laboratory BGA™, gas-sampling methods, and safety precautions.

T. GE Hitachi 550 kV Circuit Breakers

When performing a mechanism service on a GE Hitachi 550 kV circuit breaker, assess the integrity of the caulking material used to seal the top cap of the bushings. Water may have infiltrated and deteriorated the cement bond between the upper flange and the top of the porcelain. A loss of SF₆ gas is an indication that this may have occurred. For more detail, see the service advisory and illustration in Subsection 7.IV.

U. Checks Following Service

1. Following service work, check normal all items and systems that were altered during maintenance work, including annunciators and alarms, local and remote control switches, feature and cutout switches, relays, and wires.
2. Ensure that all of the tools and materials have been removed.

Section 7, Subsection VIII.V.

V. Determining Safety and Reliability

1. Determine if the circuit breaker is safe and reliable after reviewing the inspection data, condition assessments, and the operational and diagnostic test results.
2. If the circuit breaker is not safe or reliable, record the specific abnormal conditions and any repairs that are required.

W. Operational Checks

Operate the circuit breaker from all of the available locations including from the SCADA system, if applicable.

IX. Overhauling SF₆ Circuit Breakers

Overhauling an SF₆ circuit breaker includes performing a mechanism service and the following, additional tasks:

Note: To protect SF₆ circuit breakers against internal electrical tracking, keep all lubricants and fingerprints off of the internal insulating surfaces. Wear clean gloves to prevent skin and oil contact. Clean any contaminated surfaces with denatured alcohol and lint-free rags before closing the tanks.



CAUTION

Slow-close the circuit breaker by hand before electrically operating it, if any mechanical adjustment or component disassembly was performed. Check the manufacturer's instructions to verify that the circuit breaker can be slow-closed.

A. Functional-Performance Test

1. Perform a functional-performance test before clearing the circuit breaker.
2. Record the test results on a ["Distribution Circuit Breaker Functional Performance Test Form."](#) (See Section 13, "Forms.")

B. Clearance

Clear the circuit breaker and make it safe for maintenance.

C. BGA™ Gas Sample

Take an initial BGA™SF₆ gas sample and send it to the TJ/H2B Analytic Services, Inc., laboratory for a full analysis. Refer to Section 8 for laboratory BGA™, gas-sampling methods, and safety precautions.

Section 7, Subsection IX.D.**D. Contact-Resistance Tests**

Perform contact-resistance tests. Use a 100 A contact-resistance tester, if recommended by the manufacturer.

E. Cylinder-Erosion Measurements

Check and record the contact-erosion measurements for SF₆ gas cylinders on distribution-class, sealed-bottle-type circuit breakers.

F. SF₆ Circuit Breakers Without Sealed Cylinders

The following items apply only to tank-type SF₆ circuit breakers **without** sealed SF₆ gas cylinders:

1. “Before” Moisture Content

Test and record the “before” moisture content of both the SF₆ gas in the circuit breaker and the residual SF₆ gas in the handling cart.

2. Removing SF₆

Remove the SF₆ gas from the circuit breaker. Refer to Section 8.

- a. Pull a vacuum on the SF₆ system to 2 millimeters of mercury (mmHg). This may take several hours to reach this negative pressure and evacuate most of the SF₆.
- b. Refill to 0 psig with dry air before opening the interrupter chamber.

3. Inspecting for SF₆ Arc By-Products

- a. Open the circuit breaker and inspect for any SF₆ arc by-products.
- b. Clean out the arc by-products, if present. Consult with the local substation field specialist, and follow the substation and environmental policies for this work.

4. Interrupter Wear

Inspect the interrupter assemblies for wear. Record the wear percentage.

5. Contact Wear

Inspect the main and arcing contacts, and all of the visible, main current-carrying paths.

- a. Record the contacts’ wear percentages.
- b. Check for any unequal or uneven wear, heavy pitting, or grooves, any of which may indicate incorrect contact pressure.
 - (1) Check the contact pressure if any of these abnormal conditions are found.
 - (2) Refer to Section 3 for checking the contact pressure.

Section 7, Subsection IX.F.5.c.

- c. Replace the contacts, if necessary. If available, use a contact and interrupter replacement kit.

6. **Contact Stroke**

Ensure that the contact stroke is within the manufacturer's tolerances. Adjust the stroke, if necessary. Document any adjustments.

7. **Contact Wipe**

Ensure that the contact wipe is within the manufacturer's tolerances. Adjust the wipe, if necessary. Document any adjustments.

8. **Grading Capacitors or Resistors**

Ensure that the grading capacitors or resistors are within the manufacturer's tolerances.

9. **Lubrication**

Lubricate the contacts and parts as specified by the manufacturer.

Note: "Alvania EP Grease 2 (PB)" is required during overhaul for lubrication **inside** the SF₆ tanks on ABB SF₆ circuit breakers. (This grease may be ordered from ABB.)

10. **Replacing the Seals**

Replace the SF₆ seals, if required by the manufacturer.

11. **Replacing the Desiccant**

Replace the desiccant immediately before closing the SF₆ compartment.

12. **Tightening the Bolts**

Close the circuit-breaker tanks. Tighten the bolts according to the manufacturer's instructions.

13. **Refilling With SF₆**

Refill the circuit breaker with SF₆ gas. Refer to Section 8

14. **"As-Left" Moisture Content**

Test the "as-left" moisture content of the SF₆ gas in the circuit breaker. Moisture levels for in-service equipment must not exceed the limits given in the specific manufacturer's instructions. If the moisture content exceeds the manufacturer's recommended limits or is above 200 ppm, contact the local area field specialist for the next steps.

Section 7, Subsection IX.F.15.**15. “As-Left” Gas-Quality Sample**

Take an “as left” BGA™ SF₆ gas sample and send it to the TJ/H2B Analytic Services, Inc., laboratory for a full analysis. Keep the results as a benchmark for future tests.

16. Compressor Pressure-Switch Rundown Test

- a. Perform a pressure-switch rundown test on circuit breakers with air or hydraulic operators. Perform a relief-valve test on compressed air accumulators. Refer to Section 3 for the test procedures. Document test results on [TD-3322M-F12, “Compressor Service,”](#) and [TD-3322M-F24, “Compressor Rundown.”](#) (See Section 13, “Forms.”)
- b. Ensure that the compressor operations counter is working properly.

17. SF₆ Pressure-Switch Rundown Test

- a. Perform an SF₆ pressure-switch rundown test. Record the alarm, lockout, and tripping pressures, as applicable.
- b. If adjustments are necessary, see the manufacturer’s instructions for adjustment procedures.

Note: ABB circuit breakers may be tested with an ABB, SF₆ gas-density, mini-monitor tool.

18. “As-Left” Speed Shot and Travel-Trace Tests

Use a time-and-distance circuit-breaker analyzer to perform an “as-left” speed shot and travel-trace tests, if any critical components were replaced or if any measurements were changed that could affect the operational performance of a transmission-class circuit breaker. The travel-trace tests must include trip, close, and trip-free timing. If necessary, see the Vanguard CT-7000 job aid on the T/SM&C SharePoint website or contact the local area field specialist for assistance.

19. Checks Following Service

- a. Following service work, check normal all of the items and systems that were altered during maintenance, including annunciators and alarms, local and remote control switches, feature and cutout switches, relays, and wires.
- b. Ensure that all of the tools and materials have been removed.

20. Determining Safety and Reliability

- a. Determine if the circuit breaker is safe and reliable after reviewing the inspection data, condition assessments, and the operational and diagnostic test results.
- b. If the circuit breaker is not safe or reliable, record the specific abnormal conditions and any repairs that are required.

Section 7, Subsection X.

X. Performing Diagnostic Tests for SF₆ Circuit Breakers

Perform the following diagnostic tests when triggered by the Utility Standard TD-3322S [Attachment 7](#) maintenance template or a circuit-breaker condition or trouble. Refer to Section 3 for additional tests common to all circuit-breaker types.

A. Testing SF₆ Gas in a Laboratory

Refer to Section 8 for laboratory BGA™ gas-sampling methods and safety precautions.

B. Monitoring Gas Leaks

1. Procedure

All gas-system pressures normally vary with temperature changes. Any changes that are not attributable to temperature fluctuations indicate a leak.

- a. Check the gas pressures periodically and compare them to the acceptable, temperature-corrected ranges.
- b. Check for gas leaks by using Leak-Tec™, soapy water, or electronic leak detectors (sonic, halogen, laser, etc.).

2. Leak Detection Methods

Contact the local field specialist for assistance in detecting and locating SF₆ leaks.

a. Leak-Tec™ or Soapy Water

- (1) Brush, or use a spray bottle, to apply the solution directly onto pressurized pipe or gasketed joints, welded seams, shaft seals, valve stems, pipe plugs, etc.
- (2) Check for bubbles forming where the gas is leaking.
- (3) Clean and remove all of the soapy residue after checking for leaks.

b. Electronic Leak Detectors

Various types of electronic leak detectors are available.

Section 7, Subsection X.B.2.b.(1)

- (1) **Leak Seeker™ LS790B** electronic refrigerant leak detector.

This leak detector may be purchased from the following supplier for approximately \$220.

United Refrigerator Stores
1848 E. Griffith Way
Fresno, CA 93726-4819

Telephone: 1-559-228-0477

Fax: 1-559-228-0963

<http://www.uri.com>



Figure 61.

- (2) Sonic and laser leak detectors sense the sound or motion of leaking gas. They rely on detecting physical changes to the air surrounding a leak. However, wind also may cause these changes.
- (3) In windy locations, a halogen detector provides more accurate results. Halogen detectors detect SF₆ because they measure fluorines as well as halogen, chlorine, bromine, and other gases. Refer to the instrument manufacturer's instructions for details.

c. Gas Detection Service

For SF₆ leaks that require scanning to locate, contact the local field specialist or the following vendor for service.

Advanced Specialty Gases 135
Catron Drive
Reno, NV 89512

Contact: Dave Stein Telephone: 1-775-356-5500

Fax: 1-775-356-5571

Email: dave@advancedspecialtygases.com

XI. BGA™ Testing Following Relay Actions

SF₆ breakers have susceptibility to an internal flashover following a lightning strike. This was illustrated during a 2009 event at Salado Substation. A lightning strike to a line connected to Salado Substation caused the line breaker to flashover internally, operating the differential protection. The breaker was closed back in manually after an external inspection showed no evidence of a failure. An internal flashover was not suspected because the rupture disk was intact. This breaker then failed months later because of the internal contamination created by the flashover. An internal flashover may not cause the rupture disk to fail.

An internal flashover without rupture disk failure is possible for other conditions, not just lightening.

Section 7, Subsection XI.A.

A. Perform a BGA Test

Perform a BGA™ test based on the following.

1. Breaker failure or bus protection relaying has occurred.
2. The relay action indicates that an SF₆ breaker is within the fault zone and no definitive cause is identified.



CAUTION

The circuit breaker must be de-energized when drawing an SF₆ gas sample. Refer to Section 8 for sampling and safety procedures.

B. Complete the Gas Sampling and Lab Analysis

Complete the gas sampling and lab analysis within 72 hours. Take the BGA™ sample as soon as possible, and request the lab to **rush** the analysis.

C. Leave the Breaker Out of Service Until the BGA™ Results Are Returned

If operationally possible, leave the breaker out of service until the BGA™ results are returned. If not possible, re-energize the breaker.



CAUTION

A breaker with enough gas contamination may internally flashover when energized, resulting in a protective relay action and/or failing the rupture disk.

D. Keep the Breaker De-Energized If an Internal Flashover Occurred

If the BGA™ test shows signs of an internal flashover, the breaker must remain de-energized and an internal inspection performed to confirm the failure.

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Section 8

Handling SF₆ Gas

I. Purpose

This section includes information about the characteristics of SF₆ gas and methods for working safely with SF₆ gas. All employees working with SF₆ gas **must** be aware of, and comply with, the information in this section.

II. General Information About SF₆ Gas

A. Chemical Description of SF₆ Gas

1. SF₆ gas in its pure (100%) form is inert (without active properties), colorless, odorless, and nontoxic.
2. SF₆ gas is neither flammable nor corrosive.
3. SF₆ gas is approximately five times heavier than air and is highly stable, both chemically and thermally.

B. Environmental

SF₆ is a potent greenhouse gas. It has a global warming potential of 23,900 as compared to carbon dioxide. SF₆ is chemically inert in the upper atmosphere and has an atmospheric lifetime that is estimated to be between 800 and 3,200 years. For these reasons, extreme care must be taken to prevent SF₆ emissions while handling or when operating/maintaining electrical equipment that is filled with SF₆. See Section 8.II.E.3 for mandatory tracking requirements.

C. Dielectric Features of SF₆ Gas

1. SF₆ gas is an excellent dielectric medium. Its high dielectric strength and thermal stability allow SF₆ gas to be used as both an insulating and an arc-interrupting medium.
2. The dielectric strength of SF₆ gas at 30 psig is more than twice that of dry air at the same pressure. It also exceeds the dielectric strength of oil.
3. The dielectric strength of the gas increases as the pressure increases.

D. Purity Standards for SF₆ Gas

1. New SF₆ gas manufactured in North America for use in electrical switchgear and equipment is required to be 99.8% pure in order to meet ASTM Standard D-2472. The 0.2% impurities allowed have a negligible effect on the physical and electrical properties of the gas.
2. The gas must meet the requirements of the Company's [Engineering Standard No. 14, "Specification for Sulfur Hexafluoride \(SF₆\),"](#) and ASTM Standard D-2472 for purity and for water and air content.

Section 8, Subsection II.D.2.a.

- a. Water content for new gas must not exceed a maximum of 8 parts per million (ppm) by volume or a dew point greater than -45°Centigrade (C).
- b. Air content must not exceed 0.05% air (measured as nitrogen).

E. Purchasing SF₆ Gas

SF₆ gas must be purchased through a system wide program negotiated by the Company and its selected supplier. **Do not** purchase SF₆ from any other supplier. PG&E works closely with our approved supplier to track the movement of SF₆ cylinders and SF₆ usage. If you mistakenly order from another supplier, immediately contact your environmental specialist or maintenance field specialist.

1. Codes

- a. For ordering large SF₆ gas cylinders (115 pounds by gas weight), use Code 490104.
- b. For ordering medium SF₆ gas cylinders (40 pounds by gas weight), use Code 490782.
- c. For ordering small SF₆ gas cylinders (20 pounds by gas weight), use Code 034848.

2. Minimum Supply

- a. Maintain a minimum supply (determined by historical needs) at each headquarters where SF₆ gas is used.
- b. Check the present departmental ordering policy for any revisions.

3. SF₆ Gas Supply and Cylinder Tracking Program

- a. State law requires documented use and reporting of SF₆, including tracking the movement and weights of cylinders at all times. Accurate recordkeeping is essential to support our annual report of changes in installed capacity, storage, and emissions. Follow [Utility Procedure TD-3350P-01, "SF₆ Tracking and Cylinder Inventory,"](#) to document SF₆ purchases, usage, removal, and disposal.
- b. All SF₆ gas is ordered by Company material code and received from one supplier: Advanced Specialty Gases (ASG).
- c. Periodically contact ASG (775-356-5500) to pick up all of the empty and partially full cylinders when directed by the SF₆ gas supply program.

III. Health and Safety Hazards of SF₆ Gas

SF₆ gas in its **pure** form is not harmful to human health; however, there are hazards related to its use and handling.

Section 8, Subsection III.A.

A. Displacing Air

Pure SF₆ gas is not harmful to human health, except that it displaces oxygen. The gas is heavier than air and tends to collect at the low points in buildings (e.g., in basements) and in confined spaces, such as circuit breaker and transformer tanks. This could lead to oxygen deficiency and possible suffocation.

- Always avoid breathing SF₆ gas.
- To avoid ingestion, do not eat or smoke while handling SF₆ gas.
- Wash hands after handling SF₆ gas and by-products.

B. Producing Toxic Arc By-Products



CAUTION

Arc by-products are highly toxic and corrosive.

When exposed to an electric arc, SF₆ gas breaks down chemically and then recombines (i.e., “self-heals”), possibly leaving a small residue of arc by-products.

1. The type and amount of SF₆ arc by-products depend on the magnitude and duration of the arc, any contaminants present in the gas, and the type of metals used in the electrical equipment.
2. Units that have been exposed to high-current arcing or internal failures may contain abnormally high levels of the by-products.

C. Faulted SF₆ Gas

SF₆ gas is considered **faulted** when it has been exposed to an electric arc, corona, or extreme heat (e.g., 250°C or 480° Fahrenheit [F]).

1. Faulted gas must be treated as a hazardous substance.
2. Only new or reclaimed gas can be considered non-faulted.

D. Contaminants in SF₆ Gas

Contaminants in SF₆ gas reduce its “self-healing” qualities.

1. Dielectric Breakdown

- a. Water and air molecules in the gas combine with disassociated contaminant particles, eventually causing a dielectric breakdown.
- b. If water in the gas is above the threshold limits, it can condense onto the surfaces of an insulator, causing a conductive path and an eventual flashover.

Section 8, Subsection III.D.2.**2. Use of Desiccants to Prevent Contamination**

SF₆ gas-insulated circuit breakers use desiccants to remove moisture and SF₆ by-products.

- a. The most commonly used desiccants are aluminum oxide, activated alumina, or molecular sieve.
- b. These desiccants are not designed to handle large amounts of moisture and SF₆ by-products.

E. Weight of Gas Cylinders**1. Methods for Measuring Gas Cylinders**

Depending on the type of gas, different methods are used to determine the quantity of a product stored in a gas cylinder.

- a. **Pressure** is used to measure the quantity of nitrogen in a storage cylinder.
- b. **Weight** is used to measure the quantity of SF₆ gas.

2. Large SF₆ Gas Cylinders

- a. Usually, the weight of an **empty** SF₆ gas cylinder is stamped at the top of the cylinder. The tare (empty) weight of large SF₆ gas cylinders usually is between 110 and 114 pounds.
- b. SF₆ gas usually is supplied in cylinders filled with 115 pounds (by weight) of liquefied gas, bringing the total weight of a **full** cylinder to about 225 to 229 pounds.

3. Medium SF₆ Gas Cylinders

Medium cylinders containing 40 pounds by weight of liquid SF₆ are also available. The tare (empty) weight of these cylinders is approximately 55 pounds, bringing the total weight of a full cylinder to approximately 95 pounds.

4. Small SF₆ Gas Cylinders

Small cylinders containing 20 pounds by weight of liquid SF₆ are also available. The tare (empty) weight of these cylinders is between 33 and 37 pounds, bringing the total weight of a full cylinder to between 53 and 57 pounds.

**CAUTION**

Use caution when handling heavy SF₆ gas cylinders.

Section 8, Subsection IV.

IV. Safe Working Procedures

A. Safety Precautions

1. Inspecting for Arc By-Products Before Opening Tanks

Whenever equipment using SF₆ gas requires an internal inspection, its SF₆ gas **must** be tested for the presence of arc by-products **before** opening the tanks.

2. Following Confined-Space Work Procedures

- a. **Always** follow the safety rules in the [Utility Procedure TD-3320P-01](#), if entering a confined space.
- b. Pure SF₆ gas is not harmful to human health except that it displaces oxygen. The gas is heavier than air and tends to collect at the low points in buildings (e.g., in basements) and in confined spaces, such as circuit-breaker and transformer tanks. This could lead to oxygen deficiency and possible suffocation.

3. Avoiding Contact With Arc By-Products

- a. Solid arc by-products readily absorb moisture and are corrosive when wet.
- b. Gaseous and solid arc by-products are an irritant. They can cause discomfort such as breathing difficulties, coughing, eye irritation, and, if solid, a burning sensation to unprotected skin.
- c. Arc by-products are easy to detect by their pungent odor. Some smell like rotten eggs.

4. Avoiding Contact With SF₆ Gas

- a. **Always** avoid breathing SF₆ gas.
- b. To avoid ingestion, **do not eat or smoke while handling SF₆ gas**.
- c. Wash hands after handling SF₆ gas and by-products.

5. Avoiding the Release of SF₆ Gas Into the Atmosphere

- a. Never allow SF₆ gas to be released to the atmosphere except for the extremely small amount that is released when collecting a gas sample.
- b. When performing a moisture test in the field, install a filter-dryer (by using flexible tubing) on the output of the moisture tester to filter any contaminants before the gas is released. (See Subsection 8.X.B.2. for filter-dryer ordering information.)

6. Repairing Leaks

Repair **any** SF₆ gas leaks as soon as possible.

Section 8, Subsection IV.A.7.**7. Using Material Safety Data Sheets (MSDS)**

Employees handling SF₆ gas must be familiar with, and have access to, an MSDS for SF₆.

8. Sampling Gas Safely**CAUTION**

DO NOT take gas samples from energized circuit breakers.

B. Inspecting SF₆ Gas-Filled Equipment**1. Steps Before Inspection**

Perform the following steps before internally inspecting SF₆ gas-filled equipment.

a. Sampling and Analyzing SF₆ Gas

- (1) Before reporting on a clearance, take an SF₆ gas sample and send it to an approved laboratory, such as TJ/H2b Analytic Services, Inc., to analyze for arc by-products and moisture. (See Page 179 for the address.)
- (2) Assume that any SF₆ gas contains toxic by-products if it is in a chamber where arcing occurs.

Note: A positive test result confirms the presence of by-products in the gas but it is possible to have a negative test result and still have arc by-product powder present. **Always** inspect for even the slightest presence of arc by-product residue when first opening the circuit breaker's high-voltage compartments, despite receiving a negative test result on the gas sample.

- (3) Maintain a copy of all of the test laboratory's sample results in the local headquarters' equipment files.

b. Removing SF₆ Gas

Remove the SF₆ gas from the circuit breaker.

- (1) Pull a vacuum on the SF₆ gas system to 2 mmHg. It may take several hours to reach this negative pressure and evacuate most of the SF₆.
- (2) Refill the system to 0 psig with dry air before opening the interrupter chamber.

Section 8, Subsection IV.B.2.

2. Steps Before Performing Maintenance

Before performing maintenance or entering the tank, do the following:

a. Performing an Air Quality Test

- (1) Use an oxygen monitor to test and monitor the air in the tank.
- (2) Log in all of the test results.
- (3) A minimum of 19.5% oxygen is required for a safe working environment.

b. Inspecting for Arc By-Products

Inspect for even the slightest presence of arc by-product particles.

c. Using PPE

- (1) Wear full PPE while performing inspections.
- (2) The approved PPE is available through the materials department. It includes zippered, poly laminated, Tyvek™-type disposable coveralls; neoprene or latex gloves; disposable-cover booties; goggles; and an approved breathing respirator with a combination cartridge filter (GMC-H MSA No. 46027, Code 207573).

Note: Only employees with an approved medical evaluation may wear a respirator.

d. Ensuring that Eye-Wash Equipment Is Available

Ensure that battery-type eye-washing equipment is readily available at the jobsite in case of eye contact with SF₆ gas by-product powder.

e. Ensuring that Cleaning Water Is Available

Ensure that a sufficient source of flushing and cleaning water is readily available at the jobsite in case of skin contact with SF₆ gas by-product powder.

3. Steps if Arc By-Products Are Present

If **any** arc by-products are found in the contact chamber, take the following steps to completely remove the arc by-product solids **before** internally inspecting the contacts and interrupter.

a. Using PPE

Wear the full PPE described in Subsection 8.IV.B.2.c.(2) at all times.

b. Vacuuming the Surfaces

Clean all of the accessible surfaces in the chamber with an approved, heavy-duty, shop-type vacuum cleaner equipped with a hepafilter.

Section 8, Subsection IV.B.3.c.**c. Wiping Down the Interior**

Wipe down the interior of the equipment with lint-free rags and denatured alcohol.

d. Disassembling the Parts

If necessary, disassemble the parts in order to clean off all of the by-products.

4. Steps if No Arc By-Products Are Present

Perform the following steps **after** determining that no arc by-products are inside of the equipment tank.

Note: Protective clothing is not required after it is verified that no detectable arc by-products are found or remain inside the equipment tank.

a. Purging the Tank

Purge the tank for 5 minutes with an air blower or fan.

- (1) Ensure that employees are not exposed to the exhaust.
- (2) Any accumulation of toxic gases normally dissipates when exposed to the atmosphere.

b. Performing an Air Quality Test

- (1) Use an oxygen monitor to test and monitor the air in the tank.
- (2) Log in all of the test results.
- (3) A minimum of 19.5% oxygen is required for a safe working environment.

c. Following Confined-Space Work Rules

Follow the rules in [Utility Procedure TD-3320P-01](#), if confined-space entry is required.

C. Disposing of Arc By-Product Solids**1. Disposing of By-Products and Materials**

- a. Place all arc by-product solids, and all disposable materials and PPE used to clean up the by-products, in an approved hazardous-waste container.
- b. Do not put solid, uncontained wastes directly into a collector drum.
 - (1) The wastes must be packaged in smaller, sealed and labeled, plastic containers or bags before being placed in the collector drum.
 - (2) This waste material may consist of the following.

Section 8, Subsection IV.C.1.b.(2)(a)

- (a) Arc by-product solids
- (b) Cleaning rags
- (c) Molecular sieves (desiccant bags)
- (d) Vacuum bags
- (e) Disposable clothing

2. Cleaning Equipment and Tools

Thoroughly wipe down any non-disposable equipment and tools used while cleaning up the arc by-product solids.

- a. Use rags dampened with denatured alcohol.
- b. Dispose of the rags as described above.
- c. Thoroughly flush out vacuum-cleaner hoses and containers with water; then, allow them to dry.

3. Establishing a Hazardous-Waste Storage Area

Establish a temporary hazardous-waste storage area at the jobsite, following the requirements in the *Environmental Field Guide*.

- a. Apply a hazardous-waste identification label (as listed in the *Hazardous Waste Management Preparation Manual*, commonly referred to as the “Grid Appendix B”) to the collector drum with the following note: “SF₆ Gas Arc By-Product Solids - Hazardous Material.”
- b. Obtain an EPA ID number.
- c. Contact a hazardous-waste hauler to remove the waste directly from the jobsite within 90 days.
- d. Refer to the *Hazardous Waste Manual* for additional disposal information or contact the environmental specialist.

V. First-Aid Procedures

A. Inhaling SF₆ Gas

- 1. The symptoms of accidental SF₆ gas inhalation are:
 - a. Shortness of breath
 - b. Pale or blue skin (due to lack of oxygen)
 - c. Headache
 - d. Sluggishness
 - e. Tingling in the arms and legs

Section 8, Subsection V.A.1.f.

- f. Altered hearing
 - g. Possible unconsciousness.
- 2. Move the victim to fresh air.
- 3. Loosen or remove restrictive clothing.
- 4. Administer cardiopulmonary resuscitation (CPR) if the victim is not breathing.
- 5. Seek medical attention.

B. Contacting Skin With Liquid SF₆

- 1. In case of accidental skin contact with liquid SF₆, do not wait for any symptoms to appear before initiating first aid.
- 2. The symptoms of skin contact are:
 - a. Frostbite
 - b. Redness
 - c. Pain
- 3. Remove any contaminated clothing to prevent skin irritation.
- 4. **Slowly** warm the affected body area with lukewarm water. **Do not** apply direct heat.
- 5. Seek medical attention.

C. Ingesting SF₆ Gas

- 1. The symptoms of accidental ingestion of SF₆ gas are:
 - a. Nausea
 - b. Vomiting
 - c. Sluggishness
- 2. Rinse the mouth to remove any contaminants.
- 3. Drink plenty of water to dilute the ingested chemicals. **Do not** induce vomiting.
- 4. Seek medical attention.

D. Contacting Eyes With SF₆ By-Product Powder

- 1. Immediately flush the eye with water-type eye-wash equipment.
- 2. Seek medical attention.

Section 8, Subsection V.E.

E. Contacting Skin With SF₆ By-Product Powder

Flush the skin with a sufficient amount of water to completely clean the affected area.

VI. Handling, Transporting, and Storing Hazardous Materials

A. Environmental and Department of Transportation (DOT) Regulations

For important information about hazardous materials storage and transportation, including DOT requirements, see the Environmental Management page in the Company's guidance document library at: <http://pgeatwork/Guidance/EnvironmentalManagement/Pages/default.aspx>

1. Information is included on the following topics:
 - General requirements
 - Tanks
 - Transportation
 - Compressed gas cylinders
2. Contact the local Environmental Services field specialist with any questions.

B. Gas-Storage Cylinders

Note: Collect, store, purify, or reuse all SF₆ gas for both environmental and economic reasons. Do not allow SF₆ gas to escape into the atmosphere, except for the small amounts released when taking a gas sample, purging air from the fill lines while topping off, or filling a circuit breaker with new or reconditioned SF₆ gas.

1. **Heat**
 - a. Store the gas-storage cylinders away from any direct source of heat, including direct sunlight, to avoid a dangerous pressure build-up.
 - b. **Do not** allow the cylinders to be subjected to temperatures above 120°F.
2. **Flammable Materials**

Store the gas cylinders in an area free from large amounts of flammable material.
3. **Securing**

Ensure that the gas cylinders' protective caps are securely in place and that the cylinders are kept in an upright and secured position.

Section 8, Subsection VI.B.4.**4. Moisture**

Do not store the gas cylinders on damp ground or in contact with standing water.

5. Contamination

To prevent contamination, do not add unfiltered gas to storage cylinders intended for reuse.

6. Transporting

- a. Ensure that the gas cylinders are tightly secured when transporting.
- b. Ensure that the gas cylinders' protective caps are screwed properly in place.

7. New Cylinders

Perform the following steps if only part of a new cylinder is used.

- a. Weigh the gas cylinder.
- b. Test the gas moisture content.
- c. Tag the cylinder with its testing date, weight, and moisture content (in ppm).
- d. Compare the existing weight to the tare (empty) weight stamped on the cylinder to determine the amount remaining.
- e. See Subparagraph 8.II.D., "Purchasing SF₆ Gas," for instructions on documenting SF₆ cylinders.

C. SF₆ Gas-Handling Trailers**1. Description**

SF₆ gas-handling trailers, commonly referred to as "gas buggies," are used when removing gas from a circuit breaker or transformer before maintenance.

- a. The gas buggy contains an evacuating pump, filters, a storage compartment, a high-pressure pump, and a vacuum pump.
- b. Some models also have a refrigeration unit for liquefied storage and a heating unit for returning SF₆ liquid to a gaseous state.

2. Operation and Recordkeeping

- a. Use the gas buggy to collect, store, purify, evacuate, and reclaim SF₆ gas from equipment. SF₆ gas-buggy operation varies.
- b. Each buggy is equipped with its own specific operating instructions and a logbook. Record the following items in the log.

Section 8, Subsection VI.C.2.b.(1)

- (1) A dated record of all of the gas put into the buggy, including which equipment previously contained the gas.
- (2) Gas moisture-analysis data.
- (3) Filter changes.
- (4) Gas-buggy maintenance tasks.

Note: Keep a copy of the laboratory report containing the gas contaminant data in the local headquarters' equipment files.

3. Minimum Pressure

To prevent contaminants from being introduced and to meet DOT requirements, leave a positive pressure up to, but not exceeding, 10 psig in the storage tanks of old-style, non-DOT-approved gas buggies when not in use.

4. Refrigeration System

- a. Keep the gas buggy connected to its power source whenever it is being used to store SF₆ gas during a maintenance period.
- b. Some gas buggies are equipped with a thermostatically controlled, automatic refrigeration system that cools the stored SF₆ gas when the temperature approaches a critical point. The ventilation doors for this refrigeration unit **must** remain open when it is in use.

5. Oil Contamination or Seal Failure

- a. If the oil seals fail in a gas-buggy compressor system, or if oil is accidentally drawn into the SF₆ gas from the vacuum pump, the liquid SF₆ will look green instead of clear.
- b. If oil contamination occurs, return the gas buggy to the manufacturer to clean and rebuild.

6. Filters

Change the filter equipment in the gas buggies per the manufacturer's recommendations.

7. "As-Left" BGA™ Sample

- a. Take an "as-left" BGA™ sample from the circuit breaker after filtering faulted SF₆ gas during maintenance.
- b. Send the sample to a testing laboratory for analysis. The analysis provides a benchmark for future gas tests on the circuit breaker.

Section 8, Subsection VI.C.7.c.

- c. The change between the “before” and “as-left” moisture and by-product test results also indicates the effectiveness of the gas-buggy filters.

VII. Laboratory Gas Analysis**A. General Information About Gas Analysis****1. Laboratory Services**

TJ/H2b Analytic Services, Inc. provides analytic services to assist in diagnosing the internal condition of gas-filled equipment.

TJ/H2B Analytic Services, Inc.
3123 Fife Circle
Sacramento, CA 95827
Telephone: 916-361-7177

2. Safety Precautions Before Sampling

Refer to Subsection 8.IV. for safety precautions before taking an SF₆ gas sample.

B. SF₆ BGA™

BGA™ is a diagnostic tool developed by TJ/H2b for analyzing SF₆ gas. It determines the internal condition of an SF₆ circuit breaker by analyzing the SF₆ gas for contaminants, purity, moisture, and dielectric strength. PG&E is working with TJ/H2b currently to further refine this diagnostic tool. BGA™ provides a condition code and an assessment of the equipment’s internal activity.

Note: Condition-based maintenance depends on accurate sampling, testing, and analysis.

1. BGA™ Triggers

See Utility Standard TD-3322S, “Substation Equipment Maintenance Requirements,” [Attachment 7, “Circuit Breaker Maintenance Template,”](#) for the BGA™ triggers.

2. Taking Gas Samples

To obtain an accurate SF₆ gas sample on any type of SF₆-insulated circuit breaker with gas-sampling capabilities, a “gas sample collection unit” (GSCU) kit must be rented or purchased from TJ/H2b. Also, TJ/H2b sells the required adapters needed for connecting the GSCU to the sampling valves of different types of SF₆ circuit breakers. The GSCU kit contains purge and sample cylinders, a manifold, isolation valves, a vacuum/pressure gauge, stainless-steel tubing, and instructions. (See Figure 62., “GSCU Kit.”) To ensure accurate test results, follow the provided sampling instructions.

Section 8, Subsection VII.B.2., continued

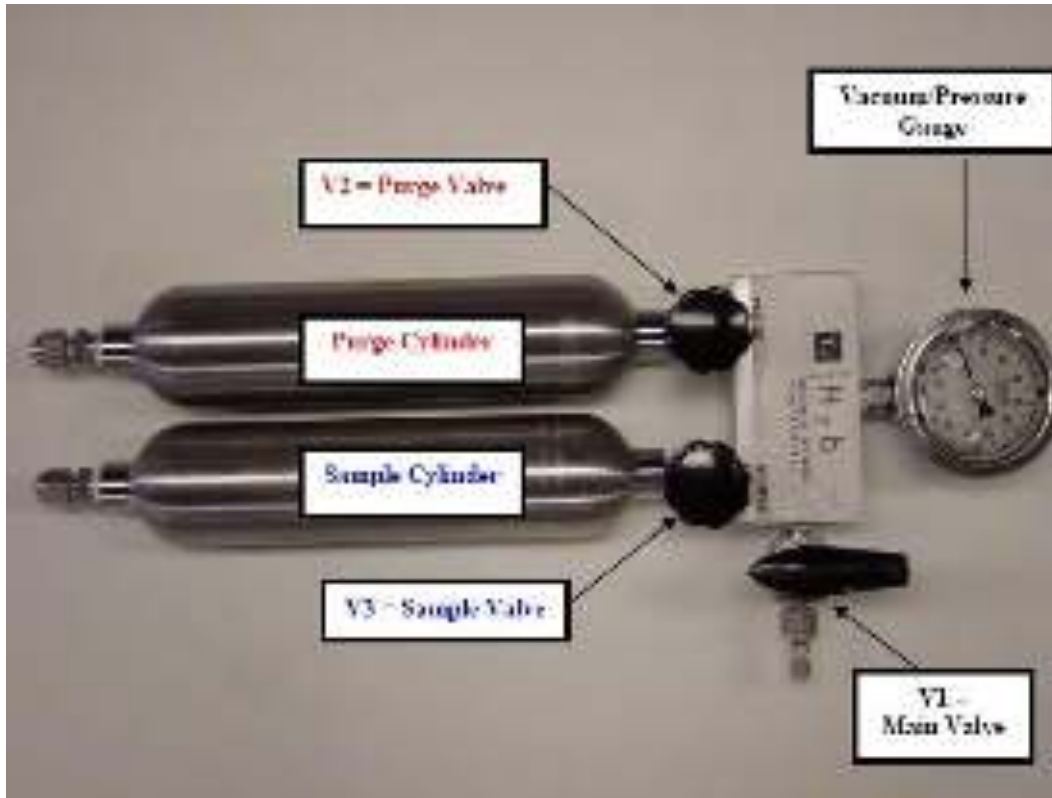


Figure 62. GSCU Kit

3. Recordkeeping for BGA™

- a. Fill out a [“BGA™ Breaker Gas Analysis Sulfur Hexafluoride \(SF₆\) Data Sheet”](#) form **accurately and completely**. (See Section 13, “Forms.”) File in the headquarters’ equipment file, along with the completed maintenance forms.
- b. Label the test sample with the circuit breaker’s serial number. This number is on the manufacturer’s nameplate, usually located either on or inside the door of the mechanism cabinet.
- c. Verify that the serial number matches the one assigned to the circuit breaker in the Maintenance Program. Proper condition-based maintenance depends on accurately tracking the equipment.

4. BGA™ Condition Codes and Assessments

The TJ/H2b laboratory assigns a condition code to indicate the condition of the equipment and provides an assessment with recommended actions.

- a. There are five codes based on using diagnostic algorithms to interpret the results of a combination of assessments. The codes are 1, 2, 3, 4, and 4*, ranging from 1 as the best to 4* as the worst.

Section 8, Subsection VII.B.4.b.

- b. The assessments include the following:
- Energy dissipation, with a recommended retest schedule.
 - Wear, with recommended ACC adjustments. (Never use the ACC adjustment recommended by a BGA™ to **reduce** the percentage of wear to a figure lower than that determined by a visual inspection.)
 - If applicable, a recommended schedule for internal inspection, based on a combination of the energy dissipation and wear results.

C. Precautions for Taking SF₆ Gas Contaminant Samples

1. Gas-Sampling Safety



CAUTION

DO NOT take gas samples from energized circuit breakers.

2. Avoiding Inhalation or Release of SF₆ Gas

Avoid inhaling faulted SF₆ gas. The gas from in-service equipment may contain toxic by-products from decomposition. However, the VMS system does not release enough faulted gas into the atmosphere to be either a safety or an environmental hazard.

3. Securing for Shipment

Ensure that the sample cylinder's valve and plug are tightly closed before packing the cylinder for shipment to TJ/H2b.

4. Protecting Fittings and Connections

Plug or cap all of the Swagelok connections to prevent damage to their threads and to avoid contamination with dirt and moisture. This increases the service life of the fittings and provides tight connections for future sampling.

VIII. Gas Transfer Procedures

A. General Information About Transferring SF₆ Gas

1. Gaseous State

- a. SF₆ may be withdrawn from its storage cylinder in a gaseous state.
- b. The SF₆ will be discharged as vapor when the cylinder is upright.
- c. The pressure (measured in psig) will drop on both the cylinder and the fill line because chilling occurs with vaporization.

Section 8, Subsection VIII.A.2.

2. Using Heating Bands

- a. Heating bands may be applied to accelerate the evacuation of gas from the cylinder. **Only** use heating bands that attach to the cylinder and are designed for this purpose.
- b. Use three heating bands per cylinder in conjunction with an insulation blanket wrapped around the cylinder to retain the heat.
- c. The heating bands use 110° F limit switches to prevent the cylinder temperatures from rising above 120° F.
- d. For ordering information, see Subsection 8.X.B.

3. Other Heating Sources

Other heat sources, such as heat lamps or barrels of hot water, are not recommended because they possibly may raise the temperature of the SF₆ gas cylinder past the maximum 120° F temperature limit.

4. Testing for Moisture

Always test for moisture in new SF₆ gas supplied in cylinders, and in reclaimed SF₆ gas removed from a piece of equipment and stored in a gas buggy, before using the gas.

- a. Use a moisture tester found on the approved tool list.
- b. The moisture-content engineering specification for **new**, electrical-grade SF₆ gas, per [Engineering Standard No. 14, "Specification for Sulfur Hexafluoride \(SF₆\)"](#), is a maximum of 8 ppm by volume or a dew point greater than -45° degrees centigrade.
 - (1) The supplier's gas contains no more than 8 ppm of moisture. However, this **must** be verified.
 - (2) Notify the gas supplier and the local field specialist if the test results for any new gas show more than 8 ppm of moisture.
- c. Moisture levels for in-service equipment must not exceed those given in the specific manufacturer's instructions.

5. Using the Vapor Transfer Method

- a. Use the vapor transfer method when less than a full cylinder of SF₆ gas is needed to fill or top off a circuit breaker.

6. Precautions When Using a Vacuum Pump

- a. **Never** turn off a vacuum pump while it is valved to a system under a vacuum because oil from the vacuum pump may possibly be pulled into the system.
- b. **Always** close the valves **before** turning off the vacuum pump.

Section 8, Subsection VIII.A.6.c.

- c. If oil is drawn into the circuit-breaker tank, open the circuit breaker and wipe down the tank to remove the oil contamination. Oil contamination causes liquid SF₆ to turn from clear to a greenish color.

7. Fill Hoses

- a. Use a fill hose with a pressure regulator to transfer SF₆ gas when the cylinder is in the upright position.
- b. Ensure that the pressure regulator is equipped with the same threaded fitting as the vaporization coil.

Note: When they are not in use, keep all of the fill hoses and coils tightly capped to prevent moisture contamination.

- c. The fill hose has a valve and tee-tap arrangement. This allows:
 - (1) Purging the vaporization coil and the fill hose to the circuit breaker.
 - (2) Evacuating the equipment with a vacuum pump and introducing SF₆ gas without needing a gas buggy.

B. The SF₆ Gas Buggy**1. Using Manufacturer's Instructions**

Always follow the procedures in the instruction manual for the specific gas buggy being used.

2. Preventing Moisture Contamination

- a. A gas buggy is a self-contained, sealed unit. Therefore, there is only a slight possibility of accidentally contaminating the SF₆ gas with external moisture. However, **always** leave a positive pressure of at least 10 psig in old-style, non-DOT-approved the gas buggies to minimize the possibility of contamination.
- b. Leave a small amount of clear SF₆ liquid in the sight glass.
- c. Perform these steps even if doing so requires using a new cylinder of SF₆ gas.

3. Recordkeeping

Always log the date the gas buggy is used, the moisture-test data, and the source of the gas stored in the buggy.

C. Using the Vapor Method for Filling Without Using a Gas Buggy

Perform the following steps to fill an SF₆ circuit breaker without using a gas buggy.

Section 8, Subsection VIII.C.1.

1. Moisture-Testing Cylinders

- a. Moisture-test **all** of the SF₆ gas cylinders that are expected to be used to fill the breaker.
- b. Verify that the cylinders containing **new** gas have a moisture content of no more than 8 ppm. Notify the gas supplier and the local field specialist if the test results for any new gas show more than 8 ppm of moisture.

2. Connecting the Equipment

- a. Attach the pressure regulator to the upright, moisture-tested cylinder.
- b. Run a fill hose, equipped with valves, a tee tap, and a filter-dryer, from the cylinder to the fill fitting on the equipment.
- c. Connect the filter-dryer between the SF₆ gas cylinder and the tee tap, as shown in Figure 63., "Connecting the Filter Dryer (1)." This position prevents backflow through the filter-dryer when purging the gas lines.

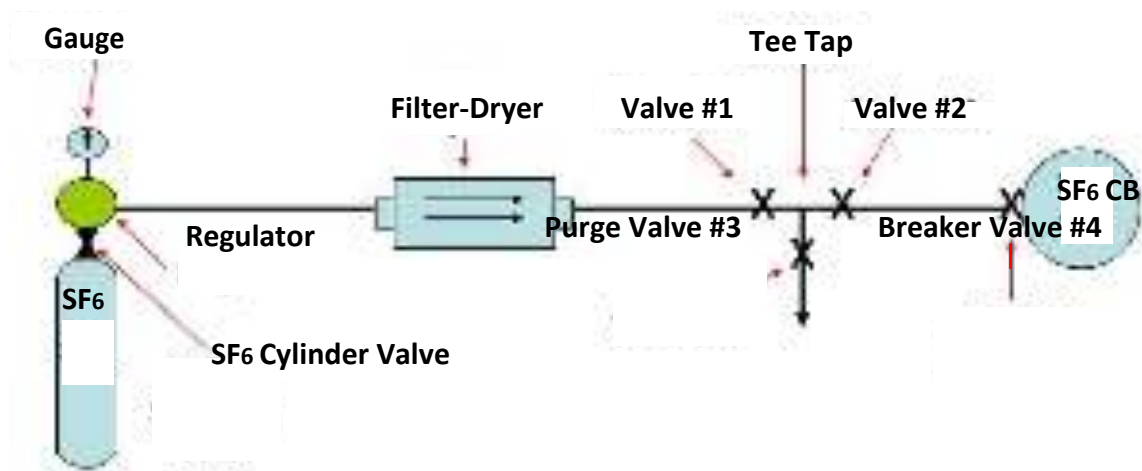


Figure 63. Connecting the Filter Dryer (1)

Section 8, Subsection VIII.C.3.**3. Evacuating Air**

Referring to the valves as numbered in Figure 46., above, perform the following steps.

- a. Ensure that all of the valves are closed. Connect a 30-cubic feet per minute (cfm) (or more) vacuum pump to Valve 3 (purge valve) at the tee tap.
- b. Open Valve 2, Valve 3, and Valve 4 (breaker valve). Evacuate the air from the circuit breaker and the fill lines by pulling a vacuum of 2 mmHg.
- c. Hold this vacuum for 2 hours with the vacuum pump running.

4. Filling With SF₆ Gas and Checking for Leaks

Referring to the valves as numbered in Figure 46., above, perform the following steps.

- a. Close Valve 3 (purge valve). Turn off the vacuum pump and remove it from the tee tap.
- b. Open Valve 1 and Valve 3 to purge the portion of the fill line containing the filter-dryer. Open the valve on the SF₆ cylinder and set the pressure regulator to purge a small amount of SF₆ gas through Valve 3.
- c. Close Valve 3 (purge valve).
- d. Set the SF₆ regulator to the approximate, temperature-compensated fill pressure of the circuit breaker.
- e. Open Valve 2 and Valve 4 (breaker valve). Begin filling the circuit breaker with gas from the SF₆ cylinder.
- f. Check for gas leaks as soon as a positive pressure is reached.
 - (1) Use the methods described in Subsection 7.X.B.
 - (2) Continue testing for leaks until the circuit breaker is at the full, temperature-compensated gas pressure.
 - (3) If necessary, repair any leaks and then repeat the leak-testing procedure.

5. Avoiding Air Contamination When Changing Cylinders

Take the following steps to ensure that no air contaminates the SF₆ gas while changing the gas cylinders during the filling process:

- a. Close the fill valve on the circuit breaker.
- b. Cap the fill lines as they are disconnected from the cylinders.

Section 8, Subsection VIII.C.5.c.

- c. When the lines are reconnected, set the pressure regulator at about 10 psig, and purge the fill lines at the tee tap.
- d. If there is positive pressure in the circuit breaker, back-purge the fill line from the circuit breaker through the tee tap with a small amount of gas.
- e. Close the tee tap purge valve.
- f. Continue filling the circuit breaker.

6. Completing the Process

- a. When the circuit breaker reaches the final, temperature-compensated pressure, **first** close the valve on the SF₆ gas cylinder, and **then** close the fill valve on the SF₆ circuit breaker.
- b. Bleed the residual SF₆ gas in the tubing through the purge valve on the tee tap.
- c. Disconnect the cylinder.
- d. Disconnect the fill-system equipment. Cap the fill lines as they are disconnected.

D. Using the Vapor-Transfer Method for Topping Off Directly From a Gas Cylinder

See Subsection 8.IX. for important policy information regarding the addition of make-up gas to equipment. Perform the following steps to top off a circuit breaker with a small amount of gas.

1. Moisture-Testing the Cylinders

Moisture-test **all** of the SF₆ gas cylinders that are expected to be used during the topping-off process.

2. Attaching and Connecting the Equipment

Note: If the circuit breaker is energized and in service, cut out or disable the low-gas tripping feature.

- a. Ensure that all of the valves are closed and that the pressure regulator is set to 0 psig.
- b. Attach the pressure regulator to the upright, moisture-tested cylinder.
- c. Run a fill hose, equipped with valves, a tee tap, and a filter-dryer, from the cylinder to the SF₆ sample-valve fitting at the circuit breaker.
- d. Connect the filter-dryer between the SF₆ gas cylinder and the tee tap, as shown in Figure 64., “Connecting the Filter Dryer (2)” below. This position prevents backflow through the filter-dryer when purging the gas lines.

Section 8, Subsection VIII.D.2.d., continued

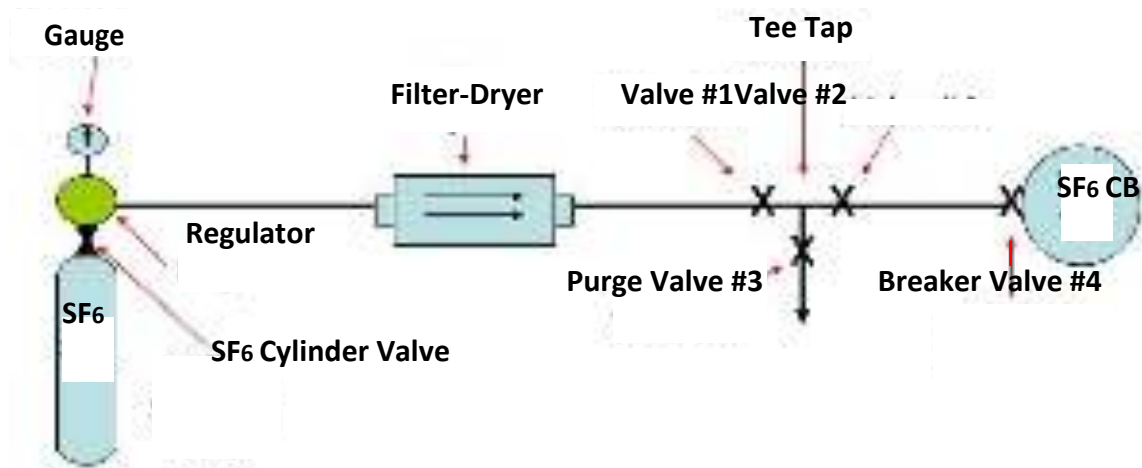


Figure 64.
Connecting the Filter Dryer (2)

3. Purging the Fill Line and Topping Off the Circuit Breaker

Referring to the valves as numbered in Figure 64., above, perform the following steps.

- a. Open Valve 1 and Valve 3 (purge valve) on the tee tap.
- b. Open the valve on the SF₆ gas cylinder.
- c. Set the pressure regulator at about 10 psig and purge a small amount of gas through the fill line at the tee tap.
- d. Close all of the valves.
- e. Crack open Valve 4 (fill valve) on the circuit breaker and Valve 2 (tee-tap valve). Back-purge a small amount of gas through Valve 3 (purge valve).
- f. Close Valve 3 (purge valve). Open Valve 1 and the SF₆ gas cylinder valve.
- g. Set the pressure regulator to **no more than** 10 psig higher than the final, temperature-compensated working pressure of the circuit breaker.

Note: This setting prevents over-pressurizing the circuit breaker.

- h. Fully open Valve 4 (sample valve). Slowly add gas to the circuit breaker until the prescribed pressure is met.
- i. Close the valve on the SF₆ gas cylinder, then close Valve 4 (sample valve) on the circuit breaker.
- j. Ensure that the circuit breaker's temperature-compensated gas pressure is correct.
- k. Open Valve 3 (purge valve) to relieve the gas pressure in the line.

Section 8, Subsection VIII.D.4.

4. Completing the Process

- a. Close all of the valves. Disconnect the fill-system equipment. Cap the fill lines as they are disconnected.
- b. Before returning the circuit breaker to service, ensure that the low-pressure alarm and tripping relays are not picked up.

IX. Adding Make-Up Gas to Equipment

A. Preparations for Adding While in Service

Adding SF₆ gas to an energized breaker is now permissible using the Energy Maintenance Technology (EMT) Smartfill system. This is the only acceptable method of adding gas to energized equipment. The steps in this section must be followed to safely add SF₆ gas to energized power circuit breakers. The EMT Smartfill is not currently approved for adding gas to energized Gas Insulated Substation (GIS) equipment. For a video tutorial, go to the [PG&E Video Portal](#) and search for “smartfill.”

Using the EMT Smartfill unit with time delay and traffic light features enables employees to avoid being in close proximity to the equipment during the filling process.



WARNING

- Use caution to prevent encroachment on the minimum working distances and be aware of the arc flash boundary when working on energized equipment.
- Always wear personal protective equipment; this includes rubber gloves when contact with energized parts 50-300 Volts is possible. Refer to [Utility Procedure TD-2360P-01](#) for guidance on rubber glove requirements.
- If the circuit breaker is locked out due to low SF₆ pressure, it will be necessary to clear the breaker and fill while de-energized.
- To avoid over pressurization of the circuit breaker, reference the circuit breaker manufacturer’s temperature compensation chart for gas fill values. It is important to know that ABS (absolute pressure, or psia) gauges are used on some circuit breakers, and that they measure from absolute vacuum. When this is the case, they will indicate 14.7 psi higher than the value given on the SmartFill, which is measured in psig, relative to standard atmospheric pressure.

Section 8, Subsection IX.A., continued

**CAUTION**

During the setup and filling process, it is possible to decrease the gas pressure in the manifold and cause a circuit breaker to inadvertently trip. Following this work procedure eliminates the issue associated with tripping from low pressure in the manifold.

Note: If a feature cutout switch FCO is not installed to cut out tripping on low gas pressure, it will be necessary to install a FCO. Refer to the SM&C Manual Circuit Breakers, Section 7, Subsection III.C., “Retrofitting Feature Switches,” and install a FCO. Contact your local area substation specialist with any questions concerning this process.

1. Notify the Control Center that has jurisdiction, and obtain permission to proceed with filling.
2. Identify the filling port the EMT Smartfill will be attached to.
 - a. If the filling port is connected to the main line/SF₆ density monitor tubing (See Figure 65), then proceed to Step 3 below.
 - b. If the filling port is connected to a valve located on the circuit breaker tank (See Figure 66), then proceed to Section B, “Smartfill System Setup.”

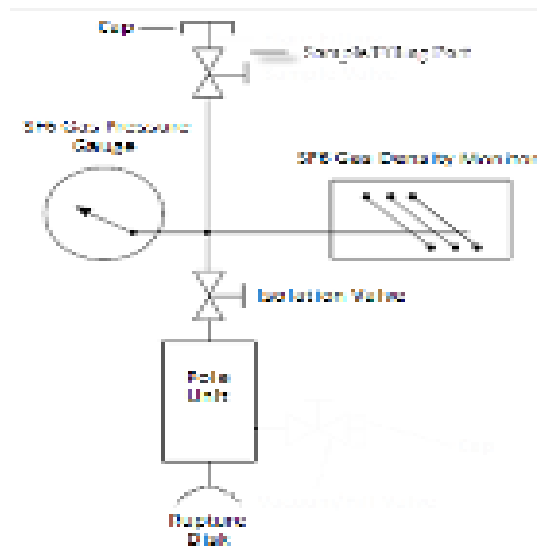


Figure 65. Filling Port on Manifold with Density Monitor

Section 8, Subsection IX.A.2.b., continued

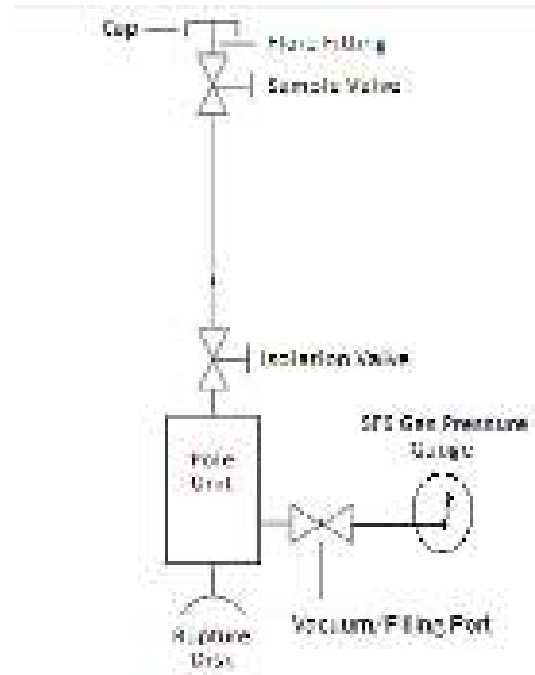


Figure 66. Fill Valve Located on Main Tank

3. In order to prevent an inadvertent trip of the circuit breaker as a result of a drop in manifold pressure during the connection process, low pressure tripping must be disabled prior to connecting the Smartfill.

Perform Steps a., b., or c. to temporarily disable low pressure tripping prior to beginning the filling process.

a. **Equipment with an FCO**

- (1) Check or Place the FCO switch on "Cut out - Blocks tripping on low SF₆ gas pressure." See Figure 67.
- (2) Place a **Caution Tag**, per [Utility Procedure TD-1403P-04, "Tags."](#)

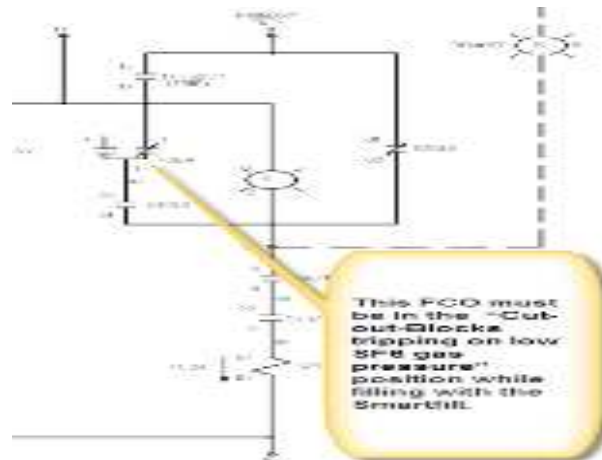


Figure 67.

Section 8, Subsection IX.A.3.b.

b. Equipment With a Trip Cut Out (TCO) Type Switch

- (1) Check or open the TCO switch. This will prevent tripping on low gas pressure.
- (2) Place a **Caution Tag**, per [Utility Procedure TD-1403P-04, "Tags."](#) See Figure 68.

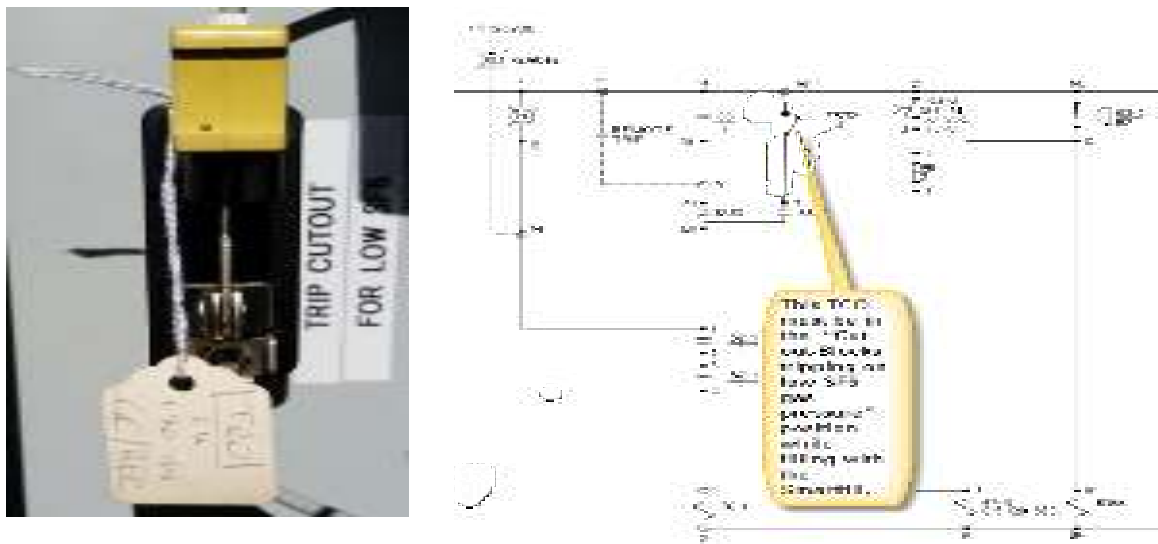


Figure 68.

c. Equipment With No Cut-Out Feature

- (1) Review the circuit breaker control print.
- (2) Verify if there is a jumper wire for "Auto-Trip" on the Low SF₆ Gas Pressure feature.
- (3) If jumper wire is present, remove and tape the jumper, isolating it from the positive terminal. See Figure 69.

Section 8, Subsection IX.A.3.c.(3), continued

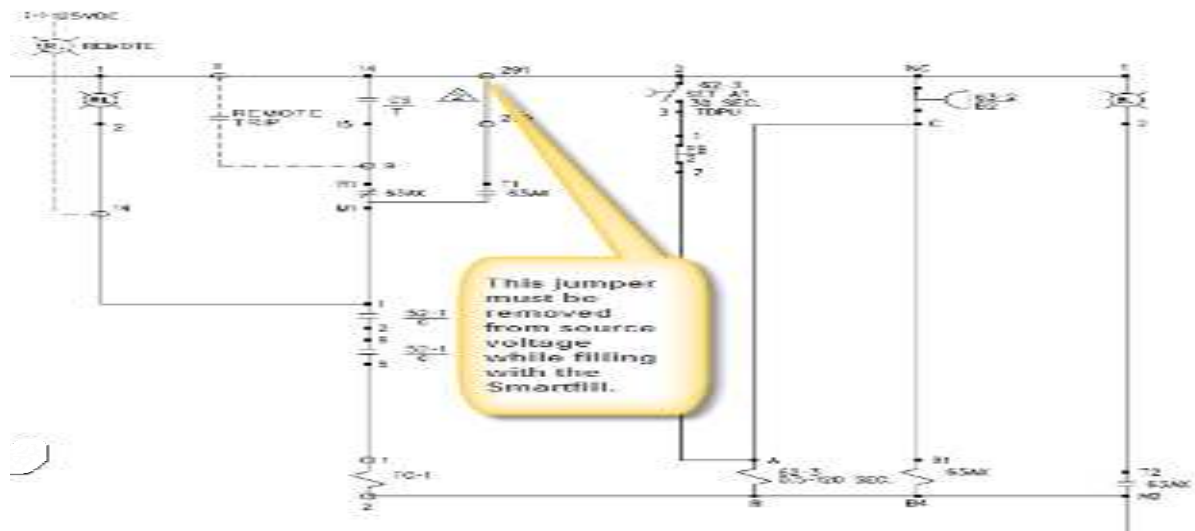


Figure 69.

B. Smartfill System Setup

1. Place the Smartfill system near the equipment being filled.
 - a. If needed, connect a power supply to the VDC power port.
 - b. Connect the traffic light to “Port A,” and place it where it is readily visible.
 - c. Turn on the Smartfill unit.
2. **Traffic Light Mode of Operation** (See Figure 70.)



Figure 70.

- Red: Alarm occurred, unit stopped
- Orange: Unit is filling
- Green: Unit is in standby

Section 8, Subsection IX.C.**C. Connecting the Smartfill Unit to the Equipment**

Note: When utilizing the Smartfill system, the filter dryer recommended in, Section 8, Subsection VIII.C.2, is not required. This is possible because the Smartfill lines are sealed, and PG&E uses “verified dry” and field tested SF₆ cylinders.

1. Place and secure the SF₆ cylinder near the equipment being filled.
2. Test the SF₆ moisture content of the cylinder being used to fill the equipment. (Ensure that the moisture level is below 8 ppm.)
3. If needed, install a cylinder heater and blanket.
4. Install the pressure regulator onto the SF₆ cylinder.
5. Using the supplied hose, connect the SF₆ cylinder regulator to the Smartfill Inlet.
6. Select the proper equipment adaptor from the SF₆ universal fitting kit.
7. Attach the supplied Swagelock fitting to the adaptor.
8. Install the adaptor onto the equipment filling valve.
9. Using the supplied hose, connect the Smartfill outlet to the adaptor.
10. Open the SF₆ cylinder valve fully.
11. Set the SF₆ regulator to 10-15 psi above the target pressure.

D. Adding Gas

Perform the following steps to add gas using the Smartfill unit.

1. Press “Start.” Figure 71



Figure 71.

2. Enter the Location, Gas zoned (CB ID#) and the name of the person operating the Smartfill unit. Figure 72.

Section 8, Subsection IX.D.2., continued

The screenshot shows a 'Data Entry' screen with the following fields and values:

Data Entry	
Location:	Merlin
GasZone:	08 4512
Operator:	TWJ1
Extra info:	10 Degrees C
Phase:	110v

At the bottom of the screen are two buttons: a red 'Back' button on the left and a green 'Next' button on the right.

Figure 72.

3. Press "Next."

The screenshot shows a 'TopUp Setup' screen with the following fields and values:

TopUp Setup	
P. Current:	52
P. Target:	87
Flow Rate:	6
Start Delay:	30

At the bottom of the screen are three buttons: a red 'Back' button, a purple 'Flush' button, and a green 'Start TopUp' button.

Figure 73.

4. Enter the "P. Target" psi value. The P Target is the desired final pressure of the equipment. Figure 73.
5. Enter "Flow Rate."
 - 6lbs/hr. for equipment with a nominal voltage rating of 115 kv or less.
 - 12lbs/hr. for equipment with a nominal voltage rating of 230 kv and higher.
6. Enter "Start Delay," and set it at 30 seconds.
7. Open the equipment fill valve.
8. Press "Start TopUp."
 - 30 seconds after pressing "Start TopUp," the traffic light will change from green to orange as the filling process begins.
9. The following five issues will cause the red alarm light and buzzer to sound:
 - Inlet Pressure Low (IPL), red blinking traffic light: Increase the inlet pressure at SF₆ regulator.
 - Battery too low: Connect AC power supply to the Smartfill unit.
 - Emergency Button Pushed: Reset the "Emergency Stop" button and continue.

Section 8, Subsection IX.D.9., continued

- Internal Network Error: Cycle the power supply and if the problem continues, contact the manufacturer.
- Pressure Transmitter Failure: Contact the manufacturer, per Figure 74.

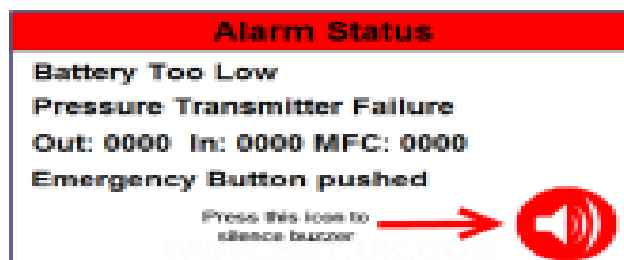


Figure 74.

10. When the target pressure is reached the traffic light will go from orange to green, and the buzzer sounds.
 - a. Close the fill valves on the equipment being filled.
 - b. Close the valve on the SF-6 cylinder.
 - c. Turn off the Smartfill unit.
 - d. Disconnect all hoses, adaptors, and fittings.

E. Returning Equipment to Service

Perform the following steps to return equipment to service.

1. Press and release the SF₆ Lockout button. Figure 75. Verify the blue indicating light is off, and use a multi-meter to verify there is no standing trip signal on the trip circuit.



Figure 75.

2. Use Steps 2a, 2b, or 2c, and return the FCO or TCO to the as found position.

Section 8, Subsection IX.E.2.a.

- a. If equipped with an FCO, remove caution tag and place the FCO in original position.
 - b. If equipped with a TCO, remove caution tag and place the TCO in original position
 - c. Replace the jumper wire with an FCO on equipment that did not have an FCO. See Section 7. Subsection III.C., “Retrofitting Feature Switches.”
 - d. Place the FCO in the cut in position.
 - e. If not equipped with a jumper wire, add a FCO at the next scheduled clearance.
3. Notify the Control Center having jurisdiction that the work is completed.



CAUTION

When not using the EMT SmartFill equipment to add gas the breaker must be cleared but grounding is not required.

F. Using Filter-Dryers When Adding SF₆ Gas to Single-Pressure, Puffer-Type Circuit Breakers.

1. Install inline filter-dryers on **all of** the SF₆ gas sample valves when adding gas to single-pressure, puffer-type SF₆ circuit breakers. These filters allow adding the gas to a circuit breaker without the danger of introducing metallic or other particulate contaminants.

Note: The manufacturer recommends changing these filters when the differential pressure across a filter reaches 4 psig (as measured across each side of the filter).

2. All filters are supplied with 0.25-inch, male, Society of Automotive Engineering (SAE)-approved flare fittings with sealing caps on the outer end to match the fittings on the fill hoses.
3. Specify the connection type and size of **each** sample valve when the filters are ordered.
4. See Subsection 8.X.B. for ordering information.
5. To prevent moisture contamination, keep the filter-dryers closed and sealed when not in use.

Section 8, Subsection X.**X. References and Ordering Information****A. References**

1. [Manufacturer's Instructions](#)
2. Smartfill Video: Use the [PG&E Video Portal](#); search for “smartfill”
3. [Utility Procedure TD-1403P-04, "Tags"](#)
4. [Utility Procedure TD-2360P-01, "50 V to 300 V, Low-Voltage Rubber Glove Work Procedure"](#)
5. [Utility Procedure TD-3350P-01, "SF₆ Tracking and Cylinder Inventory"](#)
6. [Engineering Standard No. 14, "Specification for Sulfur Hexafluoride \(SF₆\)"](#) (Company)
7. SDS for Sulfur Hexafluoride.
8. ASTM Standard D-2472. This standard describes the manufacturing requirements for SF₆ gas.
9. *California Administrative Code*, Title 8, “Industrial Safety Orders,” Article 76. This article covers compressed gas and air cylinders and contains additional information about SF₆ gas.
10. *Western Area Power Administration Maintenance Manual*, Chapter 4 (February, 1994 edition)
11. Allied Signal Technical Bulletin on Sulfur Hexafluoride

B. Ordering Information

1. Vaporization Coils
Magburg System (previously Exolon)
539 Railroad Ave.
South San Francisco, CA 94080-3450
Telephone: 1-650-792-6884
Velcon
4525 Centennial Blvd.
Colorado Springs, CO 80919-3302
Telephone: 1-719-531-5855
2. Fill Hoses, (Specify Hose Lengths), Valves, and Filter-Dryers
(Items sold individually or as a complete unit.)
Oakland Valve and Fitting Company
Contact: Peter Fraser
Telephone: 1-510-933-2500 office; 1-510-701-3158 cell
Fax: 1-510-933-2525
Email: pfraser@swaglok.com

Section 8, Subsection X,B.2., continued

Note: The filter manufacturer recommends changing these filters when the differential pressure across a filter reaches 4 psig (as measured across each side of the filter).

3. Parts for the EMT SmartFill can be obtained from ABB (Chris Roderick: 215-284-6155.) Contact your local field specialist for assistance if needed.
4. Gas Contaminant-Analysis Cylinders (for both ordering and return shipping)

TJ/H2b Analytic Services, Inc.
3123 Fife Circle
Sacramento, CA 95827

5. SF₆ Gas-Cylinder Heating Bands and Blanket

- Heating band, 500 watts, 120 V (three recommended per cylinder):
Catalog No. RT-521-SF
- Blanket: order by part name “SF₆ Cylinder Blanket”

Qcon
Gary Johnson
Concord, California
925-682-2020

Thermon
http://www.thermon.com/catalog/us_pdf_files/TEP0042.pdf
El Dorado Hills, CA
Telephone: 1-916-933-6666

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Section 9

Vacuum Circuit Breakers

I. Purpose

This section applies to inspecting, troubleshooting, servicing, and overhauling 12 to 25 kV vacuum circuit breakers. Refer also to Section 3 for general information, inspection, recordkeeping, and diagnostic procedures common to all types of circuit breakers. **Always** use the manufacturer's instructions as a reference for more detailed information, including safety precautions, when performing any maintenance.

II. General Information About Vacuum Circuit Breakers

A. Maintenance Triggers

1. For maintenance triggers, refer to Utility Standard TD-3322S, "Substation Equipment Maintenance Requirements," [Attachment 7, "Circuit Breaker Maintenance Template."](#)
2. 500 kV, tertiary, reactor circuit breakers have their own maintenance triggers due to high operating frequency. Refer to the Utility Standard TD-3322S [Attachment 7](#) maintenance template.
3. Perform an ac, high-pot test on vacuum bottles when installing or when triggered by the Utility Standard TD-3322S [Attachment 7](#) maintenance template. See the high-pot test procedures in Subsection 9.IX.B.

B. Maintenance Tasks and Service Advisories for Vacuum Circuit Breakers

1. Reference Dimensions

When installing the circuit breaker and when performing a mechanism service or an overhaul, check the reference dimensions used to indicate contact erosion of the vacuum interrupters.

- a. Compare the "breaker-closed" measurements to the manufacturer's reference dimensions.
- b. Refer to the manufacturer's instructions for erosion measurements.
- c. When the erosion limit is reached or exceeds 75%, contact the local supervisor, the local substation field specialist, and the asset manager to determine whether to replace the vacuum interrupters or the entire vacuum circuit breaker.
- d. Establish new reference dimensions when replacing vacuum bottles. See Subsection 9.IX.A. for additional information on reference dimensions and contact erosion.
 - (1) Some manufacturers do not provide an established "reference dimension" for measuring contact wear on certain types of vacuum circuit breakers (for example, GE Type PVD, ABB Type R).

Section 9, Subsection II.B.1.d.(2)

- (2) Some vacuum circuit breakers have an “erosion disk,” an “erosion indicator,” or a “wear indicator” scribe mark. These only indicate if the contact wear is still in the acceptable range.
 - (a) To track the **actual percentage** of contact wear for the purposes of an overhaul based on ACC, measure the contact wear on these circuit breakers’ vacuum bottles by the same method used to establish factory reference dimensions.
 - (b) Mark the bottles to indicate where the initial dimensions were taken. Record this information on Company Form [TD-3322M-F20, “VCB Mechanism Service”](#) (See Section 13, “Forms”).

Note: “Vacuum circuit breaker” is indicated as “VCB” on the maintenance forms listed in Section 13.

2. Interrupter-Cabinet Bolting

Note: See Subsection 2.IV.A.5.

3. Venting for Interrupter Cabinets on GE Vacuum Circuit Breakers

Some interrupter cabinets on GE vacuum circuit breakers were not provided with intentional venting. On others, the top gasket was omitted to provide venting. Add two screened vent elbows (the elbow prevents water entry) to units with unvented compartments. Locate the elbows near the top of the side walls of the circuit breaker’s high-voltage compartments.

4. Enhanced Mechanism for ABB/Westinghouse Type R Vacuum Circuit Breakers

The mechanism used in ABB/Westinghouse Type R vacuum circuit breakers has been enhanced. See Subsection 9.XI. for a description of each of these enhancements.

- a. Some enhancements are recommended, but not required.
- b. Evaluate the current status of any existing modifications in each Type R circuit breaker before planning or performing any service work.
- c. Obtain and install any parts that are recommended and will be needed during the next mechanism service or overhaul.

5. Replacement of ABB Type R-MAG Circuit-Breaker Control Connections

- a. The Phoenix-type connectors (see Figure 76., “Typical Installation of a Phoenix Connector”) used on some ABB Type R-MAG circuit breakers must be replaced because the wiring connecting the magnetic actuator to the control circuits is sometimes loose. In most cases, this problem was found during installation. PG&E has implemented a design change with the manufacturer that specifies using a four-point terminal block with ring terminals instead of the Phoenix connector. All new R-MAG circuit breakers are equipped with the terminal block.

Section 9, Subsection II.B.5.a., continued



CAUTION

To avoid the hazard of stored energy, **always** discharge the capacitors on ABB Type R-MAG vacuum circuit breakers before working on them. The electronic controller contains a 10 kilo-ohm resistor that may be used to discharge the capacitors. Refer to the manufacturer's instructions for the discharge procedure.

- b. Inspect all ABB Type R-MAG circuit breakers during installation or during the next maintenance interval to see if the magnetic actuator is equipped with the Phoenix type connector, as shown in Figure 76., "Typical Installation of a Phoenix Connector," below. Remove any Phoenix connectors and replace them with the standard, four-point terminal block, using ring-tongue compression connectors for all wiring terminations as shown in Figure 77., "Typical Installation of a Replacement Four-Point Terminal Block," below.



Figure 76.
Typical Installation of a
Phoenix Connector



Figure 77.
Typical Installation of a Replacement
Four-Point Terminal Block

Section 9, Subsection II.B.6.**6. MEPPi Circuit Breaker Model 17DV-25-12 and 17DV-25-20 Indicator Cam Replacement**

- a. Mitsubishi Electric Power Products Incorporated (MEPPI) has issued a service advisory for a potential issue with Model Type 17DV-25-12/20 circuit breakers manufactured from 2007 through 2009. These circuit breakers may fail to close “electrically” due to breakage and separation of the spring charge indicator cam. The composite material of the indicator cam was found to chemically react with the grease used in these circuit breakers. This reaction can cause micro-fractures of the indicator cam which may lead to its failure, resulting in a failure of the electrical closing circuit. The grease and indicator cam were improved, eliminating the issue for all circuit breakers produced after March 2009. The failure of the indicator cam does not prevent the circuit breaker from tripping “electrically.”

Replace the indicator cam at the next scheduled maintenance or clearance on all circuit breakers affected by this service advisory.

Refer to [Utility Bulletin TD-3322B-055](#) for direction on how to address this service advisory.

7. GE Advisory: Cracks in GE Type PVDB CTs**a. Background**

Cracks have occurred in the housings of molded-case CTs mounted inside 15.5 kV GE Type PVDBs manufactured before January 2003. The cracks occur on one corner of the CT casing, around the mounting hole to which the roof entrance bushing (REB) ground-wire termination lug is attached. GE has determined that excessive clamping pressure exerted by the termination lug on the molded case of the CT sometimes will cause the corner of the molded casing to crack.

b. Product Enhancement

GE has developed a CT mounting tube to upgrade PVDBs in the field. The tube eliminates the clamping pressure on the housing of a molded-case CT that is exerted by the termination lug. The mounting tube is installed in the CT mounting hole at the location where the REB ground-wire termination lug is attached. The tube allows for the clamping force to be applied to the termination lug itself and relieves the clamping force exerted by the mounting bolt.

Section 9, Subsection II.B.7.c.**c. Recommended Actions**

To prevent cracks from occurring in the housings of molded-case CTs mounted inside 15.5 kV GE Type PVDBs manufactured before January 2003, GE recommends installation of the mounting tube described above to eliminate the pressure exerted on the CT housing by the REB ground-wire termination lug.

d. Required Parts for the Installed CT Configuration

Maintain two set of the tubes shown in Table 15. "Mounting Tube Ordering Information," below, (ordered from GE) to ensure that the correct size will be available when needed.

Table 15. Mounting Tube Ordering Information

CT Configuration	CT Thickness	Tube Part No.	Description
1 Standard Accuracy	2.38 inches	0329A5018P001	Tube, 2.46 inches
1 High Accuracy	4.12 inches	0329A5018P002	Tube, 4.20 inches
2 Standard Accuracy	4.75 inches	0329A5018P003	Tube, 4.83 inches
1 Standard and 1 High Accuracy	6.50 inches	0329A5018P004	Tube, 6.58 inches
1 Dual Coil	6.60 inches	0329A5018P005	Tube, 6.68 inches

e. Required Tools

The following tools are required to install the mounting tube.

- 9/16-inch wrench
- 35/64-inch reamer or drill
- Small vice grips

f. Installation

Install the mounting tube, as follows.

- (1) Lock out the remote operation of the circuit breaker by pulling the red emergency knob on the low-voltage compartment door. Pull the trip- and close-control circuit fuses, and then push the manual close button. This will cause the circuit breaker to complete a trip-free cycle with the mechanism on the open condition, discharging the open and close springs and placing the mechanism in a safe condition.

Section 9, Subsection II.B.7.f.(2)

- (2) Remove the high-voltage compartment covers by removing the four $\frac{3}{8}$ x 16-inch bolts that hold each cover in place. See Figure 78., “High-Voltage Compartment Cover – Mounting Bolts.”



Figure 78.
High-Voltage Compartment Cover – Mounting Bolts

- (3) Identify the location of the ground lug between the CT and the mounting pad. See the following Figure 79., “Location of the Ground Lug.”

Note: A wire will extend inward from the lug to the REB.



Figure 79.
Location of the Ground Lug

- (4) Using a 9/16-inch wrench, remove the CT mounting bolt from the hole securing the ground lug. See Figure 80., “CT Mounting Bolt,” below.

Section 9, Subsection II.B.7.f.(4)



Figure 80.
CT Mounting Bolt

- (5) Check the size of the CT mounting bolt by inserting the mounting tube. See Figure 81., “Checking the Mounting Hole,” below.



Figure 81.
Checking the Mounting Hole

- (6) If there is any interference between the tube and the hole, ream the hole, using a 35/64-inch reamer or drill and vice grips. To ream all the way through the hole may require loosening the other three bolts to lower the CT approximately $\frac{1}{4}$ inch. Thoroughly clean all debris from the reaming operation. See Figure 82., “Reaming the Mounting Hole.”



CAUTION

Ensure that the bolts are engaged sufficiently (approximately three turns) to prevent the CT from falling while reaming the hole.

Section 9, Subsection II.B.7.f.(6), continued

Figure 82.
Reaming the Mounting Hole

- (7) Retighten the three bolts, if they were loosened in Step (6) above, and torque them to 8 to 10 foot-pounds (ft-lbs).
- (8) Place the tube over the CT mounting bolt, reinstall the bolt, and torque the bolt to 8 to 10 ft-lbs. See Figure 83., “Newly Installed Tube and Bolt.”



Figure 83. Newly Installed Tube and Bolt

- (9) Reinstall the high-voltage compartment covers, using four 3/8 x 16-inch bolts for each cover.
- (10) Unlatch the trip button. Reinstall the trip- and close-circuit fuses.
- (11) Note in the “Comments” section on the appropriate circuit-breaker maintenance form (see Section 13, “Forms,” that this work has been performed.

Section 9, Subsection II.B.7.g.

g. GE-Type PVDB Transfer Band Wear



CAUTION

Do not follow the procedure for checking transfer band wear found in the “Maintenance” section of the GE instruction manual.

Further evaluation is necessary before a reliable procedure is available and provided in a Company bulletin. The GE instruction manual’s described method is not clear and will result in an incorrect evaluation of the wear on the surface of the moving interrupter contact rod that slides through the current transfer bearing.

III. Safety Precautions

A. Using and Labeling Manually Operated, Mechanical Opening Devices

See Subsection 1.II. for safety instructions and precautions, including proper labeling, that apply to these devices for **all** circuit breakers.

B. Clearance

Perform the following steps before performing out-of-service work on vacuum circuit breakers.

1. Obtain a proper clearance for the circuit breaker.
2. Make the circuit breaker safe for maintenance by removing all control power (unless required for troubleshooting) and discharging any stored energy within the mechanism.
3. Record the “before” counter reading.

IV. Flowcharts for Periodically Maintaining Vacuum Circuit Breakers

A. For Non-CAISO-Controlled Vacuum Circuit Breakers

See Figure 78., “Flowchart for Non-CAISO-Controlled Vacuum Circuit Breakers,” for the steps to consider when testing these circuit breakers.

Section 9, Subsection IV.A., continued

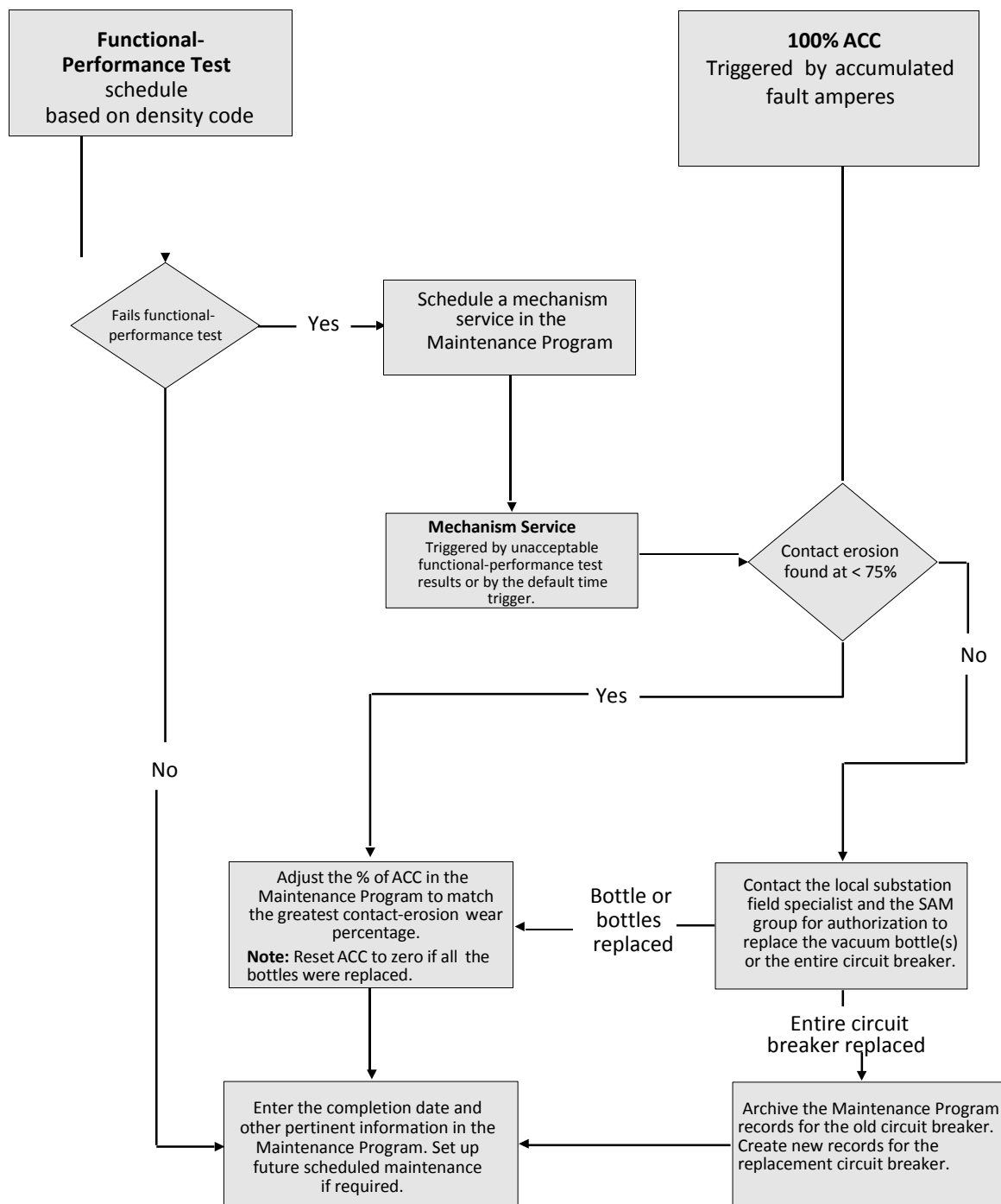


Figure 84.
Flowchart for Non-CAISO-Controlled Vacuum Circuit Breakers

Section 9, Subsection IV.B.

B. For CAISO-Controlled Vacuum Circuit Breakers

See Figure 85., “Flowchart for CAISO-Controlled Vacuum Circuit Breakers,” below, for the steps to consider when testing these circuit breakers.

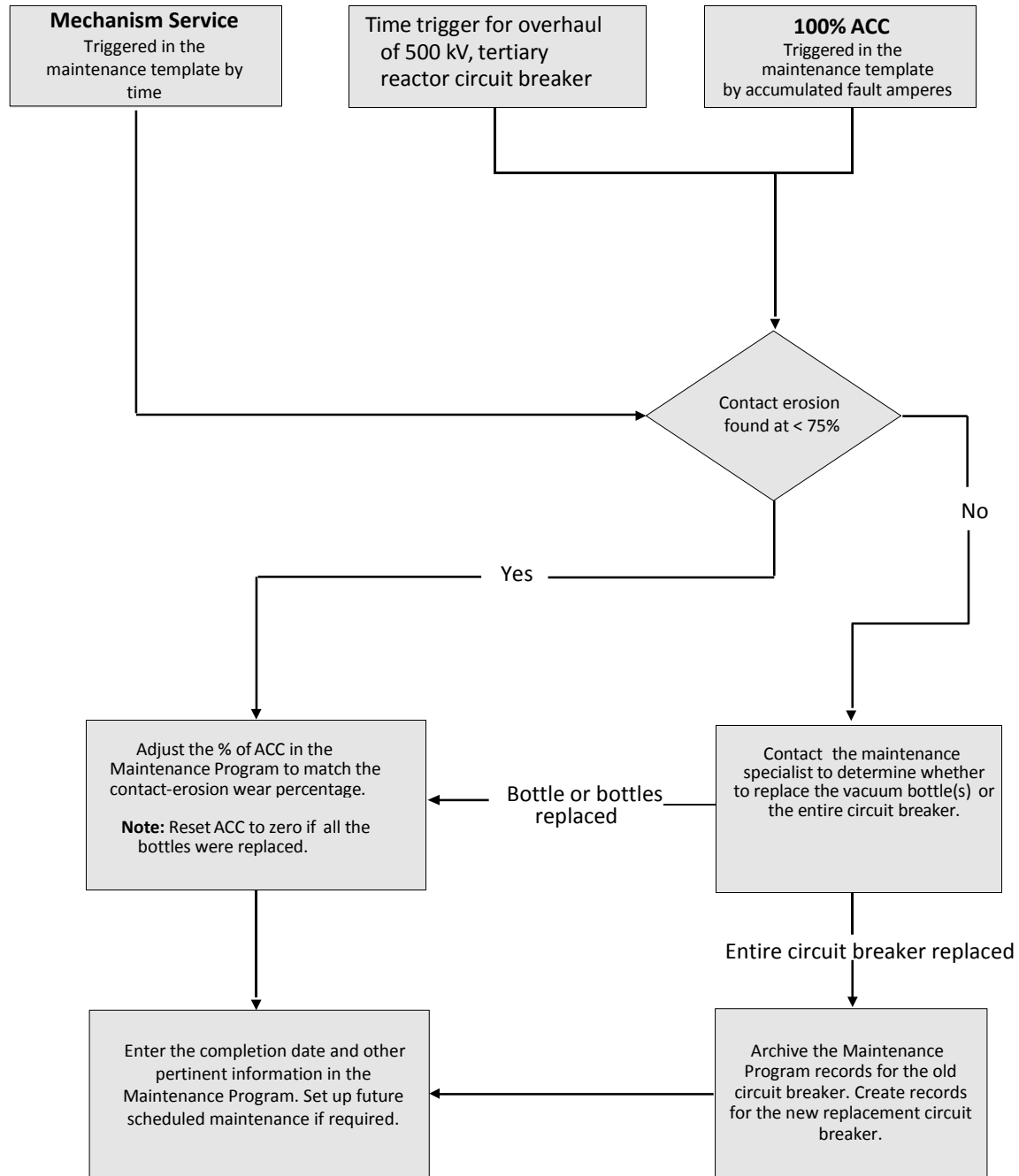


Figure 85.
Flowchart for CAISO-Controlled Vacuum Circuit Breakers

Section 9, Subsection V.

V. Inspecting Vacuum Circuit Breakers

A. Inspection Procedure

See the *SMCM*, [“Substation Inspections,”](#) for the periodic inspection procedures for circuit breakers.

B. Minimum Safe Working Distance

Observe the minimum safe working distance whenever inspecting energized or ungrounded high-voltage parts.

C. Compartments

1. While performing station inspections and circuit-breaker maintenance work, **always** ensure that all the compartment heaters are working and that compartment doors and openings are sealed properly against rain, dust, and insect contaminants.
2. Clean or replace the ventilation filters and door seals. Install new filters or seals, if necessary.
3. Maintaining a clean and dry mechanism increases the reliability of the circuit breaker. It makes lubrication more effective and reduces future cleaning and maintenance time.

VI. Planning the Job Before Performing Maintenance Work on Vacuum Circuit Breakers

The success of maintenance work depends on good job planning. Consider the following items when planning maintenance work.

A. Using Manufacturer’s Instructions

Always use the manufacturer’s instructions as a reference when performing any maintenance.

1. Most manufacturers’ instructions contain important safety information. Not all of this information is listed in the *SMCM*.
2. Employees are responsible for understanding the maintenance and safety requirements for each piece of equipment **before** beginning work.
3. Occasionally, it may be necessary to deviate from some of the manufacturer’s requirements in order to safely perform Company maintenance and troubleshooting procedures.

B. Checking Records, Service Advisories, and Information Bulletins

Before requesting a clearance, check the circuit breaker’s previous maintenance records and the monthly station-inspection information.

1. Review the circuit breaker’s operating history and note any pending repair work. This information is necessary for good job planning.

Section 9, Subsection VI.B.2.

2. Keep **all** station inspection information, maintenance records, and service advisories accurate, thorough, neat, and readily available.
3. Check Subsection 9.II.B. to prepare for any additional service work required by manufacturers' service advisories.
4. Check if there are any applicable information bulletins that have not been incorporated into this manual.

C. Relay Service

Check the last relay-test dates to see if the relays are due for service. Check the [PESTP](#) Manual for the relay-test intervals.

D. Performing a Mechanism Service on Vacuum Circuit Breakers

Perform a mechanism service for the following classes of vacuum circuit breakers.

1. All CAISO-Controlled Vacuum Circuit Breakers

Perform a mechanism service, as triggered by the Utility Standard TD-3322S [Attachment 7](#) maintenance template.

2. All Non-CAISO-Controlled Vacuum Circuit Breakers

Perform a mechanism service whenever:

- a. A circuit breaker fails to pass a functional-performance test.
- b. An online operational-timing monitor alarm is received.
- c. A thorough visual condition assessment indicates that this service is necessary.
- d. A circuit breaker does not operate correctly.
- e. The time-based default trigger is reached.

E. Overhauling Vacuum Circuit Breakers

Overhaul a vacuum circuit breaker when triggered by the Utility Standard TD-3322S [Attachment 7](#) maintenance template.

1. Perform an overhaul when the breaker reaches 100% ACC. The ACC number is determined by a combination of both fault operations and the highest, actual contact-erosion measurement found during contact-erosion diagnostic testing.
2. When a vacuum circuit breaker's vacuum bottles reach 75% actual contact erosion, contact the local supervisor, the local substation field specialist, and the asset manager to determine whether to replace the vacuum bottles or the entire circuit breaker.

Section 9, Subsection VI.F.**F. Performing a Mechanism Service at the Time of an Overhaul**

Perform a mechanism service on a vacuum circuit breaker as part of the overhaul.

G. Tools and Materials

Ensure that all the regular truck stock, safety equipment, PPE, and the following special tools and materials are always available. Take all applicable items to the jobsite where the maintenance work will be performed.

1. Tools and Materials for Mechanism Service on a Vacuum Circuit Breaker

A mechanism service on a vacuum circuit breaker requires the following tools and materials:

- a. A [“Distribution Circuit Breaker Functional Performance Test Form”](#) (see Section 13, “Forms,”) and test set (or other timing gear if this is unavailable).
- b. Test equipment for measuring the open and close operating times of the main contacts.
- c. A [“VCB Mechanism Service”](#) form (see Section 13, “Forms”).
- d. Company [Form TD-3322M-F25, “Distribution Class Circuit-Breaker Timing Test Report,”](#) if a timing test is required.
- e. The complete set of the lubricants listed in Section 10.
- f. Ventilation-filter materials for the mechanism cabinets.
- g. Door-gasket and sealing materials, and adhesives.
- h. Dashpot oil.
- i. Cleaning materials: hoses, pressure regulators, bottled gas (nitrogen or air), low-pressure air guns with siphons or pressurized solvent cans, parts-cleaning brushes, cleaning solvents, and rags.
- j. Relay-test gear (if relay tests are due).
- k. Micrometers, calipers, and feeler gauges.
- l. ABB/Westinghouse Type R mechanism-upgrade or parts kits, if applicable. See Subsection 9.XI.
- m. Screened venting elbows, if applicable, for upgrading some GE vacuum circuit breakers. See Subsection 9.II.B.3.
- n. A high-pot tester and leads.
- o. A contact resistance tester and leads (in case a condition requires its use).
- p. Torque wrenches.

Section 9, Subsection VI.G.1.q.

- q. A 500 V megger, in case a condition requires its use.
- r. CT mounting tubes for GE Type PVDB vacuum circuit breakers, if not already installed. See the GE service advisory in Subsection 9.II.B.7.

2. Tools and Materials for Overhauling a Vacuum Circuit Breaker

The same tools and materials are required for overhauling a vacuum circuit breaker as are needed to perform a mechanism service. No additional items are required.

VII. Performing a Mechanism Service on Vacuum Circuit Breakers

A mechanism service on a vacuum circuit breaker includes the following items and requirements. Thoroughly inspect the entire circuit breaker and mechanism for any loose, missing, worn, cracked, or damaged components. Correct any unsatisfactory conditions.

Note: See Subsection 9.X. for instructions specific to ABB Type R-MAG vacuum circuit breakers.

A. Clearance

Clear the circuit breaker, and make it safe for maintenance.

B. Fasteners

Check the physical condition of all the springs, cotter pins, keepers, bolts, and other fasteners.

C. Electrical Wire Terminations

Ensure that all the electrical wire terminations are tight and not corroded.

D. Switches, Relays, and Motor Assembly

Ensure that the latch-check switch and all the auxiliary switches, microswitches, X-Y anti-pump relays, and seal stacks have good electrical connections.

1. Check any accessible contacts for excessive burning or pitting.
2. Check the mechanical condition of the switches and relays, including their operating arms and linkages.
3. Check the mechanical condition of the motor assembly.

Section 9, Subsection VII.E.**E. Shock Absorbers and Dashpots**

Ensure that the mechanism shock absorbers and/or dashpots are operating properly. Use the manufacturer's instructions as a reference.

1. Inspect the dashpots for leaks and for the proper oil levels.
2. Clean, repair, and add or replace oil, as necessary.

F. Interrupter Bottles

1. Carefully inspect the interrupter bottles. Look for any cracks, including in the area of the metal-to-insulation seals at both ends of the bottles and at the mid-band ring.
2. Check the mechanical condition of the arms and linkages that operate the bottle contacts.

G. Checks Requiring Manual Closing

Slow-close the circuit breaker with the manual closing device, according to the manufacturer's instructions.

1. Check for dragging and binding of the shafts, shock absorbers, and linkage parts.
2. Refer to the manufacturer's instructions if repairs or adjustments are required.

H. Testing the Alarms, Relays, and Reclosers

Take the following steps to test the alarms, relays, and reclosers.

1. Notify the distribution operator before testing the alarms, relays, and reclosers.
2. Run the recloser to lockout by activating the protective relays.
3. Verify that the alarms, relays, and recloser are working properly.
 - a. On circuit breakers with electromechanical relays, test three-phase simultaneous targeting.
 - b. Verify the trip-free operation of the circuit breaker.
4. Reset the recloser by electrically closing the circuit breaker.
5. Record the reclosing and lockout times, and update the recloser-relay card.
6. Watch for any circuit-breaker malfunctions that require more extensive troubleshooting for permanent correction.

Section 9, Subsection VII.H.6., continued

Note: Perform and document the necessary troubleshooting tests if there are any circuit-breaker malfunctions. Check and make any required mechanical adjustments listed in the manufacturer's instructions and on the [“VCB Mechanism Service”](#) form (see Section 13, “Forms”). To ensure service reliability and safety, immediately correct **any** condition that may cause malfunctions.

I. Indicators

Verify that the circuit-breaker operations counter(s), all red and green lights, and the mechanical position semaphore(s) are working properly.

J. Lockout Devices

1. Trip the circuit breaker with the mechanical-maintenance trip device.
2. Verify that the 69 lockout device prevents further electrical operation.
3. Manually reset the lockout device.

K. Cleaning and Lubricating

1. Thoroughly clean and lubricate the entire mechanism according to the procedures in Section 10.
2. Thoroughly clean the entire high-voltage compartment.

L. Compartments

Ensure that the door seals and compartment filters are in good condition and are keeping the mechanism sufficiently clean and dry. Add, repair, or replace seals, if necessary. Ensure that the compartment heaters are working.

M. Vacuum-Bottle Erosion Measurements

1. Check and record the vacuum-bottle erosion measurements.
2. Determine and record the percentage wear of each phase.

N. High-Pot Testing

Perform a high-pot test on all the vacuum bottles. See Subsection 9.IX.B.

O. Minimum-to-Trip and Minimum-to-Close Tests

Perform a “minimum-to-trip” and a “minimum-to-close” test on all dc-operated circuit breakers with a trip or close latch:

- Whenever a mechanism service is performed.
- That have questionable operating performance.

Section 9, Subsection VII.O.1.

1. Refer to Section 3.IV.D. for general information and testing methods.
2. Refer to Subsection X.F., “Minimum to Trip and Close,” for circuit breakers that have an electronic circuit board and no trip or close coils (e.g., the ABB-type RMAG).
3. Video guidance for this procedure can be found on the [PG&E Video Portal](#); search using the term “minimum to trip.”

P. Anti-Pump Feature

Test the anti-pump feature of the control circuit.

1. Close the circuit breaker electrically with a control switch, and hold the control switch in the close position.
2. Apply a trip signal.
3. The circuit breaker should trip only once while the control switch is continuously held in the close position. It should not try to close and open repeatedly.
4. Video guidance for this procedure can be found on the [KnowledgeKeeper](#) website, using the search term “anti” or on the [PG&E Video Portal](#), using the search term “Anti-Pump.”

Q. “As-Left” Functional-Performance Test

Perform a functional-performance test to provide a return-to-service benchmark for trending purposes. Record the results on a [“Distribution Circuit Breaker Functional Performance Test Form”](#) (see Section 13, “Forms”).

R. Main-Contact Operating Times

Test the opening and closing times of the circuit breaker’s main contacts to verify that the circuit breaker is performing within the specifications given in the manufacturer’s instructions. See Subsection 3.O. for additional information.

S. Checks Following Service

1. Following service work, check normal all the systems, annunciators and alarms, local and remote control switches, feature and cutout switches, relays, and wires that were altered during maintenance work.
2. Ensure that all the tools and materials have been removed.

T. Determining Safety and Reliability

1. Determine if the circuit breaker is safe and reliable after reviewing the inspection data, condition assessments, and the operational and diagnostic test results.

Section 9, Subsection VII.T.2.

2. If the circuit breaker is not safe or reliable, record the specific abnormal conditions and any repairs that are required.

U. Operational Checks

Operate the circuit breaker from all the available locations, including from the SCADA system, if applicable.

VIII. Overhauling Vacuum Circuit Breakers

Overhauling a vacuum circuit breaker includes performing a complete mechanism service and the following, additional task.



CAUTION

Slow-close the circuit breaker by hand before electrically operating it, if any mechanical adjustment or component disassembly was performed.

A. Clearance

Clear the circuit breaker, and make it safe for maintenance.

B. Vacuum Bottles

Carefully inspect the vacuum bottles. Look for any cracks or abnormalities, including in the area of the metal-to-insulation seals at both ends of the bottles and at the mid-band ring.

C. Contact Erosion

Measure the contact erosion to determine if the bottles or the circuit breaker need to be replaced. Refer to the manufacturer's instructions for specific information on contact erosion.

D. Contact-Resistance Tests

Perform contact-resistance tests on all three phases. Perform an "after" test if any adjustments were made. Refer to Section 3.

E. Mechanical Adjustments

Perform the mechanical adjustments and checks listed on Company [Form TD-3322M-F21, "VCB Overhaul."](#) (See Section 13, "Forms.") Refer to the manufacturer's instructions.

Section 9, Subsection VIII.F.**F. Determining Safety and Reliability**

1. Determine if the circuit breaker is safe and reliable for service after reviewing the inspection data, condition assessments, and the operational and diagnostic test results.
2. If the circuit breaker is not safe or reliable, record the specific abnormal conditions and any repairs that are required.

IX. Performing Diagnostic Tests for Vacuum Circuit Breakers

Perform diagnostic tests when triggered by the Utility Standard TD-3322S, [Attachment 7](#) maintenance template or when a circuit breaker has a condition or trouble. Two diagnostic tests for vacuum circuit breakers are listed in this subsection. Refer to Section 3 for additional diagnostic tests common to all types of circuit breakers.

A. Contact-Erosion Indicators**1. Checking Reference Dimensions**

Check the dimensions used to indicate contact erosion of the vacuum interrupters when installing, performing a mechanism service, or overhauling a vacuum circuit breaker. Compare them to the manufacturer's dimensions.

- a. Refer to the manufacturer's instructions for checking contact erosion and limits.
- b. When the erosion limit is reached or exceeds 75%, contact the local supervisor, the local substation field specialist, and the asset manager to determine whether to replace the vacuum interrupters or the entire circuit breaker. If the contact wear is between 75% and 95%, the circuit breaker may be returned to service **temporarily** while the asset manager is determining the work needed.
- c. If a vacuum bottle must be disconnected and then reinstalled, note and record the reference dimension and the wear percentage before disconnecting the bottle. This ensures accurate future measurements.

2. Establishing New Reference Dimensions

Establish and record new reference dimensions on new circuit breakers or vacuum bottles where the reference dimensions cannot be verified.

- a. These measurements **must** be exact and precise. Use a micrometer depth gauge, or a dial caliper as a depth gauge, to measure and establish the dimensions.
- b. Record the dimensions. Also record how the measurements were made and which points on the interrupters and linkages were used to make the measurements. Add this information to the circuit breaker's maintenance record.

Section 9, Subsection IX.A.2.c.

- c. Permanently mark and date the reference dimensions on a non-insulating part of each interrupter. Permanently mark the points on the interrupters that were used to measure the dimensions.
- d. Some manufacturers do not provide an established “reference dimension” for measuring contact wear on certain types of vacuum circuit breakers (for example, GE Type PVD, ABB Type R).
 - (1) Some vacuum circuit breakers have an “erosion disk,” an “erosion indicator,” or a “wear indicator” scribe mark. These only indicate if the contact wear is still in the acceptable range.
 - (2) To track the **actual percentage** of contact wear for the purposes of an overhaul based on ACC, measure the contact wear on these circuit breakers’ vacuum bottles by the same method used to establish factory reference dimensions.
 - (3) Mark the bottles to indicate where the initial dimensions were taken. Record this information on the [“VCB Mechanism Service”](#) form (see Section 13, “Forms.”)

B. Vacuum-Bottle High-Pot Testing

1. Safety Precautions

The high-pot testing procedure for vacuum interrupters requires extra precautions.

a. Removing a Charge on the Main Shield

The main shield inside an interrupter, as well as other high-voltage parts, can acquire an electrical charge during normal operation and while performing high-pot testing. The shield is attached to the external mid-band ring of the insulating bottle.

- (1) The charge usually remains after the high voltage is removed.
- (2) Before touching **any** high-voltage parts, remove this charge by grounding the bushings **and** grounding the mid-band ring with a clip jumper.
- (3) Wear high-voltage rubber gloves and safety glasses while grounding the mid-band ring.

b. X-Ray Radiation Hazard

- (1) High voltage applied across an open gap in a vacuum can produce x-ray radiation.
- (2) The interrupter bottle’s internal shield and the circuit breaker’s metal panels provide some protection against x-ray radiation. Ensure that these metal panels are in place, or if there are any directly exposed interrupters under test, maintain a safe working distance of at least 3 meters (9 feet, 10 inches) from them.

Section 9, Subsection IX.B.2.**2. Procedure for High-Pot Testing**

Note: Recommended high-pot test voltages vary between manufacturers, and may vary between indoor and outdoor types of circuit breakers. Always use the test voltages recommended in the manufacturer's instructions.

Perform the following steps to high-pot test vacuum bottles.

- a. Clean the vacuum bottles, support insulators, and bushings. Use cleaning materials approved for the type of insulation.
- b. Ensure that the access panels are in place on the high-voltage compartment to ensure the maximum shielding from x-ray radiation, or maintain a safe working distance (3 meters) if any interrupters are not shielded.
- c. Ensure that the circuit breaker's main contacts are in the open position.
- d. Attach the test leads to the top of the circuit breaker's bushing terminals.
- e. Remove the grounds from the bus and line sides of the phase under test.
- f. Slowly apply the test voltage by increasing at a rate of 3 kV per second until reaching the test level recommended in the manufacturer's instructions.
 - (1) Hold this voltage for 60 seconds; then slowly decrease to 0.
 - (2) Leakage current on the disconnect insulators may cause the tester to trip before reaching the proper test voltage. If the tester trips, reapply the grounds, remove the conductors from the bus and line-side bushings, and clean all the insulating surfaces again.
 - (3) Repeat the test.
 - (4) Properly torque any loosened bolted connections.
- g. If a vacuum bottle does not withstand the high-pot test, verify that the open-gap setting of the bottle's main contact is correct, and then retest.

X. Maintenance Requirements for ABB Type R-MAG and AMVAC Vacuum Circuit Breakers

ABB Type R-MAG and AMVAC vacuum circuit breakers are equipped with a magnetic actuator mechanism instead of the conventional, mechanical, stored-energy mechanism found on most vacuum circuit breakers. The magnetic actuator mechanism, which has very few moving parts, incorporates a powerful, permanent magnet assembly. It is powered by energy stored in capacitors, which are kept charged by a constant supply of dc station power. The actuator has an electronic controller for monitoring and operating the circuit breaker.

Section 9, Subsection X., continued

Note: The information in this subsection is specific to ABB Type R-MAG vacuum circuit breakers. Because the design is different, the safety precautions and maintenance procedures are also different, though maintenance procedures for other vacuum circuit breakers apply unless specifically addressed below. Before working on these circuit breakers, employees must be thoroughly familiar with the content of the manufacturer's instructions, including the general description, safety precautions, and instructions for installing, operating, maintaining, adjusting, and troubleshooting the equipment.

A. Controls

1. Electronic Control Board Settings

The ED2.0 electronic control board is shown in Figure 86, "ED2.0 Circuit Board," below.



Figure 86.
ED2.0 Circuit Board

a. PG&E Standard Jumper and Dip Switch Settings

The following standard settings apply to all R-MAG circuit breakers in PG&E substations. During breaker commissioning or breaker functional testing, the responsible TSM&C employee must verify that the minimum voltage threshold and under-voltage trip are correctly set, as follows.

(1) Dip Switch Setting

The under voltage trip function is not used. All the R-MAG breakers should come from the factory with dip switches set to disable all the special functions:

Section 9, Subsection X.A.1.a.(1), continued

- I1002 UV Aux Open / Safe Open: Not used, leave in OFF OFF OFF positions.
- I1004 Energy failure auto trip and UV delay time: Not used, leave in OFF OFF OFF OFF positions.
- I1001 UV Threshold: Not used, can be left in any position, recommend to leave in the default setting from the factory.

Dip switches are read on power up; therefore, to make dip switch changes, the board must be powered down completely and the energy storage capacitors de-energized.

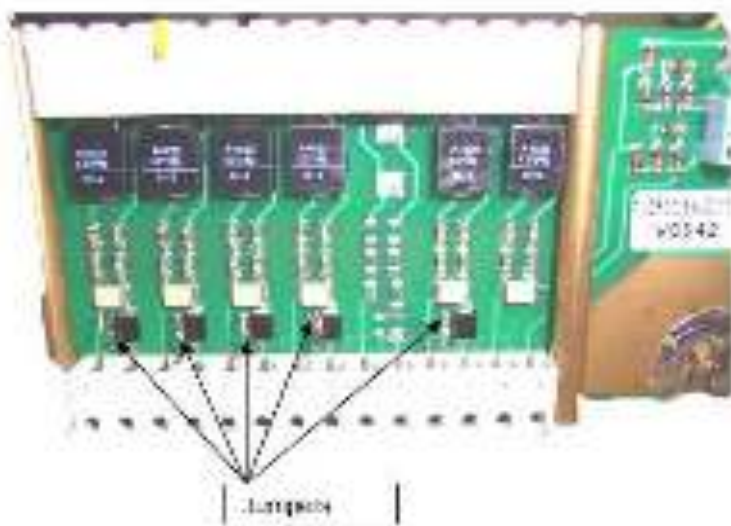


Figure 87.
Filter Card with 5 Wire Jumpers on Each Binary Input

b. Jumper Setting

The ED2.0 board has a removable filter card with 5 jumpers as shown in Figure 87. The minimum input voltage threshold on the ED2.0 board depends on the status of the 5 jumpers on the filter card.

- For R-MAG circuit breakers with 48 Vdc control power, leave the 5 jumpers on the filter card intact. This establishes a minimum input-voltage threshold of 18 Vdc.
- For R-MAG circuit breakers with 125 Vdc control power, remove the 5 jumpers on the filter card to increase the minimum input voltage threshold to 38 Vdc.

Section 9, Subsection X.A.1.b.(1)

(1) Action Plan

(a) R-MAG Circuit Breakers Ordered After March 01, 2009

The R-MAG circuit breakers ordered after March 01, 2009, should come from the factory with the dip switch and jumper settings per PG&E's requirements.

During breaker commissioning or maintenance testing, the responsible TSM&C employee should verify the correct jumper and dip switch settings and perform the testing to confirm the minimum input voltage threshold level before placing the breaker in service.

(b) R-Mag Circuit Breakers Purchased Before March 1, 2009

The R-Mag circuit breakers (approximately 125 units) ordered before February 28, 2009 were delivered from the factory with all dip switches disabled and the 5 jumpers on the filter card left installed in the default setting for 48 Vdc control power. The 5 jumpers on the filter card were left installed on a number of R-Mag breakers connected to 125 Vdc control power.

- During the upcoming maintenance interval, the breaker needs to be inspected to determine if the 5 jumpers on the filter card and the dips switches are set according to PG&E standards.
- For R-Mag circuit breakers connected to 125 Vdc control power, remove or verify that the 5 jumpers have been removed. Perform a functional performance test to ensure the minimum input voltage threshold is about 38 Vdc. Once the circuit breaker is proved, it can be returned to service.

- (2) Complete the text field on the breaker maintenance record when the work is done. This indicates the jumper and dip switch settings have been verified and operationally checked, as required.

2. "Ready" Light

The electronic controller is equipped with a "ready" light. The light stays on, flashes, or goes out, depending on the capacitor voltage, the coil continuity, and the state of the position sensors. The light stays on during normal conditions. A blinking light indicates a problem that needs to be investigated. Check the "ready" light during the monthly substation inspection and each time the circuit breaker is operated, the same way as a red light is monitored on a conventional circuit breaker.

Section 9, Subsection X.A.3.**3. Replacing ABB-Type, R-MAG, Circuit-Breaker Control Connections**

See Subsection 9.II.B.5. requiring the replacement of Phoenix-type control connections on R-MAG circuit breakers.

B. Lubrication and Maintenance Triggers

Disassembling and lubricating the magnetic actuator is not required or recommended. For the periodic lubrication of linkage pins and other wear points, follow the manufacturer's instructions and the triggers listed in the Utility Standard TD-3322S [Attachment 7](#) maintenance template.

C. Capacitor Tests**CAUTION**

To avoid the hazard of stored energy, **always** discharge the capacitors on ABB Type R-MAG vacuum circuit breakers before working on them. The electronic controller contains a 10 kilo-ohm resistor that may be used to discharge the capacitors. Refer to the manufacturer's instructions for the discharge procedure.

1. Open-Close-Open Test

Note: Clear the circuit breaker before performing this test.

Perform an open-close-open test to determine if the capacitors are working properly. Starting from the closed position, rapidly open, close, and reopen the circuit breaker. If the circuit breaker is able to complete these three operations without any delay to recharge the capacitors, the test is successful and no further capacitor testing is needed. If there is a delay, this indicates that one or more of the capacitors may be faulty and require further evaluation.

2. Verifying the Capacitor Performance**a. Description of the Capacitors**

- (1) ABB Type R-MAG vacuum circuit breakers use either two or three 100,000 micro-fared (μf), 100 V capacitors. Typically, there are two capacitors on the 15 kV and three on the 27 kV circuit breakers.
- (2) The electronic controller uses the supply voltage to charge the capacitors to 80 Vdc and monitors the capacitor voltage every 4 months.
 - (a) If the voltage drops below approximately 78 Vdc, the "ready" light will start blinking because, at this point, there is no longer enough energy to perform an open-close-open operation.

Section 9, Subsection X.C.2.a.(2)(b)

- (b) A common failure mode occurs when one of the capacitors has an open circuit. The other capacitor(s) may remain charged to 80 V, but the charge and discharge curves will be substantially different from the normal curves (see Figure 89.) and there will be insufficient energy to perform a rapid open-close-open operation.
- (c) Use the procedure in Subsection 9.X.C.2.b., below, to verify the performance of the capacitors.

b. Procedure to Verify Performance



WARNING

Removing the capacitor covers exposes live voltage and could lead to electrical shock.

Verify capacitor performance, as follows:

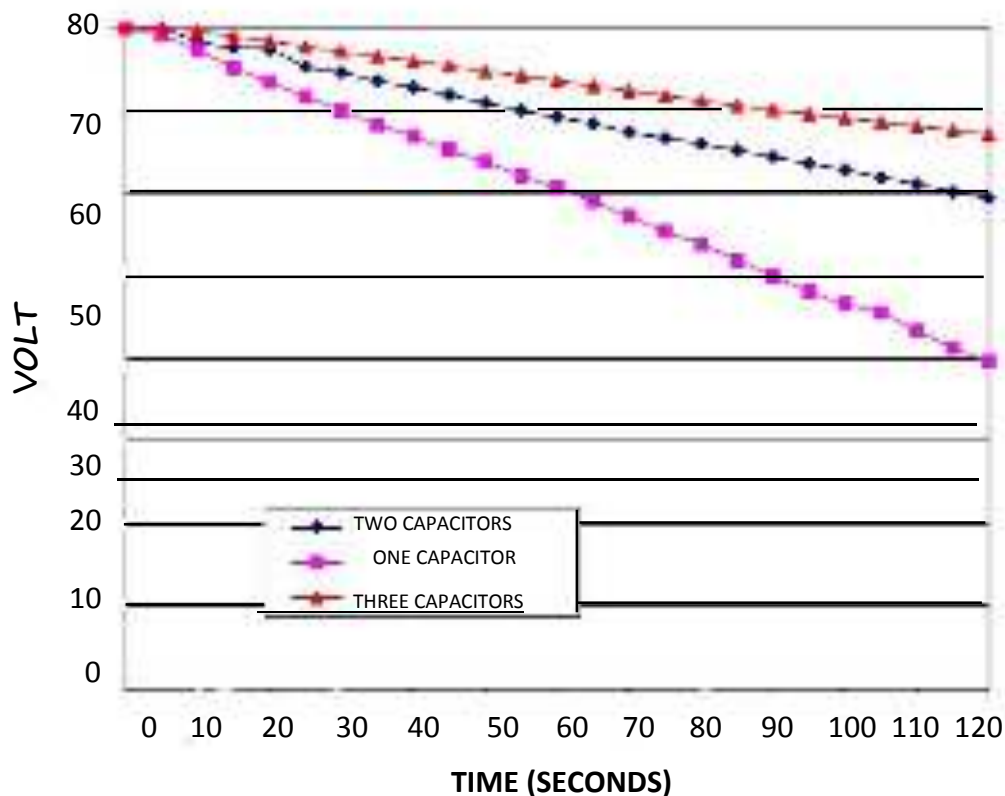
- (1) Remove the two #4 screws that attach the push-button plate. Let the plate hang down.
- (2) Remove the four 0.250 X 20 screws from the corners of the electronic controller's cover. Remove the cover.
- (3) Using insulated probes, carefully connect a digital dc voltmeter to the KM1002 Terminals 1 and 3 on the electronic control circuit board, which is illustrated in Figure 88., "Electronic Control Circuit Board," below.



Figure 88.
Electronic Control Circuit Board

Section 9, Subsection X.C.2.b.(4)

- (4) Disconnect the power to the electronic controller. Observe the immediate decay of the capacitor voltage.
- (5) Monitor the dc voltage readings every 10 seconds for 2 minutes. Compare them with those in the chart in Figure 89., "Capacitor Discharge Curve," below.

CAPACITOR DISCHARGE CURVE**Figure 89. Capacitor Discharge Curve**

- (6) Verify that the dc voltage readings for the capacitors match the appropriate curve for the number of capacitors, as shown in Figure 89. above.
- (7) If the readings do not match the appropriate curve, discharge the capacitors and test them individually until the faulty capacitor is determined. (See the manufacturer's instructions for the discharge procedure.)
- (8) Replace any faulty capacitors. Retest to verify that the capacitor readings match the appropriate curve in Figure 89. above.
- (9) After completing the tests, reinstall the electronic controller cover and the push-button plate (reverse of Steps (1) and (2)).

Section 9, Subsection X.D.

D. Time-Based Capacitor Replacement

Under normal operating conditions, replace the capacitors every 20 years. Ensure that this work is scheduled in the Maintenance Program (SAP WMS).

E. Functional-Performance Test

Given the design of the mechanism, profiles of the trip and close coils do not provide useful information. Disregard these when performing a functional-performance test. The FPT will consist only of a capacitor test (rapid open-close-open) in lieu of timing the operating coil duration.

F. Minimum to Trip and Close

Performing a minimum-to-trip or minimum-to-close test does not provide any useful information and is not required or advised.

G. Opening the Device Manually to Perform Maintenance

This type of circuit breaker is equipped with an external (trip) handle for manual opening. When it is operated, a Device 69 microswitch opens and prevents further electrical operation of the circuit breaker. To reset the manual opening device, return it to the Normal position.

The RMAG external trip handle has three positions: Normal, Close Blocked, and Manual Trip.

1. In the **Normal** position, the external trip handle is up, the close block (69) switch is closed and providing a voltage path to the block close function on the ED 2.0 board. This voltage path must be present in order for the breaker to close. The external trip handle can be locked into this position via a padlock.
2. The **Manual Trip** position is a non-latching position of the external trip handle. Unlike typical mechanical operators, tripping via the external trip handle on an RMAG requires a bit of physical force in order to break the hold that the top (closing) magnet has on the operating arm of the actuator.
 - a. Tripping should occur via a brisk thrust downward on the handle. When the external trip handle is placed in Trip, the 69 switch is opened, removing voltage from the block close function of the ED 2.0 board; the breaker is now electrically blocked from closing.
 - b. After tripping the breaker and releasing the handle, the trip-assist spring on the trip shaft will bring the external trip handle to the Close Blocked position. It is blocked from returning to the Normal position by the pull-pin of the external trip handle cover. Pulling the pull-pin aside will allow the external trip handle to be placed back into the Normal position, closing the 69 switch and allowing the breaker to electrically close.

Section 9, Subsection X.G.3.

3. Moving the handle from the **Normal** to the **Close Blocked** position will **not** open the 69 switch and **not** block closing. First, thrust the handle down to the **Trip** position and then release.

Note: This type of circuit breaker is not equipped for “slow operation.”

H. Vacuum-Bottle Contact Wear

Vacuum bottles **must** be replaced when the contacts are worn by 0.08 inches (approximately 1/12 inch) or by the amount stated in the manufacturer’s instructions.

I. Operating Specifications for ABB Type R-MAG Vacuum Circuit Breakers

ABB will be updating its instruction manuals for R-MAG models to include the following operating specifications.

- No more than two physical bounces on a close
- Total bounce time on a close: less than 2 cycles
- Close time: less than 6 cycles
- Open time: less than 2.5 cycles

XI. Modifying ABB/Westinghouse Type R Vacuum Circuit Breakers

Note: ES, ESM, ESV, and ESVA are model designations, not acronyms.

A. Purpose and Description of Modifications

1. The basic design of the mechanism used in the Type R vacuum circuit breaker, the ES oil recloser, the ESM oil recloser, and the ESV and ESVA vacuum reclosers has remained the same since 1969. However, in response to various problems, Westinghouse and ABB developed modifications to their basic designs.
2. The remainder of this subsection identifies the old and new designs, makes recommendations relative to the design changes, and specifies replacement mechanisms, modification kits, and parts numbers for the affected circuit breakers and reclosers.
3. This information applies to all Type R circuit breakers including Types R1, R2, and R3.

B. Evaluating Type R Vacuum Circuit Breakers for Modification

1. Evaluate each Type R vacuum circuit breaker mechanism for the current status of any recommended upgrades.

Section 9, Subsection XI.B.2.

2. At the next mechanism service, install the appropriate upgraded mechanism, as shown in Figure 90. and described in this subsection, on any Type R vacuum circuit breakers manufactured before March 1983 that are still using their original operating mechanisms, regardless of any individually upgraded parts, and that have interrupter wear of less than 75%. See Subsection 9.XI.B.2.a.
 - **Code 342153:** Mechanism, complete 24/48 Vdc trip (good for either voltage), ABB #FMR 113. **Description:** Mechanism with 120 Vac/125 Vdc motor (good for either voltage), close and trip coils (120 Vac close, 24/48 Vdc trip) for Westinghouse/ABB Type R1, R2, and R3 vacuum circuit breakers.
 - **Code 342155:** Mechanism, complete 125 Vdc trip, ABB #FMR 112. **Description:** Mechanism with 120 Vac/125 Vdc motor (good for either voltage), close and trip coils (120 Vac close, 125 Vdc trip) for Westinghouse/ABB Type R1, R2, and R3 vacuum circuit breakers.



Figure 90.
Replacement Mechanism

- a. If **any** Type R circuit breaker has vacuum-bottle wear greater than 75%, consider replacing the entire circuit breaker.
- b. If **any** Type R vacuum circuit breaker is experiencing operating malfunctions that cannot be corrected and has vacuum-bottle wear less than 75%, replace the operating mechanism with the appropriate, complete, new mechanism listed above.
- c. After replacement, discard old mechanisms properly.

Section 9, Subsection XI.C.

C. List of Modifications and Parts for ABB/Westinghouse Type R Vacuum Circuit Breakers

The following modifications and parts are for mechanisms manufactured since March 1983. Mechanisms manufactured before March 1983 need to be replaced with a completely new mechanism. Some parts, such as the closing coil and the trip coil, need to be replaced only if they fail. See Table 16. for a description of each modification or part.

1. General Information

- a. New Type R mechanisms received from ABB are supplied with the newer, four-hole style of transfer link. Four-hole transfer links might not work on Type R circuit breakers manufactured before 1983. If necessary, use the circuit breaker's old, three-hole transfer link when replacing the mechanism.
- b. Thoroughly inspect the old link and bushings. Ensure they are in good condition and that the alignment of the link and the coupler is compatible. If the linkage coupler needs to be adjusted, turn it in half-turn increments up to a maximum of 1½ turns.

Table 16. Modifying Type R Vacuum Circuit Breaker

	Modifications to Type R Vacuum Circuit Breakers	Page
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2.	Trip-Shaft Adjustment and Stop Bracket	212
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11.	Summary of Operating-System Design Improvements	222
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2. Center Bumper

Note: This is not part of the replacement mechanism.

a. Modification Trigger

The center-bumper upgrade is recommended, but not required. The center-bumper design change only affects Type R circuit breakers and is not a direct mechanism change. Preferably, a center bumper should be added to any Type R circuit breaker built before May 1975.

Section 9, Subsection XI.C.2.b.

b. Purpose of Adding a Center Bumper

A center bumper was added to all Type R circuit breaker designs in 1975, starting with Serial No. 75E101VB. The bumper minimizes primary-contact rebound and reduces strain on the auxiliary switch linkage.

c. Center-Bumper Kit

Purchase the Modernization Kit No. 316D804G69. This kit also includes two new closing-spring assemblies, an adjustable trip-shaft kit, field installation instructions, and a new field adjustment drawing.

d. Location of the Center Bumper

Figure 91., "Location of the Center Bumper," below, shows the location of the center bumper in relation to the main operating shaft.

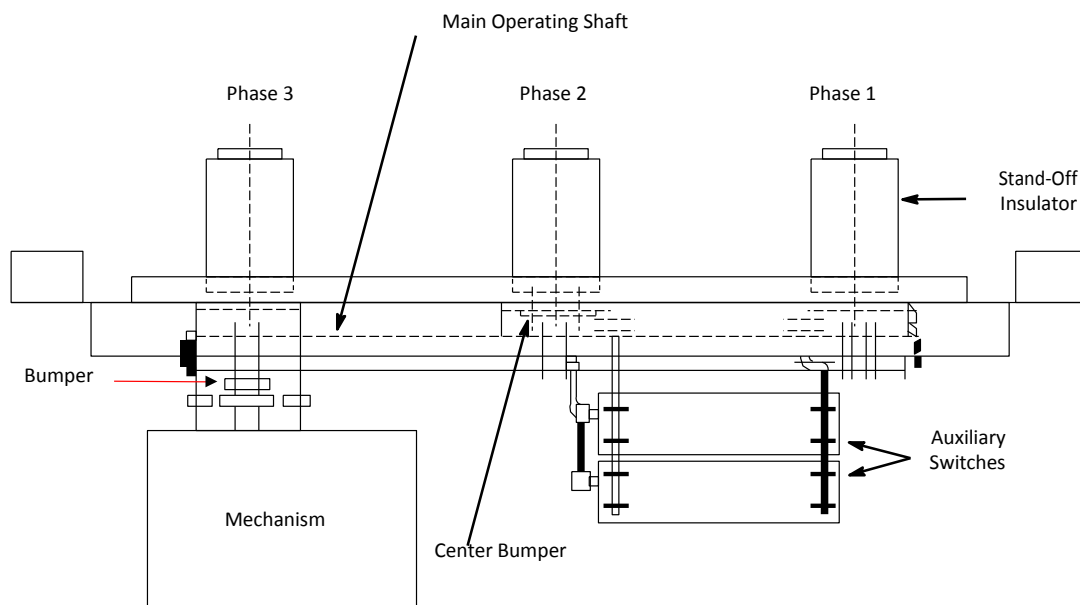


Figure 91.
Location of the Center Bumper

Section 9, Subsection XI.C.3.**3. Trip-Shaft Adjustment and Stop Bracket****a. Modification Trigger**

This modification is recommended for all standard Type R units built before January 1, 1976 (before Serial No. 76A101VB).

b. Purpose and Description of the Modification

- (1) Reduced maintenance is one of the major advantages of vacuum interrupters. The new design helps achieve reduced maintenance by minimizing the number of required operating-mechanism adjustments.
- (2) Units shipped before 1976 do not have a trip-latch wipe adjustment. The trip shaft has been redesigned to allow adjustment. The shaft now includes a stop bracket to provide a consistent, positive trip stop.

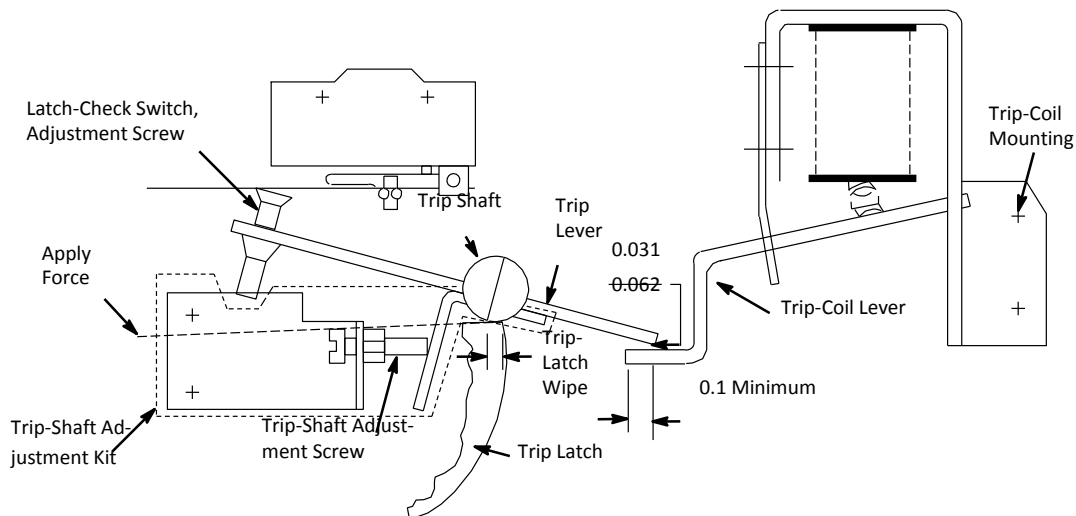
c. Trip-Latch Adjustment Kits

- (1) Kit No. 316D804G70 is a trip-latch adjustment kit with an instruction leaflet.
- (2) Modernization Kit No. 316D804G69 includes the trip-latch adjustment kit, the center bumper, two new closing-spring assemblies, instructions for field installation, and the field adjustment drawing.

d. Components of the Trip-Shaft Adjustment Modification

See Figure 92., “Trip-Shaft Adjustment Components,” below, for components and instruction.

Section 9, Subsection XI.C.3.d., continued



1. With the mechanism's opening and closing springs charged, apply downward force on the back of the trip latch.
2. Slowly rotate the trip-shaft adjustment screw clockwise until the trip shaft releases. This is the "no overlap" position.
3. To obtain the recommended trip-latch wipe, rotate the trip-shaft adjustment screw $8\frac{1}{2}$ turns in a counterclockwise direction.
4. Adjust the trip-coil lever, by adjusting the trip-coil mounting position, to clear the trip lever (0.031 to 0.062) with a 0.1 minimum overlap.
5. Set the latch-check switch's adjustment screw to trip the microswitch after the trip latch is latched.

Figure 92.
Trip-Shaft Adjustment Components

4. Close and Trip Solenoids

a. Replacement Trigger

If a coil needs to be replaced, replace it with the newer solenoid design.

b. Types of Close and Trip Solenoids

- (1) The original, industrial-type solenoids were designed before June 1976. The old, moving-armature-type solenoids are blue or yellow.
- (2) Newer solenoids use the clapper-type design.
- (3) For easy identification, both the old and the new solenoids are shown in Figure 93. through Figure 96.
- (4) See Table 17. for a list of replacement close and trip solenoids.

Section 9, Subsection XI.B.5.

5. Replacing the Closing Coil

- a. The solenoid kits include the trip-shaft adjustment kit and an instruction leaflet.

Note: The new 125 Vdc and 230 Vac closing coils have a resistance of 8 ohms. The older closing coils have a resistance of 50 ohms. Therefore, the new coil requires a higher operating current.

- b. In many cases, the **old** control-scheme designs relied on the 52X relay contacts to interrupt the current on the closing coil. It is possible that the 52X contacts may not be able to interrupt the higher coil current used with the newer design.
 - (1) Wire a spare 52B contact in series with the 52X contacts when changing out the coils. All new control schemes are already designed in this way.
 - (2) Some of the new-style 115 Vac coils chatter when energized, which prevents closing the circuit breaker.
 - (a) If the coils chatter, drill and tap a 10-32 (machine-screw size) hole in the base plate beneath, and in line with, the close lever.
 - (b) Screw in a 10-32 screw to slightly uplift the latch until the chatter has been overcome.
 - (c) Lock the 10-32 screw in place with a locknut.

c. Illustrations of Trip and Close Solenoids

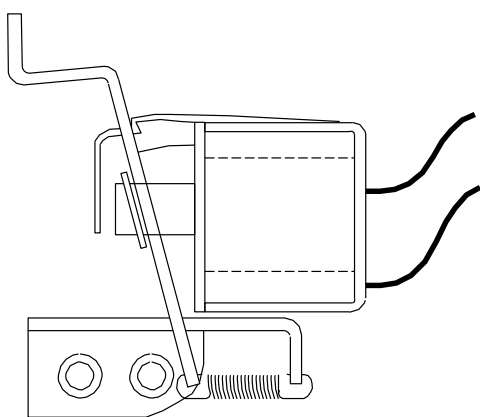


Figure 93. Old Trip Solenoid

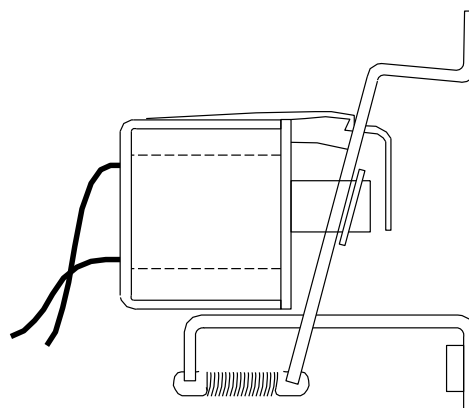


Figure 94. Old Close Solenoid

Section 9, Subsection XI.B.5.c., continued

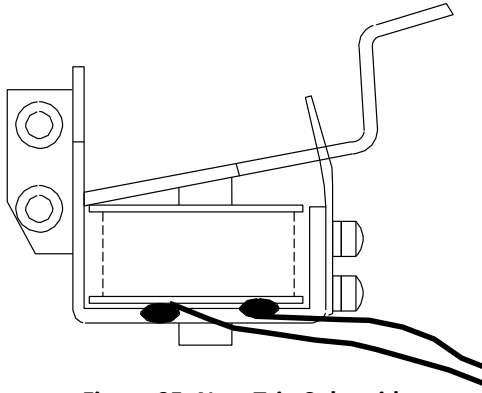


Figure 95. New Trip Solenoid

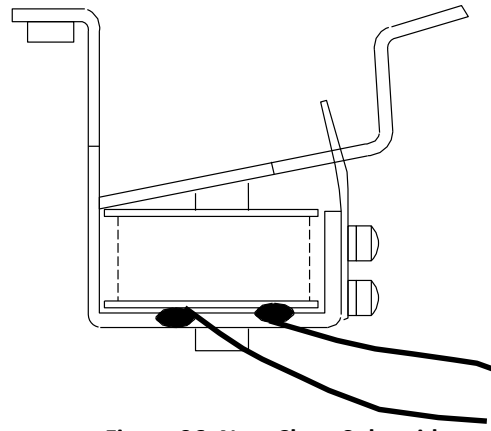


Figure 96. New Close Solenoid

d. Ordering Information for Trip and Close Coils

Table 17. Order Numbers and Company Codes for Trip and Close Coils

Coil	Voltage	Manufacturer's Order No.	Code
Trip	24 Vdc	316D804G25 (new # L915167G01)	345479
Trip	48 Vdc	316D804G26 (new # L915167G01)	345649
Trip	125 Vdc	L992147G01	340285
Close	115 Vac	316D804G31 (new # L915167G01)	345481
Close	230 Vac	316D804G26 (new # L915166G01)	345480

6. Trip-Latch Return Spring

a. Replacement Trigger

The trip-latch return spring was changed in mid-1976 to provide a more positive return of the trip latch.

b. Trip-Latch Return-Spring Kits

The trip-latch return-spring kit (No. 628A316H06) may be ordered separately or as part of the small-spring replacement kit (No. 316D804G66), which includes all the small springs used in the mechanism.

Section 9, Subsection XI.B.6.c.

c. Identifying and Locating Trip-Latch Return Springs

For identification purposes, Figure 97. and Figure 98., below, illustrate both the old and the new trip-latch return springs. Figure 99., below, shows the location of the trip-latch return spring in the mechanism.

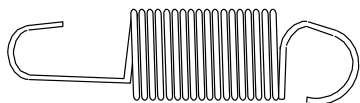


Figure 97. Old Trip-Latch Return Spring



Figure 98. New Trip-Latch Return Spring

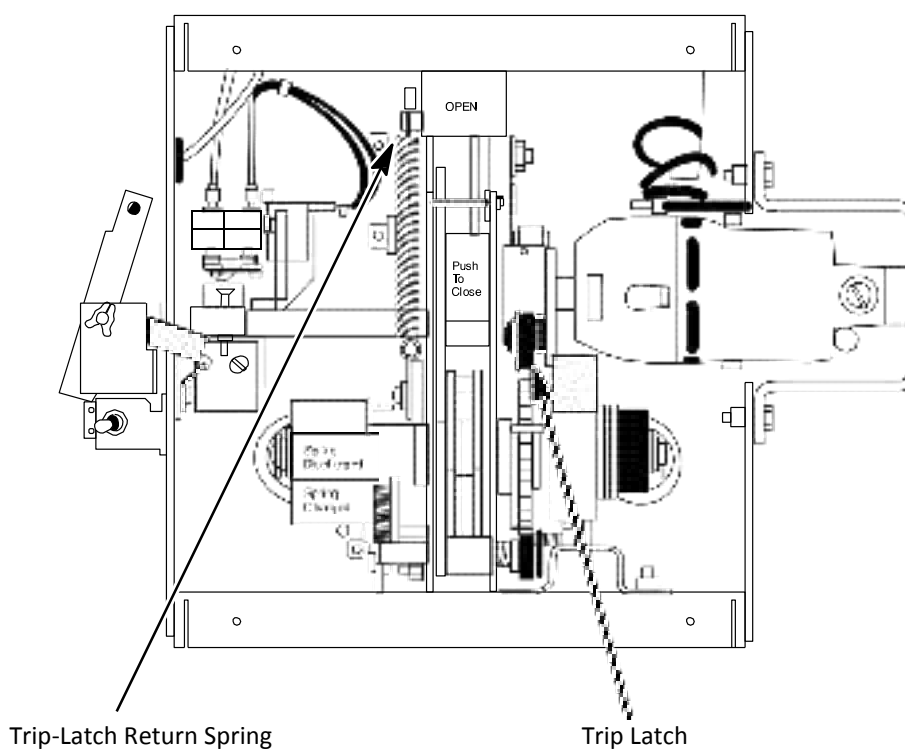


Figure 99.
Location of the Type R Mechanism's Trip-Latch Return Spring

Section 9, Subsection XI.B.7.

7. Closing Spring Kits

- a. The closing-spring kit No. 316D804G65 consists of two new closing-spring assemblies and four X washers.
- b. The closing-spring kit No. 316D804G69 consists of two new closing-spring assemblies, a new center bumper, an adjustable trip-shaft, field installation instructions, and a new field adjustment drawing.

8. Transfer Link

a. Replacement Trigger

Replacing the transfer link is **not** required.

b. Description and Application of the Transfer-Link Upgrade

- (1) The transfer link was redesigned in March 1983 to combine the recloser link and circuit-breaker link into one piece. The link is now a stainless-steel investment casting instead of a brazed assembly.
- (2) The overall size of the newer transfer link for Type R circuit breakers and ESVA reclosers is different from that of the old transfer links. The transfer links are **not** interchangeable on Type R circuit breakers. The dimensions of the earlier ES, ESM, and ESV recloser links **are** interchangeable. Before changing a complete mechanism assembly, determine which transfer link is present.

Section 9, Subsection XI.B.8.c.

c. Illustrations of Transfer Links

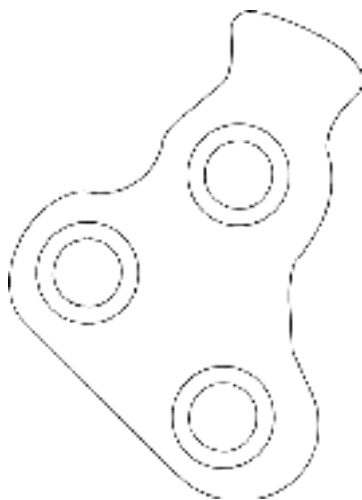


Figure 100.
Transfer Link for Old ES, ESM, and ESV
Reclosers

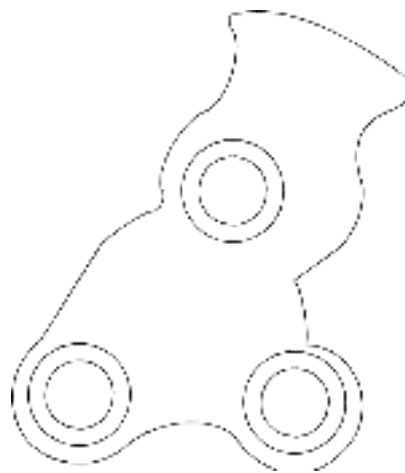


Figure 101.
Transfer Link for Old Type R Circuit
Breakers and ESVA Reclosers

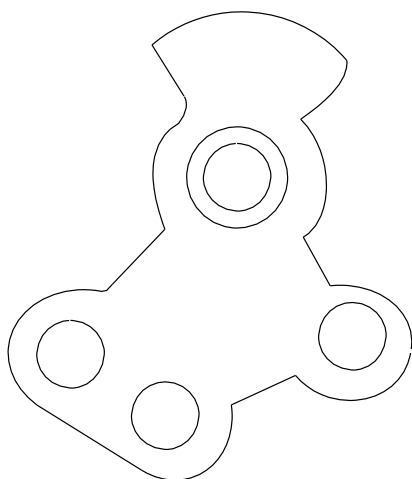


Figure 102.
Transfer Link for New ES, ESM, and ESV
Reclosers

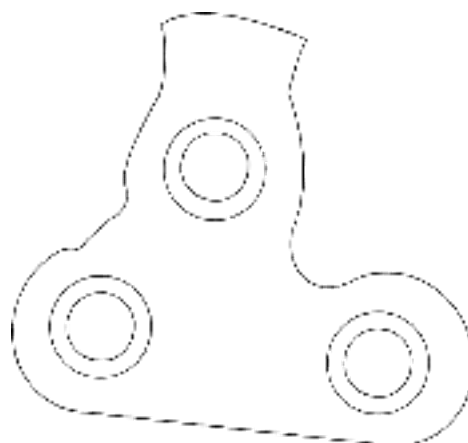


Figure 103.
Transfer Link for New Type R Circuit
Breakers and ESVA Reclosers

d. Transfer-Link Replacement Kits

The following five transfer-link replacement kits are available for order.

- (1) Kit No. 4990C92G05 provides a complete “short” mechanism including the updated crank-arm assembly. It can be used on the new or the old design by using the existing transfer link.

Section 9, Subsection XI.B.8.d.(2)

- (2) Kit No. 316D804G24 (Code 345675) provides a complete mechanism, including the new transfer link, modified for use on all designs of Type R circuit breakers and all ESVA reclosers.
- (3) Kit No. 279C693G06 provides a complete mechanism, including the new transfer link, usable on all ES, ESM, and ESV reclosers; newer-design Type R circuit breakers; and ESVA reclosers manufactured after March 1983.
- (4) Kit No. 4831B99H01 provides a new cast transfer link modified for use on all Type R circuit breakers and ESVA reclosers.
- (5) Kit No. 3911B99H01 provides a new cast transfer link that fits all Type R circuit breakers and ESVA reclosers manufactured after March 1983, and all ES, ESM, and ESV reclosers.

9. Crank Arms

a. Replacement Trigger

- (1) **Do not** change the crank arms in any reclosers.
- (2) Replace the crank arms in Type R circuit breakers, **if desired**, but only if using the modern solenoid assemblies.



CAUTION

The two crank arms **must** be the same on any mechanism.

b. Purpose of the Modification

In 1983, the crank-arm pin was rotated an additional 5° to increase the starting force and operating speed of the mechanism.

c. Crank-Arm Replacement Kit

Kit No. 316D804G68 includes two crank-arm assemblies and an instruction leaflet.

Section 9, Subsection XI.B.9.d.

d. Illustration of Crank Arms

Figure 104., “Location of the Crank Arm on a Type R Circuit-Breaker Mechanism,” shows the position and location of crank arms.

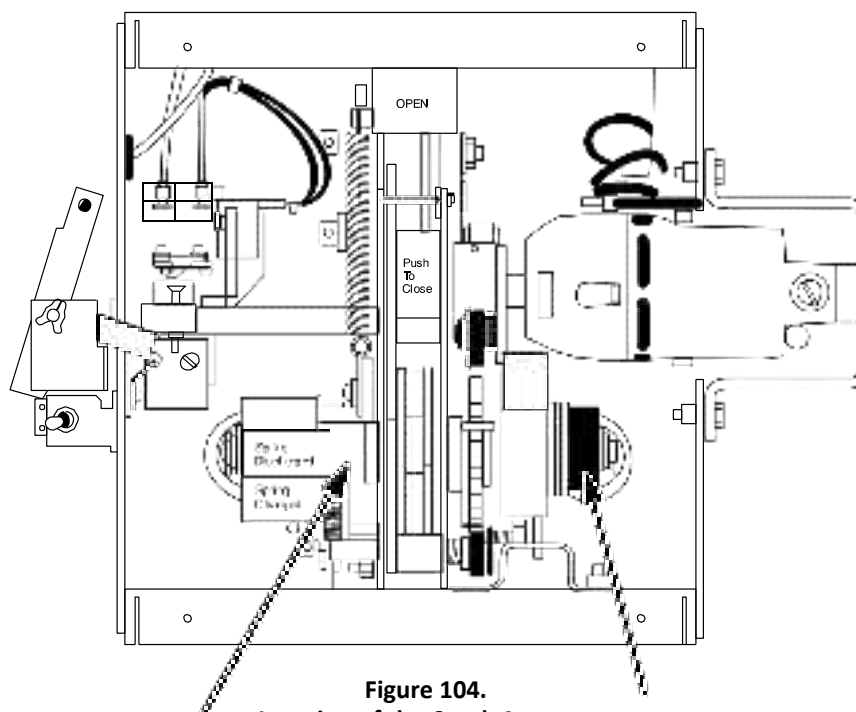


Figure 104.
Location of the Crank Arm on a
Type R Circuit-Breaker Mechanism

10. Pull Rods

a. Replacement Trigger

Replacing the pull rods is **not** a required field change. It is recommended only when insulation problems have occurred. Minor modification of the mounting assembly is required when upgrading circuit breakers with the old, phenolic pull rods.

b. History and Purpose of Pull-Rod Upgrades

- (1) In 1974, the pull-rod material was changed from phenolic to high-strength alumina porcelain. The change from phenolic improved the insulation characteristics and made the field power-factor test more accurate.
- (2) In 1983, the geometry of the pull rod was changed to align with the new, centered-mechanism circuit-breaker design.

Section 9, Subsection XI.B.10.b.(3)

- (3) In August 1990 (serial numbers after 90H-VB), the pull-rod material was changed to concrete polymer. The change to concrete polymer improved the strength and dimensional consistency by allowing the metallic connections to be molded into the pull rod during the manufacturing process.

c. Identifying Types of Pull Rods by Color

The phenolic pull rods are brown; the concrete-polymer pull rods are ASA-70 gray.

d. Pull-Rod Replacement Kits

Table 18. below shows the available pull-rod replacement kits.

Table 18. Kits for Pull-Rod Assemblies

Rating	Pre-1983 Style	Post-1983 Style
	Pre-1983 Kit No.	Post-1983 Kit No.
15 kV–600 A, R1	316D804G47	5636B86G01
15 kV–600-1,200 A - R2 and R3	316D804G47	5636B86G02
15 kV–600-1,200 A - R4	316D804G47	5636B86G03
15 kV–2,000-3,000 A (FA) - R3 and R4	NA	5636B86G06
27 kV–1,200-2,000 A - R1, R2, and R3	NA	5636B85G01

D. List of Kit Names, Numbers, and Descriptions for ABB Operating-System Modifications

1. 316D804G64: The “Spring Release Latch Replacement Kit” consists of a close prop, a spacer, a needle-bearing spring, and related hardware.
2. 316D804G65: The “Closing Spring Replacement Kit” consists of two closing-spring assemblies and four X-washers.
3. 316D804G66: The “Small Spring Replacement Kit” consists of all the small springs used in a mechanism for one unit, including the trip-latch return spring.
4. 316D804G67: The “Roller and Link Assembly Kit” (parts list available from ABB).
5. 316D804G68: The “Crank-Arm Assembly Kit” (parts list available from ABB).

Section 9, Subsection XI.D.6.

6. 316D804G69: The “Modernization Kit” consists of two closing-spring assemblies, a trip-shaft adjustment kit, bumpers, mounting hardware, and instructions.
 - a. 316D804G70: The “Trip-Shaft Adjustment Kit” consists of a clip, a lever, and an adjustment drawing.
 - b. 316D804G1: The “X Washer Replacement and Lubrication Kit” consists of six of each of the six different X washers used in the mechanism plus a tube of Dow Corning No. 33 grease.

E. Summarizing Operating-System Design Improvements

Table 19., “Operating System Design Improvement Summary,” is supplied directly from ABB. The references included in this table apply to ABB materials. Contact ABB with any questions or concerns.

Table 19. Operating System Design Improvement Summary

Serial Number or Manufacturing Date of Unit	Center Bumper	3 Trip Shaft Adjustment	3 Close and Trip Solenoids	3 Trip-Latch Return Spring	3 Lubrication	Motor	3 Closing Springs	Transfer Link	Crank Arms	Center Mechanism	Pull Rods	Recommended Kit Numbers
69A—VB—75E100VB	X	X	X	X	X	X	X	X	X	X	X	316D804G66, G69, G71
75E101VB—76A100VB		X	X	X	X	X	X	X	X	X	X	316D804G66, G69, G71
76A101VB—76E—VB			X	X	X	X	X	X	X	X	X	316D804G65, G66, G71
76E—VB—79H100VB					X	X	X	X	X	X	X	316D804G65, G71
79H101VB—1979						X	X	X	X	X	X	316D804G65
1979—1981							X	X	X	X	X	316D804G65
1981—1983								X	X	X	X	NONE
1983—90H—VB											X	NONE
Post 90H—VB												NONE
Related Kit Numbers	G69	G69 or G70		G66	G71		G65 or G69	See Section G.3.	G68	N/A	See Section J	

³ Recommended field modifications.

Section 9, Subsection XI.F.

F. Standard Control-Device Replacement Kits

Table 20., “Standard Control Device Replacement Kits,” is supplied directly from ABB.

Table 20. Standard Control Device Replacement Kits

Voltage	Standard Motor 1 (Including Crank and Roller)	Low-Temperature Motor 1 (Motor Only)	Trip Solenoid Assembly 2	Close Solenoid Assembly 2	Coil	Resistance (Ohms)
24 Vdc	N/A	N/A	316D804G25	316D804G31	L915167G01	3.10
Low Current 24 Vdc	N/A	N/A	1879B10G09	1879B09G05	L916906G01	1.00
48 Vdc	316D804G85	N/A	316D804G60	316D804G31	L915167G01	3.10
125 Vdc	316D804G23	608B144H04	316D804G61	316D804G30	L915166G01	8.00
Special 125 Vdc	316D804G23	608B144H04	1879B10G10	1879B09G07	L992147G01	12.40
120 VAC	316D804G23	608B144H04	N/A	316D804G31	L915167G01	3.10
240 VAC	316D804G55	608B144H05	N/A	316D804G32	L915166G01	8.00
Capacitor Trip	N/A	608B144H05	316D804G27	1879B09G06	L915165G01	52.00
Dual Trip Solenoid Assemblies						
48/125 Vdc			316D804G26		1 – L915166G01	8.00
					1 – L915167G01	3.10
48 Vdc/Cap Trip			1882B73G03		1 – L915167G01	3.10
					1 – L915165G01	52.00
48 Vdc/Battery Trip			1882B73G04		2 – L915167G01	3.10
125 Vdc/Cap Trip			1882B73G05		1 – L915166G01	8.00
					1 – L915165G01	52.00

¹ Standard motor for ambient temperatures to -30°C, low-temperature motor for ambient temperatures to -40°C.

² #316D804G-series solenoid kits include the trip shaft adjustment kit and an instruction leaflet.

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Section 10

Cleaning and Lubricating Mechanisms

I. Purpose

This section provides guidelines and procedures for properly cleaning and lubricating circuit-breaker mechanisms. Specific guidelines are provided in the manufacturer's instruction book. Combined use of information from these sources helps to ensure that circuit breakers are safe and reliable over the long term.

Circuit breakers must operate quickly and reliably during unpredictable emergencies.

II. General Information About Cleaning and Lubricating

A. Safety

1. Before using solvents, take time to review and understand all label instructions. Consult the MSDS for hazardous properties, PPE requirements, and emergency treatment information.
2. Use only approved pneumatic sprayers or blow guns. Limit the air pressure to no more than 30 pounds (PSIG). Follow the manufacturer's instructions.

B. Cost-Effective Maintenance

Always ensure that circuit-breaker mechanisms are kept clean, dry, and free of corrosion at all times. This reduces the maintenance clearances, work-hours, and other costs necessary to clean and maintain the mechanisms. Lubricants are used to reduce friction between the surfaces of moving parts. However, they may also trap or transport foreign particles. Poor lubrication and dirty or corroded mechanisms are the root causes of many circuit-breaker malfunctions and customer outage minutes.

1. Causes of Dirty Mechanisms

Improper or poorly functioning door seals, dirty, loose or missing vent filters, and holes that allow dust and insect invasion are the main causes of dirty mechanisms.

2. Use of Proper Materials to Reduce Maintenance

Installing and maintaining the proper materials greatly reduces malfunctions and resulting maintenance and outage costs.

Note: 3-inch-wide magnetic strips or other materials may need to be installed over a circuit breaker's door seams if the circuit breaker is exposed to heavy dust conditions and its door seals and their fit are not effective. These strips are purchased in rolls. Cut and shape the strips to fit the door seams.

Section 10, Subsection II.C.**C. Lubricant Basics**

1. Good lubricants exhibit the following characteristics:
 - High boiling point
 - Low freezing point
 - High viscosity index
 - Thermal stability
 - Corrosion inhibition
 - Resistance to oxidation
2. Grease is used for bearings in mechanisms that cannot be lubricated frequently and where lubricating oil would not stay in place.
3. Petroleum based grease consists of a base oil mixed with a thickener, typically a soap or clay.
4. Synthetic lubricants such as Polyalpha-Olefin (PAO) and Fluorosilicone grease consist of synthetic oils mixed with thickeners compatible with these types of oil. Synthetic lubricants are designed to resist oxidation preventing them from becoming gummy or solidified. They usually last much longer than petroleum-based products.

D. Lubrication Issues**1. Lubricant Problems**

- a. Lubrication problems often result from solvent attacks. Also, mixing non-compatible lubricants causes them to lose their effectiveness. Avoid mixing lubricants unless their compatibility has been established through manufacturer's instructions.
- b. Lubricants dry out over time, becoming sticky at first and later solidifying. Aging grease causes a mechanism to slow down over time. Left long enough, old grease causes stuck mechanisms and burned-out trip or close coils.
- c. Old grease is only marginally renewed by applying penetrants or grease externally. The best approach is disassembly, cleaning and inspection, followed by applying new grease before reassembly. This approach is desired throughout the circuit breaker mechanism, but it is critical with bearings that come in contact with trip and close latches. With latch type breakers, the primary cause of failures to trip and close is dried out lubrication in the trip or close latch rollers.

Section 10, Subsection II.D.1.d.

- d. **Example:** The trip latch roller bearing shown below went way too long with old grease, which became so hard it jammed the mechanism. This robbed the circuit breaker's ability to come off-latch and burned out the trip coil. The failure caused customers to do without electricity while field crews worked to switch them to an alternate source.



Figure 105. Trip Latch Bearing with Old, Hard Grease (External and Internal)

2. Precautions

- a. Circuit breaker mechanisms that are kept clean, dry, properly lubricated, and free of corrosion have a safer, longer, and more economical service lives. Promptly repair anything in the mechanism housing that allows moisture, dust, and insect invasion.
- b. Use only the approved cleaners and lubricants listed in Subsection V. when doing circuit breaker maintenance.
- c. Refer to the circuit breaker manufacturer's instructions, when provided, for the locations of specific lubrication points. Apply lubricants according to the product manufacturer's instructions. When specific guidance is not provided in the manufacturer's instructions, apply lubricants in accordance with the information in Section 10, Subsection IV.A., "General Mechanism Lubrication."

Note: According to the manufacturer's instructions, some of the newest circuit breaker mechanisms are described as not requiring periodic re-lubrication. However, if deteriorated performance is traced to lubrication failure, the mechanism must be cleaned and the lubricants must be replaced.

Section 10, Subsection II.D.3.**3. Identifying Deteriorated Lubrication, and Lubrication Triggers**

- a. The following behaviors may indicate deteriorated lubrication. Each needs to be addressed promptly as part of a complete mechanism service:
 - A circuit breaker fails to trip or close properly while in-service.
 - A circuit breaker fails a functional-performance test.
 - Absolute minimum operating voltages trend progressively higher.
 - Binding is evident during maintenance slow-close or open operations.
 - A circuit breaker fails to trip or latch closed during maintenance.
 - A circuit breaker's trip, close, or trip-free times or time/distance velocity analysis are outside of the manufacturer's specifications
- b. The required maintenance will vary depending on the design and age of the mechanisms, the requirements in the manufacturers' instructions, environmental conditions, and the occurrence of operating malfunctions.
- c. Whenever a circuit breaker has an operating malfunction or when deteriorated lubricant is identified during station inspections or functional-performance testing, perform a complete mechanism service. Thoroughly clean and re-lubricate the circuit-breaker mechanism per the instructions in Subsections 10.III and 10.IV.

4. Problems Remaining After Lubrication

- a. Following a malfunction, **do not** assume that a circuit-breaker mechanism will continue to perform normally after only one correct exercise (open-close).
- b. If cleaning, lubricating, and performing the rest of the mechanism service items, do not correct a malfunction; instead, perform further diagnostic tests, and check the mechanism's mechanical adjustments.
- c. If a mechanical operating malfunction is not corrected by properly cleaning and lubricating a fully assembled circuit breaker mechanism, pull, clean, and inspect the mechanism's pins to check for **unseen** lubrication problems and bent, galled, loose, or worn-out components. Pins found in serviceable condition may be re-lubricated and reinstalled. Check the mechanism's mechanical adjustments after assembly.

Section 10, Subsection II.D.5.

5. Using Lubricants Properly

Lubrication problems often result from the inconsistent use of lubricants.

- a. Use only the approved lubricants listed in this section for circuit-breaker maintenance.
- b. Apply lubricants according to the product manufacturer's instructions and the substation guidelines for lubrication.
- c. Refer to the circuit-breaker manufacturer's instructions for the **locations** of specific, important lubrication points, if provided. Ensure that the mechanism is operating properly and consistently.

Note: According to the manufacturer's instructions, some of the newest circuit-breaker mechanisms do not require periodic re-lubrication. However, if heavily contaminated lubricants need to be cleaned or removed, the lubricants **must** be replaced, even if periodic re-lubrication of the circuit breaker is not required. Also, to maintain proper operation, always keep the cabinets and mechanism clean and dry.

III. Cleaning the Mechanism

Perform the following steps to thoroughly clean and lubricate an entire circuit-breaker mechanism.



CAUTION

Prevent hands or other body parts from being caught in pinch points in the mechanism. Use appropriate PPE for face, eye, and hand protection when necessary or when specified by the manufacturer's instructions for the equipment being serviced and the lubricants and solvents being used.

A. Using Manufacturer's Instructions

Always check the manufacturer's instructions and recommendations before performing any maintenance. When applying any lubricants or solvents, use **only** the appropriate, Company-approved products listed in this section.

B. Cleaning the General Mechanism

Clean the mechanism and remove old lubricants, as follows:

1. Wipe down the equipment with dry, lint-free rags. Remove stubborn dust and dirt by using rags lightly moistened with approved solvents. Be careful to prevent solvent from flowing or dripping into the mechanism.

Section 10, Subsection III.B.2.

2. When needed, use a nonmetallic bristle brush or a long-handled artist's brush with stiff bristles to help remove the old grease. Surveyor's string, which does not break easily, may be used like floss to help clean accessible pins in tight areas. Also called "mason's string," it is available from local hardware stores. Use lint-free rags to remove the remaining accessible grease.

**CAUTION**

Keep the use of solvents to an absolute minimum so that they do not accidentally contaminate or degrade any lubrication. Do not spray solvents into any part of the mechanism that has bearings, bushings, or pins that are not being disassembled, cleaned, and re-lubricated.

Solvents may damage or destroy some types of plastic parts. Ensure that solvent does not come in contact with plastic parts and that any stray solvent is wiped away quickly.

3. If permitted by the manufacturer, slow-close and open the circuit breaker while cleaning to allow better access to the mechanism parts and to help prevent damage to the parts before they are re-lubricated.
4. Before applying the new lubricants, ensure that the mechanism is completely dry. If necessary, speed the drying process by applying pressurized air or nitrogen (limited to 30 psig or less) with an approved, pneumatic blow gun.

C. Cleaning Mechanism Cabinets

If necessary, dislodge and remove dust and dirt from mechanism cabinets by using rags, which may be moistened with approved solvents. Mechanisms and cabinets **must** be kept clean and well-lubricated.

D. Cleaning Bearings

1. Open bearings are easily cleaned for re-packing with new grease. Best results are achieved with the bearings removed from the mechanism.

Note: Sealed bearings cannot be re-lubricated. Any time sealed bearings stick or exhibit roughness, replace them with high quality exact duplicates from a reputable bearing dealer. Do not accept low cost substitutes.

2. Wash the bearings with an approved solvent. Best results are achieved by soaking and gently agitating from time to time or by gently rotating the bearing races by hand a few times. If the bearings are large enough for a small brush to get inside, keep the bearing partly submerged in solvent, and wash the old grease out while slowly rotating the bearing races.

Section 10, Subsection III.D.3.

3. Rinse the bearing with clean solvent until the bearings are completely clean. Using clean dry compressed air and an approved blow gun, dry the bearing, taking care not to allow the races to turn without grease in them.
4. Slowly rotate the bearing, inspecting the balls, rollers, or needles for corrosion, wear, or pitting. Feel for roughness as you roll the bearing. Replace any bearing that is rough, pitted, or corroded with high quality exact duplicates from a reputable bearing dealer. Do not accept low cost substitutes.
5. When used bearings are suitable for re-use, re-pack them, per Subsection IV, with the appropriate grease immediately after cleaning.
6. The following Figures 106 through 110 depict bearing types typically found in operating mechanisms.



Figure 106. Open Ball Bearing



Figure 107. Open Roller Bearing



Figure 108. Tapered Roller Bearing. Sometimes Called a Timken™ Bearing



Figure 109. Needle Roller Bearing Sometimes Called a Torrington™ Bearing

Section 10, Subsection III.D.3., continued



Figure 110. Shielded Bearing
Also Known as Sealed Bearings

IV. Lubricating Guidelines

Note: Synthetic lubricants are designed to avoid becoming gummy or solidified. Depending on the environment, temperature, and the mechanical condition of operating mechanisms, these lubricants usually last much longer than petroleum-based products.

A. General Mechanism Lubrication

1. Do not use too much or too little of a lubricant. Carefully apply the amount of lubricant specified in the manufacturer's instructions. A small bristle brush or a long-handled artist's brush is often useful in helping to apply some types of lubricants.
2. **Always** refer to the circuit-breaker manufacturer's instructions for the **locations** of specific, important lubrication points.
3. Clean off all excess lubricant so it will not collect dust or contaminate the other mechanism components.

B. Re-Lubricating Roller, Tapered Roller, Ball, and Needle Bearings

Re-lubricate (pack) **tapered** roller bearings as follows (see the following Figures 111 and 112).

Note: Roller, ball, and needle bearings are packed using the same basic method.

1. Check label warnings and wear protective gloves, if necessary.
2. Apply some grease in the palm of one hand.
3. Force the bearing into the grease. This action pushes the grease in between the rollers and out the top of the bearing.

Section 10, Subsection IV.B.4.

4. Continue working your way around the bearing until it has been thoroughly packed all the way around. The bearing is fully packed when grease squeezes out the top between the inner race and the bearing cage.
5. Apply grease to the outside surfaces of all rollers.
6. Apply additional grease to the inside surface of the outer race.
7. Re-assemble the bearing.



Figure 111. Technique for Packing Grease Into Roller Bearing



Figure 112. Fully Packed Open Ball Bearing

C. Applying Approved, Molybdenum Disulfide Liquid Lubricants

1. **Always** agitate the approved liquid lubricant every time the product is used, to ensure that the molybdenum disulfide ingredient is suspended thoroughly in the mineral oil.
2. When applying the liquid lubricant to a circuit-breaker mechanism's pins or knuckles, slow-close and open the circuit breaker to draw the lubricant into the internal surfaces of the pins and knuckles, if slow-closing is allowed by the circuit-breaker manufacturer. Slow manual operation during the application process prevents liquid lubricants from being sprayed around the mechanism, as can occur during power operations.
3. Power operations may be performed once the lubricant has been drawn into the inner surfaces by the slow-closing operations.

V. Lubrication Products

To ensure that the specialty products listed in this subsection are used and applied correctly, always follow the manufacturer's product information.

Section 10, Subsection V.A.**A. Mobilegrease 28****1. Operating Mechanisms**

Mobilegrease 28 is the preferred lubricant for **all** operating mechanism locations that require a grease-type product.

2. Utility Disconnect Switches

Mobilegrease 28 may be used on utility disconnect switches and disconnect-switch contacts. To prevent the lubricant from collecting dust or causing tracking on the insulating surfaces, use only a minimum amount on disconnects.

3. Metalclad Switchgear

Use Mobilegrease 28 on metalclad-switchgear, primary-coupling connections (stabs) and on current-carrying hinge points. Never use lubricants on a circuit breaker's main, intermediate, or arcing contacts unless directed by the manufacturer's instructions.

B. Molykote® 111 Compound

Molykote® 111 Compound is a silicone, fluid-thickened valve lubricant and sealant with an inert silica filler. It is nonvolatile, odorless, and resistant to a wide range of environmental dangers. Use Molykote® 111 as follows.

1. To seal vacuum and pressure systems.
2. To lubricate nitrile rubber and plastic O-rings, and other nitrile rubber parts. The silicone oil in Molykote® 111 both lubricates and rejuvenates rubber.
3. To provide an anti-stick sealant for gaskets and equipment enclosures.

**CAUTION**

Do not use on silicone O-rings or silicone rubber because it deteriorates silicone products.

Section 10, Subsection V.C.

C. Molykote® 321 Dry Film Lubricant

Molykote® 321 is a **non-penetrating** solvent dispersion of solid lubricants, including molybdenum disulfide and graphite, in an inorganic binder. When sprayed, dipped, or brushed on a surface, it dries in minutes, leaving a coating of solid lubricant that is dry to the touch. However, allow 4 hours for complete curing for the lubricant to have a long-lasting effect. It will not wash out, or attract and hold dust or dirt. **Parts must be completely clean and free of all previous lubricant. Molykote® 321 should be applied in a controlled environment. Application in the field is not recommended.**

Use Molykote® 321 to lubricate the following surfaces of disassembled parts:

1. Sliding surfaces, sleeve bearings, control-valve pistons, cylinder walls, and gear teeth.
2. Pins, rollers, and linkage where a dry film is desired and access with a paste-type lubricant is not practical after assembly.
3. All disassembled mechanisms **before** reassembling a circuit breaker.

Note: Observe the following precautions:

- a. **Do not** apply Molykote® 321 to any electrical contacts.
- b. To keep solid ingredients in suspension, continuously agitate Molykote® 321 during use. To prevent solvent loss, always close the container when not in use.
- c. Molykote® 321 may cause certain plastics, rubbers, and paints to deteriorate.

D. Molykote® Moly-Pene-Lube

1. Moly-Pene-Lube is no longer available and is not recommended for circuit breaker mechanism lubrication.
2. Remaining supplies of Moly-Pene-Lube may be used for:
 - a. Gang-operated disconnect-switch linkages (but **not** the energized parts).
 - b. Hinges.
 - c. Rusted parts or seized bolts and nuts.

Note: **Do not** allow Moly-Pene-Lube to get on any **electrical contacts** because it increases the contact resistance.

Section 10, Subsection V.E.**E. FirstPower EZ-Reach® Lubricating Oil**

This oil comes in a 110 g squeeze bottle with a 12-inch extended reach applicator. See Figure 113.



Figure 113. FirstPower EZ-Reach Lubricating Oil

1. FirstPower EZ-Reach® Synthetic PAO Oil provides protection and lubrication for a wide range of moving components in circuit breaker mechanisms. It contains rust and corrosion inhibitors and anti-wear additives and is compatible with petroleum based lubricants and Mobile 28. It is ideal for locations requiring lubrication which are not accessible for grease or paste application.

EZ-Reach® is not intended as a substitute for disassembly, cleaning, and re-lubrication of mechanism main bearings, but it may extend lubrication life when disassembly, cleaning, and re-lubrication are not practical. It is not recommended for use on trip or close latch roller bearings.

2. When applying EZ-Reach® to a circuit breaker mechanism's pins or knuckles where slow-close and slow-open are allowed, slow-close and slow-open the circuit breaker to draw the lubricant into the internal surfaces of the pins and knuckles.

F. DC G-n Metal Assembly Spray

G-n Metal Assembly Spray is no longer recommended.

G. Molykote® G-n Paste

1. G-n Paste is low friction paste lubricant similar to grease that provides protection against fretting wear and corrosion in sliding surface applications such as worm gears and open spur gears. G-n Paste is not recommended for use as a lubricant for needle, ball, or roller bearings.

Section 10, Subsection V.G.2.

2. Use a bristle brush to apply a thin film of G-n Paste to gears.

Note: *Do not* allow G-n Paste to get on any *electrical contacts* because it increases the contact resistance.

H. Conducto-Lube™

Conducto-Lube™ is no longer approved for use in any application.

VI. Cleaning Products

Products used for cleaning and maintaining electrical equipment should perform well and be safe for the workforce, the equipment, and the environment. Carefully review the products before using them. Products that contain ozone-depleting chemicals, specifically chloro-fluorocarbons (CFCs) or tri-chloro-ethane, are typically more aggressive as cleaners, but they are harmful to the environment and are not approved for use.

A. Dow Corning OS-2 Silicone Cleaner and Surface Prep Solvent

Typical applications include degreasing bearings, nuts, bolts, and chains; also, pre-cleaning silicone based products from surfaces prior to painting, sealing and bonding. OS-2 Silicone Cleaner is a suitable alternative to LPS ZeroTri Cleaner/Degreaser and LPS EFX Solvent/Degreaser.

B. LPS ZeroTri Cleaner/Degreaser

Use ZeroTri as an alternative to trichloroethane to clean and degrease operating linkages and circuit-breaker mechanisms. It is a fast-acting solvent for cleaning and degreasing parts and equipment and has no ozone-depleting chemicals. Its penetrating action instantly removes oil, grease, wax, dirt, moisture, tar, and other contaminants. It is nonconductive, but extremely flammable. Do not use ZeroTri on energized equipment. Allow the surface to dry before re-energizing the equipment. Decrease the drying time, if desired, by following the cleaning instructions in Subsection 10.III.B.4. Always follow the manufacturer's instructions for safety and use.

C. LPS EFX Solvent/Degreaser

LPS EFX Solvent Degreaser is a heavy-duty solvent with instant degreasing action. It removes grease and oil quickly and evaporates rapidly. It is safe to use on most surfaces. Use it to remove oil stains and external contaminants. Always follow the manufacturer's instructions for safety and use.

Section 10, Subsection VI.D.**D. LPS Electro 140 Contact Cleaner**

LPS Electro 140 Contact Cleaner has a high flash point, penetrates quickly, does not leave a residue, and has no CFCs or trichloroethane. Use it to clean electrical contacts.

**CAUTION**

Use caution when applying LPS Electro 140 Contact Cleaner to energized contacts. If energized contacts operate, the arc could cause the propellant to ignite.

E. Denatured Alcohol

Use denatured alcohol to clean off hand and finger prints from the internal insulating components in SF₆ circuit breakers.

VII. Mechanism Lubrication Process Flowchart

The following Figure 114., “Mechanism Lubrication Process Flowchart” aids the decision-making process for mechanism cleaning and lubrication.

Section 10, Subsection VII., continued

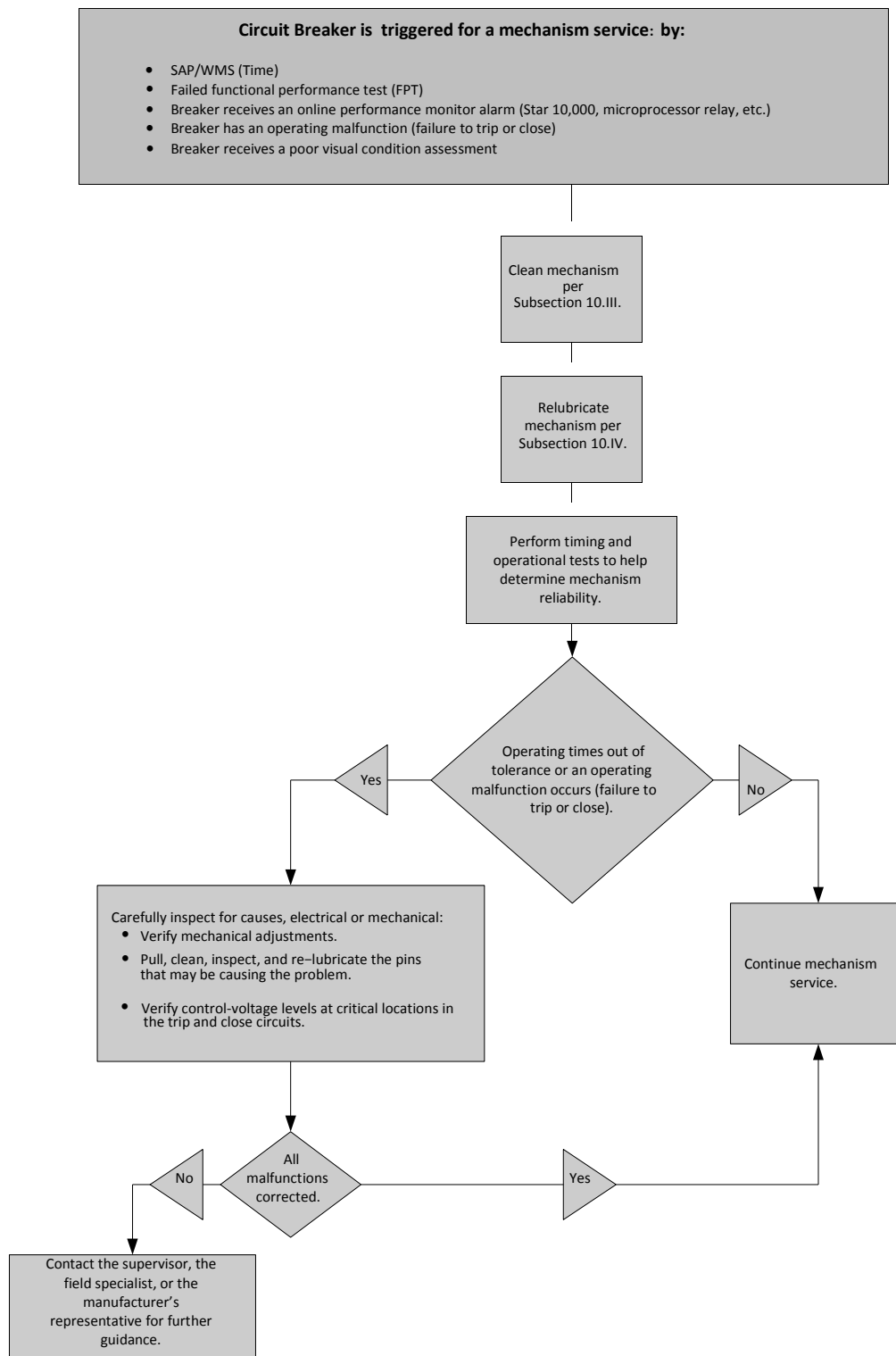


Figure 114.
Mechanism Lubrication Process Flowchart

Section 10, Subsection VIII.

VIII. Order Codes for Lubricating and Cleaning Products

Table 21., “Order Codes for Lubricating and Cleaning Products,” below provides a comprehensive list of Company-approved products.

Table 21. Order Codes for Lubricating and Cleaning Products

Product	S	Code
Mobilegrease 28	12-ounce tube	500027
Molykote® 111 Silicone Compound, Valve Lubricant, and Sealant	5.3-ounce tube	490409
Molykote® 321 Dry Film Lubricant	16-ounce aerosol	500111
FirstPower EZ-Reach® Lubricating Oil	110 g squeeze bottle	Available from FirstPower Website http://www.firstpowergroupinc.com/FPG%20-%20FirstPower%20Group%20LLC%20-%20Lubricants.htm
Molykote® G-n Paste	80 g tube	Available from FirstPower Website http://www.firstpowergroupinc.com/FPG%20-%20FirstPower%20Group%20LLC%20-%20Lubricants.htm
Dow Corning® OS-2 Silicone Cleaner and Surface Prep Solvent	283 g aerosol	Available from FirstPower Website http://www.firstpowergroupinc.com/FPG%20-%20FirstPower%20Group%20LLC%20-%20Lubricants.htm
LPS ZeroTri Cleaner/Degreaser	15-ounce aerosol	500035
LPS EFX Solvent Degreaser	15-ounce aerosol	500036
LPS Electro 140 Contact Cleaner	11-ounce aerosol	490699
	1 gallon, bulk	490700
Penetrox™ Contact Grease	1 quart	495242
Exxon XD-3 Oil	Set of six 1-gallon containers	490754
Hydraulic Fluid: Exxon-Mobil Univis HVI-13	1 gallon	495238
Alvania EP Grease 2 (PB) — Required during overhaul of ABB SF ₆ circuit breakers for lubrication inside the SF ₆ tanks.	—	Order this grease directly from ABB.

Section 11

Accessories, Contact Kits, and New Technology

I. Purpose

This section lists diagnostic tools, materials, and accessories for circuit breakers, some of which are new or under development. New technologies, tools, materials, and diagnostic testing equipment are constantly being introduced. The intent of this section is to provide information about existing accessories and increase awareness of new tools and technologies.

II. New Diagnostic Technology

A. Vibration Testing

Vibration testing detects the abnormal operation of certain moving components in circuit-breaker mechanisms.

1. Normal operation creates a specific characteristic vibration known as a “vibration signature” for each moving circuit-breaker component.
2. Deviations from the normal vibration signatures may indicate the following problems:
 - a. Bent or broken mechanisms or linkage parts.
 - b. Improper shock-absorber or dashpot operation.
 - c. Abnormal mechanism speed.
 - d. Abnormal wear of circuit-breaker components.
 - e. Moving parts that are striking other parts or sticking.

B. Real-Time Monitoring and Diagnostics

Various online monitoring and diagnostic systems indicate when a circuit breaker exceeds preselected mechanical or operating parameters, measures contact wear, and can forecast leak rates of SF₆ breakers.

1. Types of Online Monitoring and Diagnostic Systems

- a. Some systems use features presently found in microprocessor relays.
- b. More complex systems are designed specifically to measure and monitor preselected mechanical and operating points.
- c. “Smart breakers” include various advanced devices or systems for monitoring and diagnostics.

2. Diagnostic Uses

- a. Online monitoring and diagnostic devices and systems reduce maintenance and capital costs by providing data and alarms related to fault operations, fault currents, arc sound signatures, pressure alarms, circuit-breaker timing, trip and close-coil current, etc.

Section 11, Subsection II.B.2.b.

- b. These systems may be used to trigger inspections and maintenance work before a failure or serious damage occurs.

III. Order Codes for Circuit-Breaker Contact Kits

Table 22., “Circuit-Breaker Contact Kits,” provides a list of the Company-approved, circuit-breaker contact kits that are available through the Emeryville Materials Facility.

Table 22. Circuit-Breaker Contact Kits

Code	Title	Description
342472	General Electric Type FKD, 14.4 kV, Oil Circuit Breaker Kit (14.4 kV, 600 A)	Circuit Breaker Kit: 14.4 kV, 600 A, High Voltage #5000-031k, for General Electric Type FKD 14.4 kV OCB . Contents: 36 - Main Finger Contacts #5000-702 (342473) 6 - Moving Contact Rods #5000-690 (342474) 6 - Arcing-Plate Contact #5000-689 (342475) 6 - Baffle Stack #5000-453 (342476)
342477	Westinghouse, 14.4 kV, GC 250, Oil Circuit Breaker Kit (14.4 kV, 600 A)	Circuit Breaker Kit: 14.4 kV, 600 A, Normandie Machine #7411300000, for Westinghouse 14.4 kV GC 250 OCB . Contents: 3 - Main Moving Arcing Contact AY #7411010000 (342478) 3 - Main Stationary Arcing Contact #7411020005 (342479) 3 - Vent Stack AY #7411911010 (342480)
342458	ITE, 14.4 kV, KS-500-12B, Oil Circuit Breaker Kit (15 kV, 1,200 A)	Circuit Breaker Kit: 15 kV, 1,200 A, High Voltage #1010-003k, for ITE 14.4 kV KS-500-12B OCB . Contents: 6 - Contact Rod Assembly #1010-185 (342481) 6 - Baffle Stack #1010-141 (342459) 6 - Contact Assembly #1010-112 (342460) 6 - Contact Arcing #1010-111 (342461)
342462	Allis Chalmers ITE, 14.4 kV KS-500-12/16D Oil Circuit Breaker Kit (15 kV, 600 A)	Circuit Breaker Kit: 15 kV, 600 A, High Voltage #1010-002k, for Allis Chalmers ITE 14.4 kV KS-500-12/16D OCB . Contents: 6 - Contact Rod Assembly #1010-179 (342463) 6 - Baffle Stack #1010-098 (342464) 6 - Contact Assembly #1010-051 (342465) 6 - Contact Arcing #1010-110 (342466)
342467	Allis Chalmers SDO 15 kV Oil Circuit Breaker Kit (15 kV, 600 A)	Circuit Breaker Kit: 15 kV, 600 A, High Voltage #3010-004k, for Allis Chalmers SDO 15 kV OCB . Contents: 6 - Contact Finger AY #3010-111 (342468) 6 - Arcing Nozzle #3010-099 (342469) 12 - Washer #3010-095 (342470) 6 - Moving Contact AY #3010-071 (342471)
342453	Allis Chalmers SDO 23 kV Oil Circuit Breaker Kit (23 kV, 1,200 A)	Circuit Breaker Kit: 23 kV, 1,200 A, High Voltage #1010-005K, for Allis Chalmers SDO 23 kV OCB . Contents: 6 - Contact Finger Assembly #3010-111 (342191) 6 - Arcing Nozzle #3010-099 (342469) 12 - Washers #3010-095 (342470) 1 - Moving Contact Assembly #3010-069 (342190)

Continued on the next page...

Section 11, Subsection III., continued

Table 22. Circuit-Breaker Contact Kits, continued

Code	Title	Description
340411	Siemens 121 kV Type SPS Circuit Breaker Kit (40 kA, 2,000 A)	Circuit Breaker Kit: 121 kV, 40 kA, 2,000 A, #72-181-779-801, for Siemens Energy Type SPS Power Circuit Breaker . Contents – Major inspection parts, including gaskets, contacts, and nozzles
342193	Allis Chalmers Type SDO-15-250 Circuit Breaker Kit (15 kV, 600 A)	Circuit Breaker Kit: 15 kV, 600 A, 250 MVA High-Voltage Supply, #3010-004K, for Allis Chalmers SDO 15-250 OCB . Contents: 6 - Contact Finger Assembly #3010-111P (342191) 6 - Arcing Nozzle #3010-099 (342469) 12 - Washers #3010-095 (342470) 6 - Moving Contact Assembly #3010-071P (342190)

IV. Desiccant Dryer for Circuit-Breaker Air-Compressor Systems

A. Purpose of a Desiccant Dryer

High moisture in the air compressor tanks can cause corrosion of the main control valves and operating pistons on pneumatically operated circuit breakers. This may prevent the circuit breaker from closing following a fault, thus prolonging customer outages. Installing a desiccant dryer in the compressed air system prevents moisture from accumulating in the air tanks.

B. Description of a Desiccant Dryer

The desiccant dryer consists of a metal housing filled with desiccant, installed between the air compressor and the air tanks. Velcon filters and associated equipment can be ordered from : <http://www.velcon.com/utility/>

1. Housing Filter, Velcon, No. VF43, 0.5-inch, NPT (National Pipe Thread), anodized aluminum, 18 inches long, 3.75-inch diameter.
2. Bag Filter, molecular sieve, Velcon (three bags required).

C. Changing Desiccant Bags

Blow down the air compressor tanks during station inspections. Change the desiccant bags whenever the air tanks begin to discharge moisture. If the desiccant needs to be replaced more than once per year, check for and repair any air leaks in the compressor system.

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Section 12

Acronyms and Definitions

I. Interpretations

- A. Apply the following interpretations throughout *SMCM*:
1. will: mandatory under normal circumstances.
 2. must: mandatory under normal circumstances.
 3. should: strongly suggested or advisory, represents the best advice available at the time of publication.
 4. may: permissible choice, optional, possible.

II. List of Acronyms, Definitions, Abbreviations, and Symbols

- A. This list applies to *SMCM*, "Circuit Breakers."
1. A: amperes ("amps")
 2. ABB: Asea Brown Boveri (company)
 3. ac: alternating current
 4. ACC: accumulated critical current. ACC is a measurement of accumulated fault amperes that could indicate contact deterioration. It is used to determine when to service or overhaul circuit breakers.
 5. ASG: Advanced Specialty Gases (company)
 6. ASTM: American Society for Testing and Materials. The ASTM is an organization that provides standards recognized by industry for all kinds of products and materials.
 7. BGA™: Breaker Gas Analysis™. BGA™ is an external method for analyzing the condition of SF₆ gas-filled circuit breakers.
 8. BOA™: Breaker Oil Analysis™. BOA™ is an external method for analyzing the condition of oil circuit breakers.
 9. bus: an electrical circuit configuration that supplies power to multiple circuit breakers which, in turn, supply power to pieces of equipment or other, smaller buses.
 10. °C: degrees Celsius or Centigrade
 11. CAISO: California Independent System Operator. CAISO is an agency with jurisdictional control of most transmission-class equipment operating at 60 kV or greater and including some low-voltage equipment and battery banks that could directly affect this equipment.
 12. CFCs: chlorofluorocarbons. CFCs are hazardous chemicals used in some cleaning products.

Section 12, Subsection II.A., continued

- 13. cfm: cubic feet per minute
- 14. CGA: Compressed Gas Association. The CGA is an organization that provides industry standards for compressed gases.
- 15. circuit-breaker analyzer: a computerized performance-testing device used for contact timing, travel velocity, and other electrical values.
- 16. [*Code of Safe Practices*](#): the PG&E safety-rule book, formerly called the *Accident Prevention Rules*.
- 17. CO₂: the chemical symbol for carbon dioxide.
- 18. CPR: cardio-pulmonary resuscitation
- 19. CT: current transformer. A CT measures current for instrumentation and other electrical devices that require current measurements.
- 20. dc: direct current
- 21. DC: Dow Corning (company)
- 22. DCP: Diablo Canyon Power Plant
- 23. DCS: Distribution and Customer Services. DCS is the former name of a PG&E division.
- 24. DDP: Data Display Products (company)
- 25. DGA: dissolved-gas analysis. DGA is a method of testing for dissolved gases in circuit-breaker insulating oil and analyzing circuit-breaker performance based on the quantities and types of gases found.
- 26. DOT: Department of Transportation (a federal regulatory entity)
- 27. EPA: Environmental Protection Agency
- 28. °F: degrees Fahrenheit
- 29. FPE: Federal Pacific Electric (company)
- 30. ft: foot or feet
- 31. ft-lbs: foot-pounds
- 32. functional-performance test: a test with a specific set of instruments, including a current transformer, used to evaluate the condition of a circuit-breaker mechanism through analyzing the timing of the first operation as compared to successive operations.
- 33. GASVU™: not an acronym but the brand name of a certain gas-analyzer test instrument.
- 34. GE: General Electric (company)
- 35. GIS: Gas Insulated Substation

Section 12, Subsection II.A., continued

- 36. GSCU: gas sample collection unit
- 37. high-pot: high potential, a method of testing the integrity of the insulating medium in an electrical device by subjecting it to high voltages (potential).
- 38. HVB: high-voltage breaker
- 39. i.e.: that is (Latin)
- 40. k: kilo (one thousand)
- 41. kV: kilovolt
- 42. kVac: kilovolts alternating current
- 43. lb.: pound
- 44. LED: light-emitting diode
- 45. m: milli (one thousandth) or meters (see mm, ms, and m/s)
- 46. M: mega (one million)
- 47. Maintenance Program: the generic term for the computer program that is used for planning, scheduling, and documenting substation maintenance tasks. It contains the substation equipment database, maintenance history, equipment monitoring data, and information about equipment failures. (Also see SAP below [the current program].)
- 48. mechanism service: a set of circuit-breaker maintenance tasks triggered by the Maintenance Program or by a trouble condition.
- 49. megger: a test instrument using an ohmmeter to measure the insulating resistance in an electric device, also refers to the test method used with this instrument.
- 50. MEPP: Mitsubishi Electric Power Products, Inc. (company)
- 51. metalclad switchgear: circuit breakers and associated equipment usually installed in metal cabinets.
- 52. μ : micro (one millionth)
- 53. μ f: microfarad
- 54. μ : micro-ohm
- 55. mm: millimeter
- 56. mmHg: millimeters of mercury. A measurement of atmospheric pressure.
- 57. MOC: mechanically operated control
- 58. ms: millisecond
- 59. m/s: meters per second

Section 12, Subsection II.A., continued

- 60. MSDS: material safety data sheet
- 61. No.: number
- 62. NPT: national pipe thread. A standard measurement of pipe thread.
- 63. OCB: oil circuit breaker. An OCB uses insulating oil to extinguish arcing.
- 64. Ω : the symbol for ohms. An ohm is a unit of measurement of the electrical resistance in a circuit.
- 65. overhaul: a certain set of maintenance tasks triggered by the Maintenance Program or by a trouble condition.
- 66. PCB or PCBs: polychlorinated biphenyl(s). PCBs are hazardous chemicals formerly used in insulating oils and may still be present in small quantities in certain equipment.
- 67. [PESTP](#): *Protective Equipment Standard Test Procedures*. The *PESTP* is a PG&E manual.
- 68. PG&E: Pacific Gas and Electric Company
- 69. $\emptyset$: the symbol for phase.
- 70. power factor: the ratio of real power to the apparent power being used in a circuit.
- 71. PPE: personal protective equipment
- 72. ppm: parts per million. ppm is a measurement of concentration defined as the number of “parts” of a substance by either weight (ppmw) or volume (ppmv) found within a million “parts” of another substance.
- 73. psi or psia: pounds per square inch (absolute). Psi (or psia) is an absolute measurement of pressure.
- 74. psig: pounds per square inch gauge. Psig is a measurement of pressure that factors out the existing atmospheric pressure. It is more commonly used than psi.
- 75. PT: potential transformer. A PT measures voltage for instrumentation and other electrical devices that require voltage measurements.
- 76. ®: registered trademark
- 77. RE: Registered Engineer. Also, “responsible engineer” in some Company documents.
- 78. REB: roof entrance bushing
- 79. SAE: Society of Automotive Engineers. The SAE is an organization that provides industry-recognized standards for various products, such as oils, not necessarily limited to automotive use.

Section 12, Subsection II.A., continued

- 80. SAP: Systems Applications and Products in Data Processing. SAP is the computer program used by PG&E to order materials, track inventory, and schedule and document specific equipment repairs.
- 81. SCADA: Supervisory Control and Data Acquisition. SCADA is a computerized communication and control system used in electric transmission and distribution systems.
- 82. SF₆: the chemical symbol for sulfur hexafluoride. SF₆ is a gas that is used sometimes for circuit-breaker insulation and arc-quenching.
- 83. SF₆ Circuit Breaker: a circuit breaker that uses sulfur hexafluoride gas to extinguish arcing.
- 84. SHL: safe handling limit
- 85. *SMCM or SM&C Manual: Substation Maintenance and Construction Manual.*
- 86. SPCC: Spill Prevention Control and Countermeasures Plan. An SPCC is a legally required environmental document that provides guidelines for preventing and managing hazardous materials spills at a specific site.
- 87. tare: a shipping term referring to the empty weight of a container.
- 88. template: a standard listing, presented in a template (chart) format, of the maintenance and construction tasks for each type of equipment.
- 89. timing: testing that determines the exact time taken for the contacts in a circuit breaker to open or close.
- 90. TM: trademark
- 91. trigger: a feature of the Maintenance Program that uses various inputs to determine when equipment should receive periodic maintenance. “Trigger” may also refer to a trouble condition that requires performing maintenance.
- 92. triggered: scheduled for maintenance by a Maintenance Program trigger or as required by a trouble condition.
- 93. trip-free test: a testing situation where a circuit breaker is closed while a trip signal is present to simulate closing into a fault condition.
- 94. trouble condition: a malfunction or an electrical-system problem or condition that could be related to a such a malfunction.
- 95. T/S M&C: transmission/substation maintenance and construction
- 96. V: volt
- 97. Vac: volts alternating current
- 98. VCB: vacuum circuit breaker. A VCB uses a vacuum to extinguish arcing.

Section 12, Subsection II.A., continued

- 99. Vdc: volts direct current
- 100. VMS: vacuum manifold system. A VMS is a device for extracting gas for analysis.
- 101. WMS: Work Management System. A component of SAP used for tracking equipment maintenance.
- 102. www: World Wide Web
- 103. X or x: times

Section 13

Forms

See the following circuit-breaker maintenance and installation forms:

1. [TD-3322M-F10, "Installation Form for New Distribution Circuit Breakers"](#)
2. [TD-3322M-F11, "Transmission Class Circuit-Breaker Timing Test Report"](#)
3. [TD-3322M-F12, "Compressor Service"](#)
4. [TD-3322M-F13, "Distribution Circuit Breaker Functional Performance Test Form"](#)
5. [TD-3322M-F14, "Metalclad Circuit Breaker Mechanism Service"](#)
6. [TD-3322M-F15, "Metalclad Circuit Breaker Overhaul"](#)
7. [TD-3322M-F16, "OCB Mechanism Service"](#)
8. [TD-3322M-F17, "OCB Overhaul"](#)
9. [TD-3322M-F18, "SF₆ Circuit Breaker Mechanism Service"](#)
10. [TD-3322M-F19, "SF₆ Circuit Breaker Overhaul"](#)
11. [TD-3322M-F20, "VCB Mechanism Service"](#)
12. [TD-3322M-F21, "VCB Overhaul"](#)
13. [TD-3322M-F22, "BGA™ Breaker Gas Analysis Sulfur Hexafluoride \(SF₆\) Data Sheet"](#)
14. [TD-3322M-F23, "AM 15-500 Supplemental Maintenance Record"](#)
15. [TD-3322M-F24, "Compressor Rundown"](#)
16. [TD-3322M-F25, "Distribution Class Circuit-Breaker Timing Test Report"](#)
17. [TD-3322M-F26, "Installation Form for New Transmission Circuit Breakers"](#)
18. [TD-3322M-F81, "Hybrid Density Monitor Testing"](#)

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