

**BY ORDER OF THE  
SECRETARY OF THE AIR FORCE**

**AIR FORCE HANDBOOK 32-1282V1  
1 JULY 1999**

***Civil Engineering***



***Field Guide for Inspection, Evaluation and Maintenance  
Criteria for Electrical Substations and Switchgear***

This handbook summarizes procedures and guidance to Air Force electricians for the inspection, evaluation, and maintenance of substations, switchgear, and associated devices. It will also assist maintenance engineers and quality assurance evaluators in specifying and inspecting contractor performance.

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NOTE: Product and manufacturer names are included in this handbook for the purposes of illustration and do not carry the specific endorsement of the Air Force.

## CHAPTER 1. OVERVIEW OF THE GUIDE

**1-1. Scope.** The condition of electrical power apparatus found in substations is crucial to the successful operation of all electrical power systems. Switchgear and related equipment are significant components of the systems. This handbook identifies field procedures which allow early detection of equipment degradation and other defects which will adversely affect reliability. Appropriate corrective actions can then be accomplished.

**a. General Categories of Substation Equipment.** *Table 1-1* lists the general categories of substation equipment covered in this Air Force maintenance handbook. *Figures 1-1, 1-2, 1-3, 1-4, 1-5, and 1-6* have been provided to remind the technician of similar and differing features of various circuit breaker and switchgear types. Substation equipment categories discussed in AFH 32-1282V2 (*Field Guide for Inspection, Evaluation, and Maintenance Criteria for Electrical Transformers*) are listed in *Table 1-2*.

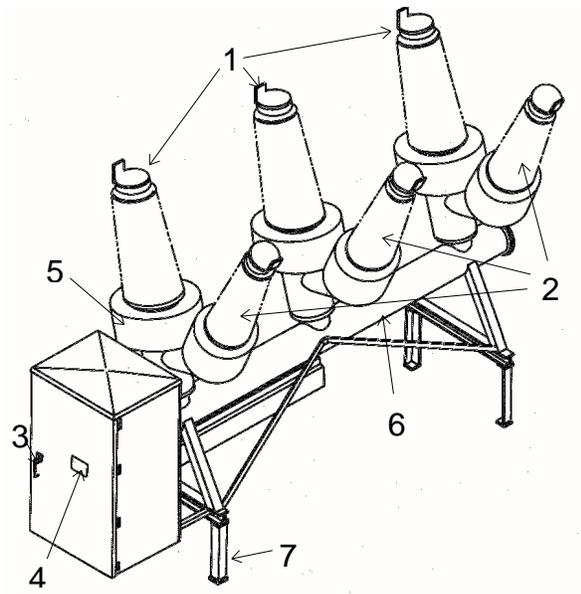
**Table 1-1. Equipment covered in this handbook**

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Substation support elements providing area safety
Transmission/distribution power-line switching
! Circuit breakers
! Load interrupter switches
Power-line switching unit/assembly necessary sub-elements
! Switchgear/switchboard assemblies
! Battery installations
! Protective sensing, processing, and action devices

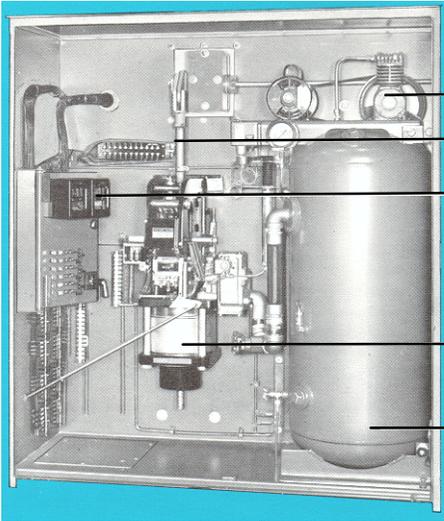
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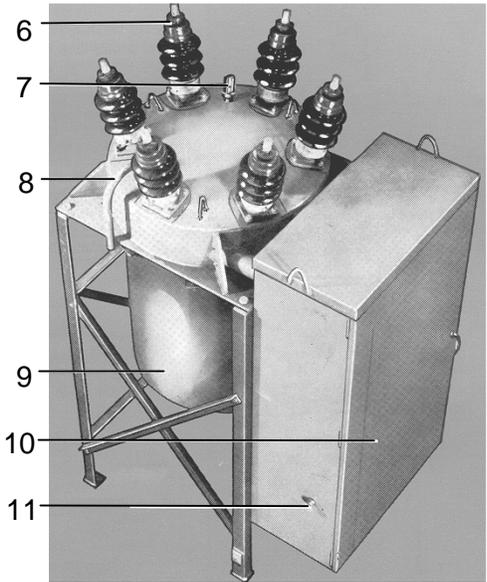


1. Interrupters
2. Bushings
3. Control cabinet
4. Pressure gauges and operation counter
5. Current transformers
6. Steel base
7. Base legs

*Figure 1-1*  
**High-voltage SF<sub>6</sub>-gas-insulated circuit breakers**

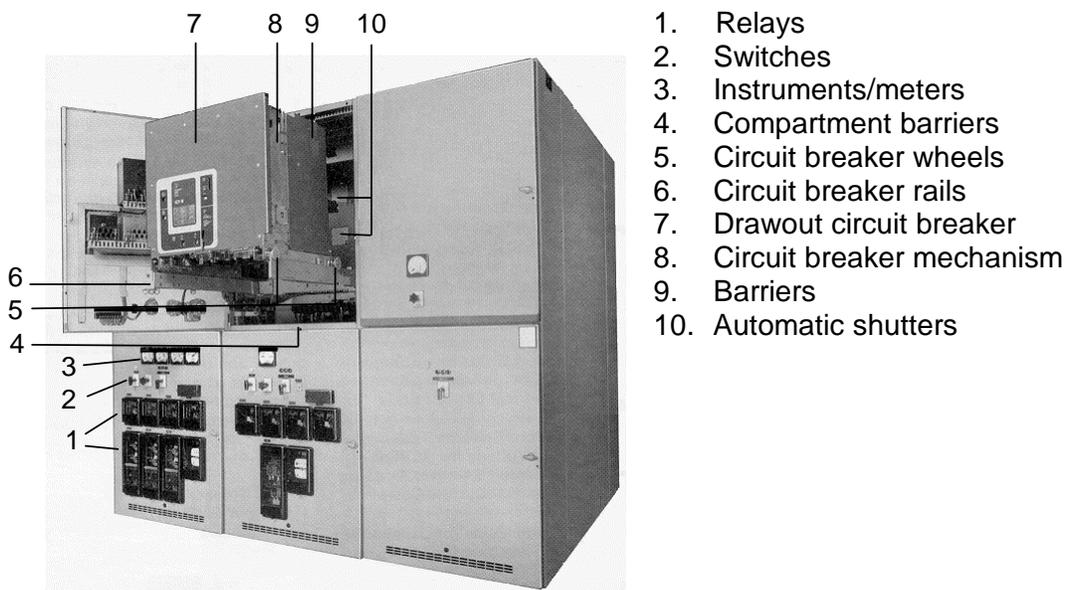


- 1. Compressor
- 2. Pull rod
- 3. Control panel
- 4. Mechanism
- 5. Reservoir
- 6. Bushing
- 7. Oil level indicator
- 8. Oil vent
- 9. Tank
- 10. Mechanism housing
- 11. Local control



*Figure 1-2*  
**High-voltage oil-insulated circuit breakers**





*Figure 1-3*  
**Medium-voltage metal-clad vacuum circuit breaker switchgear**

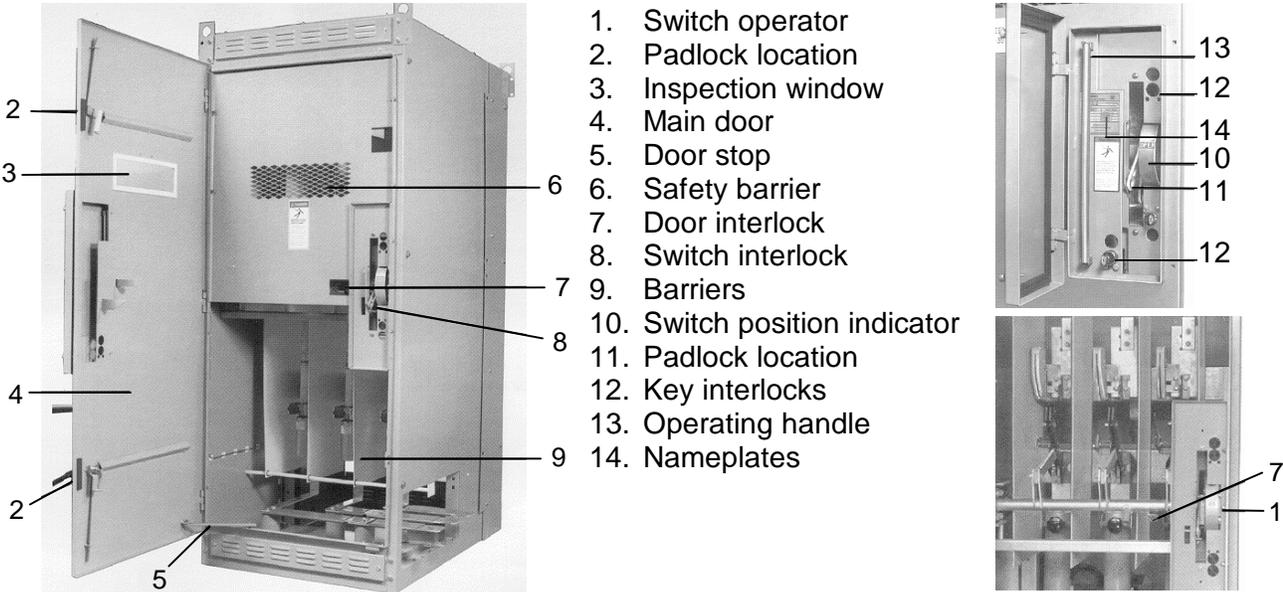
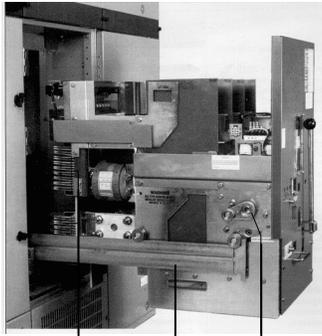


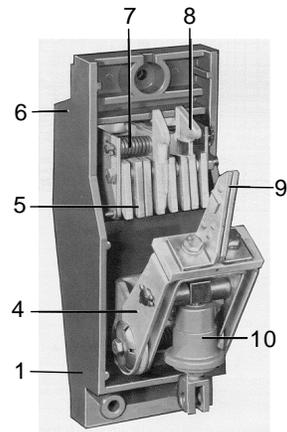
Figure 1-4

Medium-voltage metal-enclosed load-interrupter switchgear

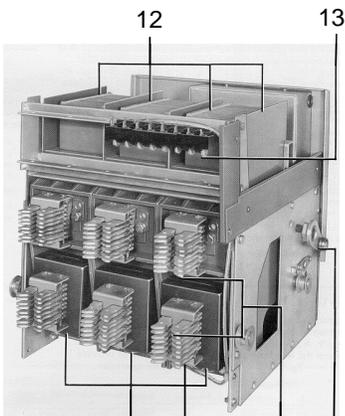




- 1. Finger clusters
- 2. Extension rail
- 3. Levering arm



- 4. Moving contacts
- 5. Stationary contacts
- 6. Molded base
- 7. Arcing contact spring
- 8. Stationary arcing contact
- 9. Moving arcing contact
- 10. Insulation link



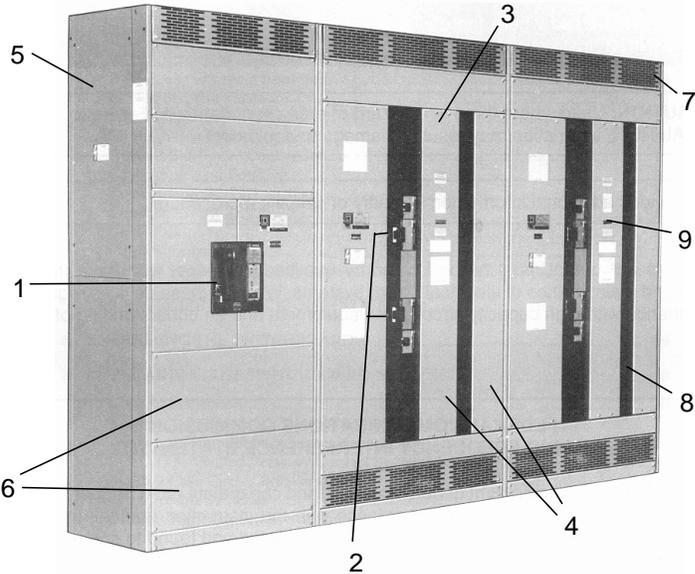
- 11. Pole unit
- 12. Interface barriers
- 13. Secondary disconnect contacts
- 14. Levering device arm
- 15. Main disconnect contacts
- 16. Sensors



- 17. Drawout circuit breaker
- 18. Switchgear
- 19. Rail mounted lifter

Figure 1-5

**Low-voltage air circuit breaker switchgear**



- 1. Main circuit breaker
- 2. Group-mounted circuit breakers
- 3. Vertical bus behind
- 4. Hinged wiring access panels
- 5. Side access panel
- 6. Removable cover plates
- 7. Ventilation grille
- 8. Blank filler plates
- 9. Warning and manufacturer's labels

*Figure 1-6*  
**Low-voltage molded-case circuit breaker switchboard**



**Table 1-2. Equipment covered in AFH 32-1282V2**

Power/distribution transformers	Bushings
Instrument transformers	Surge arresters

**b. Purpose.** Equipment deterioration needs to be identified before the equipment malfunctions or fails (that is, preventative maintenance). This handbook allows local preparation of electrical preventative maintenance (EPM) procedures. It does not cover catastrophic or operational failures. Its purpose is to prevent equipment failures resulting from a lack of proper preventative maintenance.

**c. Technician Testing Limitations.** The handbook is not a training guide. Air Force technicians should not use testing/metering/scanning devices around or on energized equipment unless they have been trained in their use and have satisfactorily demonstrated their knowledge of appropriate safety precautions.

**1-2. Supplementary Information.** The maintenance technician should be familiar with and have available Air Force electrical design, maintenance, and safety manuals.

**a. Design.** Refer to the installation requirements of AFMAN 32-1180(I) (*Electrical Power Supply and Distribution*) which provides Air Force policy and guidance for design criteria and standards for electrical power supply and distribution systems.

**b. Maintenance.** Refer to AFMAN 32-1280(I) (*Facilities Engineering, Electrical Exterior Facilities*) which amplifies the maintenance and repair guidance of this handbook.

**c. Safety.** Refer to AFMAN 32-1185 (*Electrical Safe Practices*) which provides safety standards for the work being done. Maintenance work should be done only by workers in accordance with the electrical work classifications of AFMAN 32-1185, including AFSC 3E011 equivalent (helper), AFSC 3E031 equivalent (apprentice), AFSC 3E051 equivalent (journeyman), or AFSC 3E071 equivalent (craftsman). AFH 32-1285 (Electrical Worker Safety Field Guide) should be available to you to use in the field.

**1-3. Basis for Developing Field Procedures.** This handbook is intended as summary guidelines and procedures. Actual maintenance/repair program requirements should be adjusted as appropriate for your specific electrical apparatus.

**a. Handbook Information.** This handbook covers generic apparatus performance, test data, and generally applicable component element checks. Use this handbook as a reminder of general maintenance requirements.

(1) Performance. Each component of major electrical apparatus performs essentially a simple operation. Complexity in maintenance is caused by the large and varied types of electrical components in the apparatus. This handbook provides figures and pictures to illustrate the most important of these components.

(2) Tests. Electrical equipment must be tested to ensure its continuing operating capability.



(a) Test Descriptions. Descriptions of the most commonly used tests are included in this handbook. Acceptable values of the tests are provided when possible. Reference to the manufacturer's literature may be required for other tests.

(b) Comparisons for Trends. All tests/readings should be compared to previous values (acceptance, maintenance, or repair). This will assist in recognizing trends that indicate a need for more frequent testing. Permanent changes to equipment/devices that are overloaded, misapplied, or inadequate for the duty to which they are subjected may be required.

(3) Component Element Checks. Tables are included in this handbook which outline the most important components to be checked. Additional information on these components can be found in AFMAN 32-1280(l) and the manufacturer's literature.

**b. Locally Developed Field Procedures.** Each facility should maintain a copy of all applicable documents related to the installation, operation, and maintenance of electrical systems. Locally developed EPM procedures are essential to proper maintenance.

**1-4. Preinspection Procedures.** Prior to performing any field work, review historical EPM data and applicable safety requirements.

**a. Apparatus Documentation.** Assemble all documentation applying to the apparatus to be checked.

(1) Documentation Maintenance. The Base Civil Engineer (BCE) should ensure all documentation is maintained for each specific item of electrical apparatus which makes up the facility electrical power systems.

(a) Available From Design/Construction Files. The available data may include all of the inspection and testing procedures for the facility, copies of previous reports, single-line diagrams, schematic diagrams, electrical equipment plans, records of complete nameplate data, and manufacturer's service manuals and instructions.

(b) Locally Prepared. Prepare local EPM forms as necessary for installed equipment. Each item of apparatus should be shown on an equipment location plan. (See *Paragraphs 3-2, 5-1, 6-1, 7-4, 8-4, 9-3, and 10-4*). Provide unique apparatus designations along with a locally prepared safety electrical one-line diagram and equipment location plan. *Table 2-2* summarizes the minimum recommended features of a safety electrical one-line diagram.

(2) Specific Assembling of Data: Assemble the following data, if available, for each specific item of apparatus.

- ! Locally prepared forms.
- ! As-built drawings for electric equipment layouts and elevations.
- ! Trend analysis data which should include:
  - (a) Installation acceptance data test results.
  - (b) Previous EPM reports including any previous systematic evaluations.



- ! Manufacturer's service manuals including practices and procedures for:
  - (a) Installation.
  - (b) Disassembly/assembly (interconnection).
  - (c) Wiring diagrams, schematics, bills of materials
  - (d) Operation (set-up and adjustment)
  - (e) Maintenance (including parts list and recommended spares)
  - (f) Software programs.
  - (g) Troubleshooting guidance.

(3) Systematic Evaluation of Apparatus Condition. Electric apparatus should receive a systematic evaluation of its condition after an EPM which indicates repairs were necessary beyond normal expected maintenance. The systematic evaluation should include:

- ! Reasons for the required repairs.
- ! Work required to complete the repairs.
- ! Assessment of the remaining service life.
- ! Determination of the need for a more frequent EPM.

**c. Safety Requirements.** Working on or near normally energized lines or parts requires observance of rules applying to safe working distances, work methods related to whether the line has been de-energized or left hot, and recognition of work hazards which require more than one worker for safety. Workers must be qualified for the work and use approved work methods and equipment. Refer to the requirements of AFH 32-1285 as amplified by AFMAN 32-1185. Always include a tailgate meeting to address existing site conditions and the procedures to be followed. Work will be done de-energized unless energized line work is specifically authorized.

(1) De-Energized Electrical Line Work. Follow the safe clearance (lockout/tagout) procedures given in AFH 32-1285. Remember lines are considered energized if the de-energized systems have not been provided with proper protective grounding. The safe clearance may require a job hazard analysis.

(2) Energized Electrical Line Work. Work on energized lines and equipment only when authorized by the electrical supervisor/foreman/lead electrician (per local organization) based on the need to support a critical mission, to prevent injury to persons, or to protect property. Insulating means must be provided to isolate workers from a source of potential difference. A job hazard analysis is required for energized line work. (See AFH 32-1285).

**d. Understanding Maintenance Frequencies.** Frequency of maintenance should be locally adjusted based on the application of the equipment. See additional guidance in NFPA 70B (*Electrical Equipment Maintenance*). Adjust the frequency of inspection based on the criticality of the apparatus, the severity of the loading conditions, and an environment where unusual service conditions stress the equipment. Generally, usual service conditions extend only to elevations of not more than 3,300 feet (1 kilometer) and ambient temperatures of no more than 30 to 40 degrees C. Check with the manufacturer for other than normal service conditions.

- e. Inspection Materials/Devices.** Basic items needed for an EPM include the following:
- ! A facility electrical truck
  - ! Available documentation.
  - ! EPM forms.
  - ! Directions as to any input or approval needed from the appropriate using or operating agency



- ! Test equipment such as an
  - (1) Automatic insulation test set
  - (2) Dielectric test set
  - (3) Digital ground resistance test set
  - (4) Fault gas analyzer
  - (5) Infrared imager
  - (6) Circuit breaker test set
  - (7) Corona tester
  - (8) Motion analyzer
  - (9) Null balance (megohmmeter) earth test set (Megger7)
  - (10) Power factor test set
  - (11) True root-mean-square (rms) digital multi-electrical parameters meter
  - (12) SF<sub>6</sub> gas moisture analyzer
- ! Measurement instruments and miscellaneous devices such as a
  - (1) Cycle counter or timer
  - (2) Digital thermometer
  - (3) Multirange ac and dc voltmeters and ammeters
  - (4) Multirange noninductive load resistor
  - (5) Phase shifter
  - (6) Phase angle meter
  - (7) Three-phase sequence indicator
- ! Contamination washing devices such as a portable nozzle washer truck
- ! Miscellaneous tools such as
  - (1) Binoculars
  - (2) Flashlights (insulated)
  - (3) Insulated fuse puller
  - (4) Magnifying glass
  - (5) Tape recorder, tape, and batteries
  - (6) Video camera and accessories
  - (7) Oil sample bottle and syringes and gas sample bottles

- ! Cleaning devices
  - (1) Vacuum cleaner
  - (2) Compressed air cleaner (not for use in medium or high voltage enclosures or other locations where dust could cause flashover)
- ! Miscellaneous materials as necessary to clean, wipe, paint, insulate, solder, or for other small field-fix repairs.



Chapter 1. Overview of the Guide

