RECLAMATION

Managing Water in the West

Facilities Instructions, Standards, and Techniques
Volume 4-1B

Maintenance Scheduling for Electrical Equipment

U.S. Department of the Interior
Bureau of Reclamation
Denver, Colorado

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This document establishes minimum recommended practices for maintenance of electrical equipment in Bureau of Reclamation hydroelectric power and large pumping plants. Included in this document are recommended maintenance activities, maintenance intervals, and references.

15. SUBJECT TERMS
Electrical equipment, maintenance scheduling, maintenance, annunciators and alarms, arresters, batteries, bushings, buswork, enclosures, insulators, power cables, circuit breakers, carbon dioxide systems, coupling capacitors, overhead cranes, hoists, elevators, emergency lighting, governors, motors, relays, generators

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Maintenance Scheduling for Electrical Equipment

Hydroelectric Research and Technical Services Group

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Acronyms and Abbreviations

ac	alternating current
AVR	automatic voltage regulator
CARMA™	Capital Asset and Resource Management Application
CCVT	coupling capacitor/voltage transformer
CO_2	carbon dioxide
dc	direct current
DGA	dissolved gas analysis
EHV	extra high voltage
EPSS	emergency power standby systems
FIST	Facilities Instructions, Standards, and Techniques
GSU	generator step-up
HECP	Hazardous Energy Control Program
hp	horsepower
HVDC	high voltage direct current
hipot	high potential tests
IR	infrared
kV	kilovolt
kVA	kilovoltampere
O&M	operations and maintenance
PEB	Power Equipment Bulletin
PI	Polarization Index
PO&M	Power Operation and Maintenance
PPE	personal protective equipment
PSS	power system stabilizer
RCM	reliability centered maintenance
Reclamation	Bureau of Reclamation
RSHS	*Reclamation Safety and Health Standards*
SCADA	Supervisory Control and Data Acquisition
UPS	uninterruptable power supply
V	volt
Vac	volts alternating current
Vdc	volts direct current
%	percent
>	greater than
<	less than

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1. Introduction

The recommended intervals listed in this document will supersede all intervals within existing Facilities, Instructions, Standards, and Techniques (FIST) and Power Equipment Bulletins (PEB) documents. References within the maintenance schedules identify appropriate FIST volumes and PEBs for the established electrical maintenance practices. FIST volumes are available on the World Wide Web. Power Equipment Bulletins are available only to Bureau of Reclamation (Reclamation) personnel and may be found on the Intranet.

Frequencies stated by this FIST are based on a standard time-based maintenance[1] scheduling system for which all maintenance activities will be performed. It does not address followup work generated by preventive maintenance activities. The adoption of other techniques must be implemented via a variance. These other techniques must be consciously chosen, technically sound, effectively implemented, and properly documented. The alternative to a time-based maintenance program includes a condition-based maintenance program or a reliability-centered maintenance (RCM) based program that may justify longer (or shorter) time intervals.

FIST procedures, practices, and schedules that appear in black bold and bracketed text are considered Reclamation standard practice. FIST procedures, practices, and schedules that appear in red bold and bracketed text are related to compliance issues, such as safety (Occupational Safety and Health Administration) or reliability (North American Electric Reliability Corporation) and cannot be varied from. "Recommended Intervals," listed in the tables, are recommended maximum times between maintenance cycles.

Variation from the adopted Reclamation standard practice is acceptable provided that an approved variance exists. Variances only are required when an alternative practice, procedure, or schedule does not meet the maximum time intervals listed within the Reclamation standard. Procedures, practices, and schedules that are in plain text are suggested, not a minimum operations and maintenance (O&M) activity level. Variations from suggested procedures, practices, and schedules do not require a variance.

Reclamation standard practices, including recommended intervals defined in FIST volumes, are based on power industry best practices, published standards, and Reclamation's experience maintaining equipment in hydroelectric powerplants (defined within as Reclamation Best Practice). This FIST volume includes references to other published FISTs and PEBs that may contain further instruction.

[1] Reference FIST 6-2 for other maintenance approaches.

To access Reclamation's FIST volumes:

- Printed FIST volumes:
  - Reclamation offices:
    - Phone: 303-445-2922.
    - Mail: Power Resources Office – 86-61600
  - All others, contact National Technical Information Service:
    - Internet: http://www.ntis.gov
    - Phone: 1-800-553-6847
    - Mail:
      National Technical Information Service
      5301 Shawnee Rd.
      Alexandria, VA 22312
- Digital FIST volumes in pdf:
  - http://www.usbr.gov/power/data/fist_pub.html

1.1 Maintenance

Equipment and situations vary greatly, and sound engineering and management judgment must be exercised when applying these recommendations. It should not be the sole source of information used in conducting maintenance activities. Other sources of information should be consulted (e.g., manufacturer's recommendations, unusual operating conditions, personal experience with the equipment, etc.) for references associated with these maintenance schedules.

Performing maintenance on electrical equipment can be hazardous. Electrical and mechanical energy can cause injury and death if not managed properly. All maintenance activity must be conducted in accordance with FIST 1-1, Hazardous Energy Control Program (HECP), and Reclamation Safety and Health Standards (RSHS).

1.2 Maintenance Schedules and Documentation

Complete, accurate, and current documentation is essential to an effective maintenance program. Whether performing preventive, predictive, condition-based, or reliability-centered maintenance, keeping track of equipment condition and maintenance—performed and planned—is critical.

Critical equipment is defined in the Reclamation Standards Asset and Maintenance Management Glossary of Terms (Document Control No. 01-12.0-

001). This standard defines critical equipment as any system, asset, or component whose failure could cause:

1. A loss of ability to convey water or the shutdown or load reduction of power generation
2. Loss of transmission capability or reduction in capacity
3. Serious personnel injury or violation of a safety regulation
4. An environmental hazard resulting in harm to the public, environment, or damage to public property

Maintenance schedules contained in this volume should be used as the basis for establishing a local maintenance program. This schedule states frequencies as multiyear, annually, monthly, weekly, etc.

- Weekly: Calendar week (Sunday to Saturday)
- Monthly: Calendar month (first day through the last day of the month)
- Quarterly: A calendar quarter consisting of 3 calendar months
- Semi-annually: Six calendar months
- Annually: A calendar year (January 1 through December 31)
- Multiyear: Multiple calendar years (e.g., 5-year – January 1, 2011, through December 31, 2015)

It is up to the individual office to document the tolerances associated with these stated frequencies.

Many offices use the concept of a maintenance season to describe the timeframe for performing maintenance scheduled on an annual interval. A maintenance season will be considered the period of time from October 1 of the current year through May 31 of the following year.

1.3 Job Plan Templates

Existing job plans created by the various facilities are available in the Capital Asset and Resource Management Application (CARMA™) to use as templates. Local development of complete job plans that match maintenance requirements can be expedited by using these as templates.

1.4 Power O&M Forms

Power O&M (PO&M) forms have been updated and placed on the Intranet for facility use in documenting maintenance. These forms can be filled out online and printed or printed and completed by hand. PO&M forms are available at http://intra.usbr.gov/~hydrores/pomreview/, select "Power O&M Forms" from the menu on the left or from the Reclamation forms Web site at http://intra.usbr.gov/forms/.

Word format files of the forms can be acquired from the Hydroelectric Power Technical Services Group at 303-445-2300, if modification for specific facility use is desired.

Electrical Equipment Maintenance Schedules

2. Annunciators and Alarms

2.1 General

The maintenance schedule for annunciator and alarms only pertains to circuits associated with critical equipment as defined in section 1.2 of this document.

Annunciators and alarms provide essential plant condition status information to O&M personnel. Two aspects must be considered:

1. Correct operation of annunciator and alarm devices
2. Integrity of the annunciator and alarm circuits

2.2 Maintenance Schedule for Annunciators/Alarms

Maintenance or Test	Recommended Interval	Reference
[Operational test]	**[Weekly]**	PEB 43
[Functional test]	**[2 years]**	PEB 43

3. Arresters

3.1 General

Lightning or surge arresters provide protection for important equipment from high energy surges. These arresters are static devices that require fairly infrequent maintenance. Most maintenance must take place while the associated circuit is de-energized. However, crucial visual inspections and infrared (IR) scans can take place while energized.

3.2 Maintenance Schedule for Arresters

Maintenance or Test	Recommended Interval	Reference
[Visual inspection]	**[Semi-annually]**	PEB 44
[Clean insulator and check integrity of connections]	**[6 years]**	PEB 44
[Insulation test] (Doble test – power frequency dielectric loss, direct current [dc] insulation resistance, power factor)	**[6 years]**	PEB 44

4. Batteries, Battery Chargers, and Battery Monitoring Systems

4.1 General

Battery systems provide "last resort" power for performing communication, alarm, control, and protective functions (relaying and breaker tripping) when other sources of power fail. Battery system maintenance should have highest priority. Computerized, online battery monitoring systems can be installed to supplement a maintenance program and reduce costs. Battery chargers require regular maintenance as well.

4.2 Maintenance Schedule – Flooded, Wet Cell, Lead Acid Batteries

Maintenance or Test	Recommended Interval	Reference
[Battery float voltage (charger meter)]	**[Weekly]**	FIST 3-6, section 1.3.A
[Visual inspection]	**[Monthly]**	FIST 3-6, section 1.7
[Check accuracy of charger meter]	**[Monthly]**	FIST 3-6, section 1.3.D
[Cell float voltage pilot cells with meter]	**[Monthly]**	FIST 3-6, section 1.3.E
[Cell float voltage all cells]	**[Quarterly]**	FIST 3-6, section 1.3.F
[Specific gravity pilot cells]	**[Monthly]**	FIST 3-6, section 1.4.A
[Specific gravity (10 percent [%] of all cells)]	**[Quarterly]**	FIST 3-6, section 1.4.B
[Specific gravity all cells]	**[Annually]**	FIST 3-6, section 1.4.C
[Temperature (pilot cell)]	**[Monthly]**	FIST 3-6, section 1.5.A
[Temperature (10% of all cells)]	**[Quarterly]**	FIST 3-6, section 1.5.B
[Connection resistance (this may be checked by IR scan while loaded)]	**[Annually]**	FIST 3-6, section 1.6.B
[Capacity testing]	**[5 years][1]**	FIST 3-6, section 3.2
[Safety equipment inspection]	**[Monthly]**	FIST 3-6, sections 1.7.A and 8

[1] **[Annually if capacity less than 90%.]**

4.3 Maintenance Schedule – Valve Regulated, Lead Acid (Gel Cell) Batteries

Maintenance or Test	Recommended Interval	Reference
[Battery float voltage (charger meter)]	**[Weekly]**	FIST 3-6, section 5.7.B
[Visual inspection]	**[Monthly]**	FIST 3-6, section 5.6
[Check accuracy of charger meter]	**[Monthly]**	FIST 3-6, section 5.7.E
[Cell float voltage pilot cells with meter]	**[Monthly]**	FIST 3-6, section 5.7.D
[Cell float voltage all cells]	**[Semi-annually]**	FIST 3-6, section 5.7.F
[Temperature (all cells)]	**[Quarterly]**	FIST 3-6, section 5.8.B
[Connection resistance (25% of all connections)]	**[Quarterly]**	FIST 3-6, section 5.10.B
[Connection resistance (all connections)]	**[Annually]**	FIST 3-6, section 5.9.C
[Internal resistance of all cells]	**[Quarterly]**	FIST 3-6, section 5.10.B
[Capacity testing]	**[Annually]**	FIST 3-6, section 5.11.B
[Safety equipment inspection]	**[Monthly]**	FIST 3-6, sections 5.6 and 8

4.4 Maintenance Schedule – Vented Nickel Cadmium Batteries

Maintenance or Test	Recommended Interval	Reference
[Battery float voltage (charger meter)]	**[Weekly]**	FIST 3-6, section 6.6.A
[Visual inspection]	**[Monthly]**	FIST 3-6, section 6.11.A
[Check accuracy of charger meter]	**[Monthly]**	FIST 3-6, section 6.6.D
[Cell float voltage pilot cells with meter]	**[Quarterly]**	FIST 3-6, section 6.6.E
[Cell float voltage all cells]	**[Semi-annually]**	FIST 3-6, section 6.6.F
[Temperature (pilot cell)]	**[Quarterly]**	FIST 3-6, section 6.7A
[Specific gravity all cells]	**[5 years]**	FIST 3-6, section 6.12

Maintenance Schedule – Vented Nickel Cadmium Batteries (continued)

Maintenance or Test	Recommended Interval	Reference
[Retorque intercell connections]	**[Annually]**	FIST 3-6, section 6.4.A
[Capacity testing]	**[5 years[1]]**	FIST 3-6, section 6.9.B
[Safety equipment inspection]	**[Monthly]**	FIST 3-6, sections 1.7 and 6.8

[1] **[Annually if capacity less than 90%.]**

4.5 Maintenance Schedule – Battery Chargers

Maintenance or Test	Recommended Interval	Reference
[Check each charger and verify that charger will hold the load]	**[Quarterly]**	Reclamation Standard Practice
[Check float and equalize charge settings]	**[Annually]**	Reclamation Standard Practice
[Check and clean enclosures]	**[Annually]**	Reclamation Standard Practice
[Check connection integrity]	**[Annually]**	Reclamation Standard Practice

4.6 Maintenance Schedule – Battery Monitoring System

Maintenance or Test	Recommended Interval	Reference
[Inspect unit for indication of power failure or alarms]	**[Weekly]**	PEB 49
[Verify monitoring system battery float voltage]	**[Annually]**	PEB 49
[Verify monitoring system cell voltages to manual readings at the battery cells]	**[Annually]**	PEB 49
[Verify monitoring system overall battery current]	**[Annually]**	PEB 49
[Verify monitoring system cell connection resistance]	**[Annually]**	PEB 49
[Verify monitoring system battery room temperature]	**[Annually]**	PEB 49

Maintenance Schedule – Battery Monitoring System (continued)

Maintenance or Test	Recommended Interval	Reference
[Verify cell temperature monitoring system equipment[1]]	**[Annually]**	PEB 49
[Verify cell fluid level monitoring system equipment[1]]	**[Annually]**	PEB 49
[Verify specific gravity monitoring system cell equipment[1]]	**[Annually]**	PEB 49

[1] [These functions must be tested if present and used to assist in the maintenance of the battery system.]

5. Bushings

5.1 General

Bushings are critical components of medium and high voltage circuit breakers and transformers. Bushing maintenance usually is conducted at the same time maintenance is performed on the circuit breaker or transformer, or at least during an outage on that equipment.

5.2 Maintenance Schedule for Bushings

Refer to the circuit breaker and transformer maintenance sections of this document for bushing maintenance requirements.

6. Buswork, Enclosures, and Insulators

6.1 General

Buswork conducts current from one part of the powerplant or switchyard to another. Buswork usually is constructed of flat or round copper or aluminum busbar and can be either isolated-phase or nonsegregated. Except for infrared scanning, bus maintenance must be conducted de-energized. Standoff buswork insulators provide isolation of "live" power circuits from ground and other circuits. Failure of insulators will cause a power system fault and a forced outage.

6.2 Maintenance Schedule for Buswork, Insulators, and Enclosures 5–15 Kilovolts (kV)

Maintenance or Test	Recommended Interval	Reference
[Check integrity of connections]	**[6 years]**	Reclamation Standard Practice
[Check and clean enclosures]	**[6 years]**	Reclamation Standard Practice
[Insulation test] (Hipot or Doble test – power frequency dielectric loss, dc insulation resistance, power factor)	**[6 years]**	Reclamation Standard Practice

7. Power Cables – Energized at 2 kV and Above

7.1 General

Periodic maintenance tests are needed during the life of the cable to determine whether or not there has been significant insulation deterioration due to operational or environmental conditions.

The maintenance schedule for power cables only pertains to cables associated with critical equipment as defined in section 1.2 of this document.

High potential tests (hipot) effectively reduce inservice failures from faults of the cable or its accessories. When done properly, maintenance tests can detect problems in cables that are approaching failure without accelerating the deterioration process.

Except for infrared scanning, de-energize the cable circuit before maintenance. For assistance in determining appropriate test methods and voltage levels for a specific cable installation, contact the Hydroelectric Power Technical Services Group (86-68440) at 303-445-2300.

7.2 Maintenance Schedule for Power Cables

Maintenance or Test	Recommended Interval	Reference
[Insulation test] (DC ramp test)	**[5 years]**	FIST 3-1, sections 21 and 49
[Insulating oil – dissolved gas analysis (DGA), physical, and chemical tests]	**[Annually]**	Reclamation Standard Practice

8. Carbon Dioxide Systems

8.1 General

Carbon dioxide (CO_2) systems provide fire suppression for generator and large motor windings. These systems consist of CO_2 storage bottles or tanks, piping and valves, and electrical control systems.

8.2 Maintenance Schedule for CO_2 Systems

CAUTION: CO_2 is dangerous and costly to replace. Take care to avoid inadvertent CO_2 discharge during maintenance and testing.

Maintenance or Test	Recommended Interval	Reference
[Visual inspection and check gauges]	**[Weekly]**	FIST 5-12, section 15
[Weigh CO_2 bottles]	**[Semi-annually]**	FIST 5-12, section 12.2
[Function check controls]	**[Annually]**	FIST 5-12, section 15, table 2
[Operate routing valves]	**[Annually and after painting]**	FIST 5-12, section 15, table 2
[Overall CO_2 system functional test]	**[5 years]**	FIST 5-12, section 15, table 2
[Cylinder hydrostatic test]	**[12 years] [Any discharged cylinder not hydrostatically tested in the past 5 years must be tested prior to refill.]**	FIST 5-12, section 15, table 2
[Visually inspect and functional test CO_2 discharge warning beacons and alarms]	**[Annually]**	FIST 5-12, section 15, table 2

9. Circuit Breakers

9.1 General

Circuit breakers interrupt electrical current to stop power flow both for switching operations and during fault conditions. The maintenance schedule for molded case circuit breakers only pertains to breakers associated with critical equipment as defined in this document.

- Molded case circuit breakers located in low voltage distribution panels are typically 125 to 250 volts direct current (Vdc); 120, 208, 240, 277, and 480 volts alternating current (Vac); or used for control, protection, and auxiliary power. These molded case breakers should not be loaded more than 80% of the rated value unless the breaker is specified as a continuous type capable of being loaded to 100%.

- As well as low voltage drawout and fixed air circuit breakers, 480-Vac power type molded case circuit breakers can be located in motor starter cabinets, motor control centers, station service switchgear, or similar power distribution enclosures and auxiliary power panels. Breakers in this category or class usually have some type of adjustable trip capabilities. Adjustable settings for this class of breaker may have single trip adjustments, multiple trip adjustments, or solid-state tripping devices and modules. Final time delays and trip settings need to be coordinated closely with the specific equipment it is trying to protect. Settings should be verified by the Electrical Design Group of the Denver Technical Service Center.

- Medium voltage circuit breakers generally are located in station-service metal clad switchgear or in separate enclosures as unit breakers. Examples are 4,160-Vac station service and 11.95- and 13.8-kV unit breakers. These breakers may be air, air blast, vacuum, or SF_6.

- High voltage circuit breakers are located in separate breaker enclosures, either indoors or outdoors. These are oil, air-blast, or SF_6 breakers. Examples are 115- and 230-kV breakers located in the switchyard.

- Extra high voltage (EHV) circuit breakers are not addressed in this FIST volume. Reference the manufacturer's instruction books.

Most breaker maintenance (except infrared scanning) must be performed with equipment de-energized.

9.2 Molded Case Breaker Maintenance Schedule

Maintenance or Test	Recommended Interval	Reference
[Exercising by hand]	**[6 years]**	PEB 45
[Routine Maintenance Tests]	**[6 years]**	FIST 3-16, section 2.2 PEB 45

9.3 Low Voltage (600 Volts [V] and Less [480 V] Draw Out and Fixed Air Circuit Breaker Maintenance Schedule

Maintenance or Test	Recommended Interval	Reference
[Preventive maintenance and inspection]	**[3 years[1]]**	FIST 3-16, section 3.1
[Insulation test]	**[5 years]**	FIST 3-1, section 4
[Overcurrent fault trip testing and verify settings]	**[3 years]**	Reclamation Standard Practice

[1] **[Breaker should be inspected after interrupting fault current.]**

9.4 Medium Voltage (601–15 kV Rated) Air and Air Blast Breaker Maintenance Schedule

Maintenance or Test	Recommended Interval	Reference
[Inspection]	**[Annually]**	FIST 3-16, section 4.3
[Preventive maintenance]	**[3 years]**	FIST 3-16, section 4.3
[Overcurrent trip settings and testing; test all trips]	**[3 years]**	PEB 47
[Contact resistance measurement]	**[3 years]**	PEB 47
[Breaker timing (Motion analyzer)]	**[3 years]**	PEB 47
[Insulation test] (hipot or Doble test – power frequency dielectric loss, dc insulation resistance, power factor)	**[3 years]**	PEB 47

9.5 Medium Voltage (601–15,000 Vac) Vacuum Breaker Maintenance Schedule

Maintenance or Test	Recommended Interval	Reference
[Record operations counter]	**[Monthly]**	FIST 1-11
[Inspection]	**[Annually]**	FIST 3-16, sections 4.1 and 4.5
[Preventive maintenance]	**[3 years]**	FIST 3-16, sections 4.1 and 4.5
[Insulation test] (alternating current (ac) hipot or Doble test – power frequency dielectric loss, dc insulation resistance, power factor)	**[3 years]**	FIST 3-16, section 4.5
[Contact resistance measurement]	**[3 years]**	FIST 3-16, section 4.5
Breaker timing (motion analyzer)	6 years	Reclamation Standard Practice

9.6 Medium and High Voltage SF_6 Breaker Maintenance Schedule

Maintenance or Test	Recommended Interval	Reference
[Preventive maintenance (external inspection)]	**[Annually]**	FIST 3-16, section 5 (needs to be revised)
[Record gas pressure and temperature; compare with tolerances and prior readings]	**[Monthly]**	FIST 3-16, section 5 (needs to be revised)
[Record operations counter]	**[Monthly]**	FIST 3-16, section 5 (needs to be revised)
[Visual inspection]	**[Monthly]**	FIST 3-16, section 5 (needs to be revised)
[Check contact wear]	**[6 years]**	FIST 3-16, section 5 (needs to be revised)
[Check foundation, grounds, paint]	**[6 years]**	FIST 3-16, section 5 (needs to be revised)
[Check external screws, bolts, electrical terminals tight]	**[Annually]**	FIST 3-16, section 5 (needs to be revised)

Medium and High Voltage SF_6 Breaker Maintenance Schedule (continued)

Maintenance or Test	Recommended Interval	Reference
[Contact resistance test]	**[6 years]**	FIST 3-16, section 5 (needs to be revised)
[Insulation test] (hipot or Doble test – power frequency dielectric loss, dc insulation resistance, power factor)	**[6 years]**	FIST 3-16, section 5 (needs to be revised)
[Motion analysis]	**[6 years]**	FIST 3-16, section 5 (needs to be revised)
[Moisture test on gas]	**[6 years]**	FIST 3-16, section 5 (needs to be revised)
[Verify operation and calibration of temperature and pressure switches and gauges]	**[6 years]**	FIST 3-16, section 5 (needs to be revised)
[Check lube points, heater operation, tightness of terminals, linkages, screws, bolts, latch, linkage, operating mechanism adjustments]	**[6 years]**	FIST 3-16, section 5 (needs to be revised)
[Overhaul breaker with new seals, contacts, nozzles]	**[10 years]**	FIST 3-16, section 5 (needs to be revised)

9.7 Medium and High Voltage Oil Breakers Maintenance Schedule

Maintenance or Test	Recommended Interval	Reference
[Preventive maintenance]	**[3 years]**	FIST 3-16, section 4.4 PEB 47
[Visual inspection]	**[Weekly]**	FIST 3-16 PEB 47
[Insulation test] (hipot or Doble test - power frequency dielectric loss, dc insulation resistance, power factor)	**[3 years]**	FIST 3-2 FIST 3-16 PEB 47
[Contact resistance]	**[3 years]**	FIST 3-16 PEB 47
[Breaker timing (motion analyzer)]	**[3 years]**	FIST 3-16 PEB 47
[Insulating oil, DGA, and dielectric strength]	**[Annually]**	FIST 3-16 PEB 47

10. Control Circuits

10.1 General

The maintenance schedule for control circuits only pertains to circuits of critical equipment as defined in section 1.2 of this document.

Control circuits (usually 125 Vdc, 250 Vdc, or 120 Vac) provide the path for all control functions for major equipment in the powerplant. Reliability of these circuits is paramount. Although tested during commissioning, these circuits can become compromised over time through various means:

- Modifications and construction work that unintentionally break circuit integrity or introduce wiring errors
- Age, misuse, and inadvertent damage or deterioration of wiring and connections rendering the system nonfunctional

Verifying the integrity of the control devices and interconnecting wiring requires a "functional test" of these circuits. Functional testing of control circuits may be considered completed in the course of normal plant operation. However, control circuits that rarely are used should be functionally tested on a periodic basis.

10.2 Maintenance Schedule for Control Circuits

Maintenance or Test	Recommended Interval	Reference
[Functional test control circuits]	**[2 years]**	PEB 43

11. Coupling Capacitors

11.1 General

Coupling capacitor/voltage transformers (CCVTs) are instrument transformers that provide a path for communications, metering, control, and relaying equipment without allowing power system frequency energy to pass. These are static devices requiring relatively little maintenance. Except for infrared scanning, maintenance must be conducted with equipment de-energized. This equipment normally is oil-filled and must be checked for oil leaks.

11.2 Maintenance Schedule for Coupling Capacitors

Maintenance or Test	Recommended Interval	Reference
[Visual inspection]	**[Annually]**	Reclamation Standard Practice
[Insulation test] (Doble test for oil-filled only)	**[6 years]**	FIST 3-25

12. Overhead Cranes, Hoists, Elevators

12.1 General

Cranes, hoists, and elevators are important to the O&M of the facility. Proper maintenance of cranes and hoists will ensure they are ready for service, which will reduce time and cost of maintaining other equipment.

12.2 Maintenance for Elevators

Maintaining elevators is important to the convenience and safety of staff, visitors, and the public. Also, elevators must be inspected periodically by a certified elevator inspector. Maintenance of these types of equipment is important to the safety of everyone. Elevators are required by State law to be certified by a State-licensed inspector annually in most States. Elevator maintenance is not covered in this document; for complete requirements for required maintenance, see FIST 4-1A, section 6.14, and FIST 2-10.

12.3 Maintenance Schedule for Cranes and Hoists

Mechanical maintenance of cranes, hoists, and elevators is covered in FIST 4-1A, Maintenance Scheduling of Mechanical Equipment. Only the electrical components are covered here.

The definitions and table below are excerpted from the electrical portions of FIST 4-1A. For complete requirements and references, see FIST 4-1A, sections 6.2, 6.10.7.7, and 6.10.7.8.

12.3.1 Startup and Daily Inspections

[On each shift, before operating the crane, the operator shall perform the following operations on the electrical controls:

- **Test all controls. Any controls that do not operate properly should be adjusted or repaired prior to the start of any operation.**
- **Verify operation of the primary upper-limit switch. The trip setting of the primary upper limit switches shall be checked under no load conditions by inching the block into the limit (running at low speed).]**

Maintenance	Recommended Interval	References
[Inspect and clean electromagnetic braking system]	**[Annually]**	FIST 4-1A, section 6.10.7.6
[Inspect, insulation test, and clean motors]	**[Annually]**	FIST 4-1A, section 6.10.7.7
[Inspect and clean controllers]	**[Annually]**	FIST 4-1A, section 6.10.7.8
[Inspect and clean resistor bank]	**[Annually]**	FIST 4-1A, section 6.10.7.8
[Inspect and verify settings of hoist-limit devices]	**[Annually]**	FIST 4-1A, section 6.10.7.8
[Inspect and torque bridge and trolley conductors and collectors]	**[Annually]**	FIST 4-1A, section 6.10.7.8

13. Overhead Distribution Lines

13.1 General

Distribution lines carry midvoltage electrical power. The maintenance and inspection of distribution lines and their components are required.

13.2 Maintenance Schedule for Overhead Distribution Lines

Maintenance or Test	Recommended Interval	Reference
[Visual inspection]	**[Semi-annually]**	Reclamation Standard Practice
[Inspect wood poles and crossarms]	**[12 years[1]]**	FIST 4-6

[1] If minor decay is noted, 6 years.

14. Electrical Drawings

14.1 General

Electrical drawings, especially one-line, switching diagrams, control and protection schematics, and wiring diagrams, are the most important references for the safety and O&M of a facility. Ideally, these drawings will be kept current with all modifications and replacements to plant equipment. Every effort must be made to keep electrical drawings of critical equipment up to date and should be accessible to all O&M personnel to avoid risk to equipment and staff. Critical equipment is defined in section 1.2 of this document.

The following drawings should be kept current and available:

- Critical control and protection schematics
- Critical wiring diagrams
- One-line, three-line, tripping, switching diagrams
- Relay data sheets

15. Emergency Lighting

15.1 General

Reliable plant emergency lighting is essential for personnel safety.

15.2 Maintenance Schedule for Emergency Lighting

Maintenance or Test	Recommended Interval	Reference
[Functional test (30 seconds)]	**[Monthly]**	PEB 34
[Functional test (1½ hours)]	**[Annually]**	PEB 34

16. Exciters and Voltage Regulators

16.1 General

Exciters and voltage regulators comprise excitation systems that provide appropriate direct current excitation for the field of generators and synchronous motors. Excitation systems may be rotating or static.

16.2 Maintenance Schedule for Exciters and Voltage Regulators

Components of excitation systems (e.g., transformers, circuit breakers, protective relays, annunciators, and buswork) require maintenance similar to that described in like sections of this document. Exciter and voltage regulator manufacturer's instructions may recommend supplemental maintenance tasks.

Automatic voltage regulator (AVR) performance testing ("alignment") is a specialty, requiring specialized training and unique equipment as well as knowledge of current power system stability requirements. It is recommended that performance testing be performed by qualified personnel. The Hydroelectric Power Technical Services Group (86-68440) at 303-445-2300 has qualified staff to perform these tests.

Maintenance or Test	Recommended Interval	Reference
[Visually inspect and clean exciter and voltage regulator]	**[Annually]**	Reclamation Standard Practice
[Voltage regulator model validation]	**[5 years]**	Reclamation Standard Practice
[AVR and power system stabilizer (PSS) performance testing]	**[5 years]**	FIST 1-11, sections 5.3.1 and 5.3.6

17. Facility Equipment Ratings and Protective Relaying Reviews

17.1 General

Facility equipment conditions tend to change over time. A periodic review of these conditions and settings for both normal operation and maximum fault conditions is necessary to ensure management awareness of current plant status and capabilities. For assistance in performing the facilities equipment ratings and protective relay reviews, contact the Hydroelectric Power Technical Services Group (86-68440) at 303-445-2300.

A Facility Equipment Rating Review is an evaluation of the loading and protective capabilities of all equipment listed below. The Facility Equipment Rating Review shall include the following:

- Verification of equipment ratings and load requirements and identification of the greatest load limiting component. As stated above, this review must include the complete powertrain and shall include any equipment limitations as well as turbine limitations.

- Fault current analysis and verification of interrupting capabilities of all protective equipment.

17.2 Maintenance Schedule for Facility Equipment Ratings Review

Maintenance or Test	Recommended Interval	Reference
[Arresters]	**[5 years]**	Reclamation Standard Practice
[Buswork]	**[5 years]**	Reclamation Standard Practice
[Power cables – 5 kV and above]	**[5 years]**	Reclamation Standard Practice
[Breakers – molded case]	**[5 years]**	Reclamation Standard Practice
[Breakers – low voltage (600 V and below) draw out air]	**[5 years]**	Reclamation Standard Practice
[Breakers – medium voltage (601–15 kV) air and air blast]	**[5 years]**	Reclamation Standard Practice

Maintenance Schedule for Facility Equipment Ratings Review (continued)

Maintenance or Test	Recommended Interval	Reference
[Breakers – medium voltage (601–15 kV) vacuum]	**[5 years]**	Reclamation Standard Practice
[Breakers – medium and high voltage SF_6]	**[5 years]**	Reclamation Standard Practice
[Breakers – high voltage (greater than [>] 15 kV) oil]	**[5 years]**	Reclamation Standard Practice
[Coupling capacitors]	**[5 years]**	Reclamation Standard Practice
[Distribution lines]	**[5 years]**	Reclamation Standard Practice
[Fuses]	**[5 years]**	Reclamation Standard Practice
[Personal protective grounds]	**[5 years]**	Reclamation Standard Practice
[Switches, disconnects – medium and high voltage]	**[5 years]**	Reclamation Standard Practice
[Transformers – station and distribution (less than 500 kilovoltamperes [kVA])]	**[5 years]**	Reclamation Standard Practice
[Transformers – instrument]	**[5 years]**	Reclamation Standard Practice
[Transformers – dry type power (500 kVA and larger)]	**[5 years]**	Reclamation Standard Practice
[Transformers – oil-filled power]	**[5 years]**	Reclamation Standard Practice
[Transmission lines]	**[5 years]**	Reclamation Standard Practice
[Facility energy source for blackstarting the unit]	**[5 years]**	Reclamation Standard Practice

17.3 Protective Relay Settings Review

Maintenance or Test	Recommended Interval	Reference
[Protective Relay Settings Review]	**[5 years]**	Reclamation Standard Practice

17.4 Arc Flash Hazard Analysis

Maintenance or Test	Recommended Interval	Reference
[Arc Flash Hazard Analysis]	**[5 years]**	FIST 5-14

18. Fire Detection and Alarm Systems

18.1 General

Fire detection and alarm systems provide indication and warning of fire in the facility. They are crucial to safety of personnel and the public. Correct operation also may minimize damage to equipment by an early response. Regular maintenance of systems in unstaffed facilities is particularly important because O&M staff usually is not present to detect problems.

18.2 Maintenance Schedule for Fire Detection and Alarm Systems

Maintenance or Test	Recommended Interval	Reference
[Visual inspection – batteries]	**[Monthly]**	Reclamation Standard Practice
[Lead acid battery 30-minute discharge and load voltage test]	**[Semi-annually]**	Reclamation Standard Practice
[Nickel cadmium battery 30-minute discharge and load voltage test]	**[Annually]**	Reclamation Standard Practice
[Visual inspection of detection and control equipment (fuses, interfaces, lamps, light emitting diodes, primary power supply)]	**[Annually]**	Reclamation Standard Practice
[All circuits – functional test]	**[Annually]**	Reclamation Standard Practice
[Fire extinguisher visual inspection]	**[Monthly]**	FIST 5-2, section 3.3
[Fire extinguisher maintenance]	**[Annually]**	FIST 5-2, section 3.3

19. Blackstart Generators

19.1 General

Upon complete loss of the power system (blackout), it will be necessary to establish initial generation and begin system restoration at select powerplants. Initiating (main unit) generators are referred to as system blackstart generators and are designated as such in system blackstart restoration plans. They must be able to self-start without any source of offsite electrical power and maintain adequate voltage and frequency while energizing isolated transmission facilities and auxiliary loads of other generators.

19.2 Testing Schedule for Blackstart Generators

Maintenance or Test	Recommended Interval	Reference
[Each unit tested to verify it can start and operate without being connected to the system]	**[3 years]**	Reclamation Standard Practice

20. Engine Generators

20.1 General

Engine generators that feed critical equipment at powerplants, dams, and other water-related facilities are crucial to the continued operation of these facilities during the loss of the normal power source. The maintenance schedule for engine generators only pertains to those generators associated with critical equipment as defined in section 1.2 of this document. Engine generators must be maintained and tested regularly to ensure they will perform as expected.

Engine generators provide essential power to supply critical loads in the event of loss of the normal power source. Spillway or outlet gates/valves may need to be operated for water release purposes with engine generator power. Powerplant critical loads such as sump pumps, fire pumps, and battery chargers also are dependent on reliable power. Engine generators also may be used to power unit auxiliaries and the generator excitation system for blackstart generators assigned to restore the power system after a blackout.

20.2 Maintenance Schedule for Engine Generators

Maintenance or Test	Recommended Interval	Reference
[Inspect all emergency power standby systems (EPSS) components]	**[Weekly]**	PEB 28
[Inspect and maintain generator set battery]	**[Weekly]**	PEB 28
[Exercise generator sets per PEB 28 for a minimum of 30 minutes]	**[Monthly]**	PEB 28
[Electrically operate transfer switch in both directions]	**[Monthly]**	PEB 28
[Manually exercise circuit breakers]	**[Annually]**	PEB 28
[Operate EPSS at available load for assigned class duration or minimum of 4 hours]	**[2 years]**	PEB 28

21. Generators and Large Motors

21.1 General

Generators produce electrical energy from mechanical power transmitted from the turbine. Large motors drive pumps to move water. Generators and large motors included in this section are synchronous machines performing the primary function of the power or pumping plant. Small motors are covered in Section 23, Motors (less than [<] 500 horsepower [hp]).

21.2 Maintenance Schedule for Generators and Large Motors

Maintenance or Test	Recommended Interval	Reference
[Visual inspection]	**[Weekly]**	Reclamation Standard Practice
[Visual inspection and preventive maintenance]	**[5 years]**	Reclamation Standard Practice
[Thrust and upper guide bearing insulation test]	**[Annually]**	FIST 3-11
[Stator winding and core – physical inspection]	**[5 years]**	Reclamation Standard Practice
[Stator winding – insulation test] (hipot or Doble test – power frequency dielectric loss, dc insulation resistance, power factor)	**[5 years]**	FIST 3-1
[Rotor – physical inspection]	**[5 years]**	Reclamation Standard Practice
[Rotor – insulation test]	**[5 years]**	PEB 29
Stator winding – wedge tightness measurements	Performed after rotor is removed (particularly if unit has been in operation for 20–25 years without rewedging)	FIST 3-1, section 2

22. Governors

22.1 General

Governors control generator power and frequency output by regulating water flow to the turbine. Governors may be mechanical type or electrohydraulic type having electronic controls. New digital governors substitute digital control circuits for analog electronic controls of older electrohydraulic governors. Governor manufacturer's instructions may recommend supplemental maintenance tasks.

Mechanical governor maintenance is fully described in FIST 2-3, Mechanical Governors for Hydraulic Units. Mechanical maintenance requirements for all types of governors are identified in FIST 4-1A, Maintenance Scheduling for Mechanical Equipment. The electrical maintenance schedule below supplements these mechanical maintenance requirements.

22.2 Maintenance Schedule for Governors

Maintenance or Test	Recommended Interval	Reference
[Visually inspect and clean governor control systems and cabinets]	**[Annually]**	Reclamation Standard Practice
[Governor model validation[1]]	**[5 years]**	Reclamation Standard Practice
[Control system alignment[1]]	**[5 years]**	FIST 2-3, section 7

[1] The Hydroelectric Power and Technical Services Group (86-68440) at 303-445-2300 has qualified staff to perform a control system alignment.

23. Motors (< 500 hp)

23.1 General

Motors of this type drive pumps, valves, gates, and fans. They are usually induction motors and are generally less than 500 hp but may be somewhat larger. Critical motors should be tested routinely. The maintenance schedule for motors (< 500 hp) only pertains to those associated with critical equipment as defined in section 1.2 of this document.

23.2 Maintenance Schedule for Motors

Maintenance or Test	Recommended Interval	Reference
[Visual/physical inspection]	**[Annually]**	Reclamation Standard Practice
[Insulation resistance test]	**[Annually]**	FIST 3-4, section 2.2

24. Personal Protective Equipment

24.1 General

Personal protective equipment (PPE) is used by maintenance workers to provide protection from hazardous electrical energy. Integrity of this equipment is paramount; therefore, maintenance should be scheduled and accomplished similar to equipment maintenance.

24.2 Maintenance Schedule for Personal Protective Equipment/ Hot Line Tools

Maintenance or Test	Recommended Interval	Reference
[Personal protective grounds – visual inspection]	**[Before each use]**	FIST 5-1; FIST 3-29
[Personal protective grounds – dc millivolt drop test]	**[Annually[1]]**	FIST 5-1; FIST 3-29
[Hot stick – visual inspection and cleaning]	**[Before each use]**	FIST 5-1; FIST 3-29
[Hot stick – electrical withstand test]	**[Annually[1]]**	FIST 5-1; FIST 3-29
[Gloves, sleeves, leather protectors, blankets, insulating mats, voltage test indicators, insulated and insulating hand tools – visual inspection]	**[Before each use]**	FIST 5-1; FIST 3-29
[Gloves – air test]	**[Before each use]**	FIST 5-1; FIST 3-29
[Insulated gloves – electrical withstand test]	**[Semi-annually[1]]**	FIST 5-1; FIST 3-29
[Blankets and sleeves – electrical withstand test]	**[Annually[1]]**	FIST 5-1; FIST 3-29
[Voltage test indicators, insulated and insulating hand tools – visual inspection]	**[Before each use]**	FIST 5-1; FIST 3-29
[Voltage test indicators – calibration and certification]	**[Annually[1]]**	FIST 5-1; FIST 3-29

[1]Test as service conditions require based on events that may have adversely affected the PPE's integrity.

25. Potheads

25.1 General

Potheads provide mechanical support and electrical insulation for cables. Insulating capability of these devices is important to prevent a fault and resulting forced outage. Potheads, being an integral part of a cable, generally are tested when the cable is tested.

25.2 Maintenance Schedule for Potheads

Maintenance or Test	Recommended Interval	Reference
[Visual inspection for leaks, cracks]	**[Annually]**	FIST 3-1, section 46
[Insulation test] (Doble ac loss measurement (hot collar) or dc ramp with cable	**[5 years]**	FIST 3-1, section 46

26. Relays and Protection Circuits

26.1 General

Protective relays provide critical protection functions for all types of plant equipment associated with power generation and power delivery. The protective devices must operate during abnormal plant operating conditions and, in most instances, are the last line of defense to protect equipment from a catastrophic failure. It is critical, then, that these protective devices function properly to adequately protect the associated piece of equipment and that adjustments and calibrations are routinely conducted to eliminate the possibility of the protective device misoperation. Therefore, it is imperative to conduct periodic maintenance testing to validate that the operational parameters of the functional protective device are properly set and coordinated.

Protective relays currently in use within Reclamation include electromechanical, solid-state, and microprocessor-based packages. The protection relays contained within this FIST section also shall include the lockout relay to ensure that the proper operational and functional testing of the device and associated control circuits is performed on a regular maintenance interval as prescribed in the associated table. Calibration and maintenance recommendations differ from type to type because of the different design and operating features of the protective device.

26.1.1 Calibration and Maintenance

This process usually includes removing the relay from service to a test environment. Injecting current and/or voltage into the relay and observing the response according to the manufacturer's test procedure verifies the recommended settings. Calibration of electromechanical relays is recommended frequently since operating mechanisms can wear and get out of adjustment. Calibration of solid-state and microprocessor-based relays is recommended less frequently since there are fewer ways for them to get out of calibration.

26.1.2 Relay Functional Test

This process verifies that the protective outputs of the relay (e.g., contact closures) actually operate as intended. This can be accomplished as part of the calibration procedure in most cases, but relay functional testing should be verified according to the prescribed maintenance schedule associated with the particular type of relay being tested.

26.1.3 Protection Circuit Functional Testing

Protective relays operate into protection circuits to accomplish the desired protective action. Similar to control circuits, protection circuit integrity may be compromised by construction, modifications, deterioration, or inadvertent damage. A compromised protection circuit may not provide

the system and plant protection desired. Periodic functional testing is recommended to ensure the integrity of protection circuits.

This process verifies that the entire protective "trip path" from protective relay through circuit breakers (or other protective equipment) is intact and functional. This requires actually operating the entire circuit to verify correct operation of all components.

26.2 Maintenance Schedule for Electromechanical Relays

Maintenance or Test	Recommended Interval	Reference
[Calibration maintenance]	**[2 years]**	FIST 3-8, section 12.1
[Relay functional test]	**[2 years]**	FIST 3-8, section 12.1

26.3 Maintenance Schedule for Solid-State Relays

Maintenance or Test	Recommended Interval	Reference
[Check for relay power supply indicating light]	**[Weekly]**	FIST 3-8, section 13.3
[Calibration maintenance]	**[2 years]**	FIST 3-8, section 13.1
[Relay functional test]	**[2 years]**	FIST 3-8, section 13.1

26.4 Maintenance Schedule for Microprocessor Relays

Maintenance or Test	Recommended Interval	Reference
[Check for relay trouble light]	**[Weekly]**	Reclamation Standard Practice
[Relay functional test[1] Monitored[2]]	**[6 years]**	FIST 3-8, section 14.2
[Relay functional test[1] Unmonitored[2]]	**[4 years]**	FIST 3-8, section 14.2

[1] Relay functional testing of microprocessor relays shall include the testing of the digital and analog inputs and outputs.

[2] Monitored – A microprocessor relay is considered unmonitored unless facility monitoring meets all the following requirements:

- Real time monitoring and alarm of the relay internal self-monitoring alarm
- Real time monitoring and alarm for dc supply or power supply failure
- Monitoring of trip coil continuity (either real time or via red light check interval)
- If applicable, monitoring of protection telecommunication system (real time or periodically per test interval)
- Monitoring dc battery voltage (real time or per test interval)
- Verification of relay inputs and outputs (real time or per test interval)

26.5 Maintenance Schedule for Lockout Relays

Maintenance or Test	Recommended Interval	Reference
[Coil continuity – red light check]	**[Daily]**	FIST 1-11, section 7.3; FIST 3-8, section 9.4
Clean and lubricate (removable cover type only)	6 years	PEB 6 FIST 3-8, section 9.2
[Contact operation functional tests]	**[2 years]**	PEB 6 FIST 3-8, section 9.2

26.6 Maintenance Schedule for Protection Circuits

Maintenance or Test	Recommended Interval	Reference
[Protection circuit functional tests]	**[2 Years]**	FIST 3-8, section 9

27. SCADA Systems

27.1 General

Supervisory Control and Data Acquisition (SCADA) systems are computer-based, real-time control systems. Theses SCADA systems are used to monitor and control water and power operations at a variety of Reclamation facilities. These systems operate continuously and, in many ways, are self-diagnosing; but some maintenance and testing of these devices are necessary to ensure system integrity and identify potential failures. As well, circuits that are infrequently used may require periodic functional testing to ensure they will be operational when the need arises.

Although the SCADA FIST 3-33 covers requirements for management, operational, maintenance, and technical support training and documentation requirements, the section listed below will focus only on the requirements associated with maintenance and general operational inspections.

27.1.1 Input and Output Circuit Functional Testing

The functional testing process (also considered points checks) verifies the correct operation of all components within the circuit path. Therefore, functional testing requires activation of an initiating device (in the field), monitoring of the point into the SCADA system for correct operation, and activation of the correct SCADA output point as anticipated.

27.2 Maintenance Schedule for SCADA Systems

Maintenance or Test	Recommended Interval	Reference
[Lamp integrity tests]	**[Monthly]**	Reclamation Standard Practice
[Enclosure physical inspections]	**[Monthly[1]]**	Reclamation Standard Practice
[Circuit functional tests (all inputs and outputs)]	**[2 years]**	Reclamation Standard Practice
[SCADA power supplies and uninterruptible power supply [UPS] systems[2]]	**[3 years]**	Reclamation Standard Practice
[Communications testing[3]]	**[6 years]**	Reclamation Standard Practice

[1] Physical inspection may be required more often if the SCADA equipment is located in areas that would warrant a more frequent inspection schedule.

[2] Station battery systems used to supply power to the SCADA system and equipment shall be tested according to FIST 3-6, Storage Batteries Maintenance and Principles.

[3] Communications systems associated with the SCADA system shall be tested in conjunction with the circuit functional tests (points checks) to test all input and output points.

28. Security Systems

28.1 General

The goal of this section is not to duplicate requirements for physical security addressed in other Reclamation plans, documents, or policies but rather to identify and document requirements and procedures to properly operate and maintain the security equipment at Reclamation facilities. Security systems at powerplants are critical for protection of Reclamation personnel, the public, and facility equipment. Most security systems are site specific, including many different manufacturers of cameras, receivers, card key systems, gates, gate controls, and other types of equipment.

These systems operate continuously and, in many ways, are self-diagnosing; but some maintenance and testing of equipment associated with these systems are necessary to ensure system integrity and identify potential failures. As well, circuits that are infrequently used may require periodic functional testing to ensure they will be operational when the need arises. Therefore, it is imperative that personnel at each plant understand and follow standard operating procedures and instructions for maintenance and testing the particular installed equipment.

28.2 Maintenance Schedule for Security Systems

Maintenance or Test	Recommended Interval	Reference
[Visually inspect and clean all security system control cabinets and camera equipment]	**[Annually]**	Reclamation Standard Practice
[Alarm circuit functional tests]	**[Annually]**	Reclamation Standard Practice
[Vehicle barrier and gate control functional tests]	**[Annually]**	Reclamation Standard Practice
[Key card control circuit functional tests]	**[Annually]**	Reclamation Standard Practice
[Camera and monitor control circuit functional tests]	**[Annually]**	Reclamation Standard Practice
[Security system power supplies and UPS systems[1]]	**[3 years]**	FIST 3-6

[1] Station battery systems used to supply power to the security system and equipment shall be tested according to FIST 3-6, Storage Batteries Maintenance and Principles.

29. Switches, Disconnect – Medium and High Voltage

29.1 General

When open, disconnect switches permit isolation of other power system components, thus, facilitating safety during maintenance procedures. Disconnect switches may be manually or motor operated and, in some cases, may integrate fuse protection. Preventive maintenance shall be considered synonymous with any type of general maintenance, major maintenance, or overhaul functions to be performed on the equipment.

29.2 Maintenance Schedule for Disconnect Switches

Maintenance or Test	Recommended Interval	Reference
[Visual inspection]	**[Semi-annually]**	Reclamation Standard Practice
[Preventive maintenance]	**[6 years]**	Reclamation Standard Practice

30. Switchyard/Substation Ground Connections

30.1 General

Grounding is an essential part of protecting staff and equipment from high potential caused by electrical faults. Grounding conductors of switchyard equipment and gate structures are subject to failure due to corrosion, loose connections, and mechanical damage. Grounding also may be compromised during equipment addition and removal or other construction type activities. Verifying grounding system integrity through periodic testing is an important maintenance activity. The Hydroelectric Power and Technical Services Group (86-68440) at 303-445-2300 has qualified staff to perform ground system testing.

30.2 Maintenance Schedule for Switchyard/Substation Ground Connections

Maintenance or Test	Recommended Interval	Reference
[Visual/physical inspection]	**[Annually]**	PEB 26
[Grounding electrode and substation/switchyard grid tests]	**[6 years]**	Reclamation Standard Practice
[Ground loop impedance test]	**[6 years]**	Reclamation Standard Practice

31. Switchyards, Substations, and Transmission Lines

31.1 General

Switchyards, substations, and transmission lines are used to deliver high voltage electrical power.

31.2 Maintenance Schedule for Switchyards and Substations

Maintenance or Test	Recommended Interval	Reference
[Visual inspection]	**[Semi-annually]**	Reclamation Standard Practice
[Vegetation management]	**[Annually]**	Reclamation Standard Practice

31.3 Maintenance Schedule for Transmission Lines

Maintenance or Test	Recommended Interval	Reference
[Visual inspection]	**[Semi-annually]**	Reclamation Standard Practice
[Vegetation management]	**[Annually]**	Reclamation Standard Practice

32. Thermographic Maintenance (Infrared Scanning)

32.1 General

Throughout this FIST volume, infrared scanning is recommended as a regular maintenance procedure. Infrared scanning and analysis have become an essential diagnostic tool throughout all industries and have been used in Reclamation to detect many serious conditions requiring immediate corrective action. Several forced outages already have been avoided. Infrared scanning is nonintrusive and is accomplished while equipment is in service. It can be used not only for electrical equipment but also to detect mechanical and structural problems. Therefore, IR scanning is recommended as a regularly scheduled maintenance procedure. Effective IR scanning and analysis require the following:

- The scanning equipment (IR camera and accessories) must be high quality and correctly maintained and calibrated.
- The IR camera operator should be trained on use of the equipment.
- The IR system operator should document results of problems found.

Maintenance or Test	Recommended Interval	Reference
Arresters	Annually	Reclamation Standard Practice
Flooded, wet cell, lead acid batteries – cells and connections	Annually	Reclamation Standard Practice
Valve regulated, lead acid (gel cell) batteries – cells and connections	Quarterly	Reclamation Standard Practice
Vented nickel cadmium batteries – cells and connections	Annually	Reclamation Standard Practice
Battery chargers – cables and connections if visible	Annually	Reclamation Standard Practice
Fuse	Annually	Reclamation Standard Practice
Buswork and enclosures 5–15 kV – if visible	Annually	Reclamation Standard Practice
Buswork insulators – if visible	Annually	Reclamation Standard Practice

Thermographic Maintenance (Infrared Scanning) (continued)

Maintenance or Test	Recommended Interval	Reference
Medium and high voltage cables solid dielectric and oil-filled – if visible	Annually	Reclamation Standard Practice
Coupling capacitors – if visible	Annually	Reclamation Standard Practice
Molded case feeder and critical control and protection breakers – if visible	Annually	Reclamation Standard Practice
Low voltage (600 V and less [480 V]) draw out air breaker – if visible	Annually	Reclamation Standard Practice
Medium voltage (601–15 kV rated) air and air blast breaker - if visible	Annually	Reclamation Standard Practice
Medium voltage (601–15,000 Vac) vacuum breaker – if visible	Annually	Reclamation Standard Practice
Medium and high voltage SF_6 breaker – if visible	Annually	Reclamation Standard Practice
High voltage (> 15,000 Vac) oil circuit breaker – if visible	Annually	Reclamation Standard Practice
Exciters and voltage regulators	Annually	Reclamation Standard Practice
Commutator and brushes	Annually	Reclamation Standard Practice
Fuses	Annually	Reclamation Standard Practice
Motors (< 500 hp)	Annually	Reclamation Standard Practice
Switches, disconnect – medium and high voltage	Annually	Reclamation Standard Practice
Station/distribution transformers less than 500 kVA	Annually	FIST 3-30

Thermographic Maintenance (Infrared Scanning) (continued)

Maintenance or Test	Recommended Interval	Reference
Instrument transformers	Annually	FIST 3-30
Dry-type power transformers – 500 kVA and larger	Annually	FIST 3-30
Oil-filled power transformers	Annually	FIST 3-30
Electrical connections	Annually	Reclamation Standard Practice
Switches (disconnect)	Annually	Reclamation Standard Practice
Switchgear	Annually	Reclamation Standard Practice
Transmission lines	Annually	Reclamation Standard Practice
Distribution lines	Annually	Reclamation Standard Practice

33. Transducers/Meters/Switches

33.1 General

Transducers convert electrical and mechanical data into electrical signals that may be used as inputs into monitoring systems. The accuracy and reliability of transduced signals are of extreme importance when used for metering, alarm, control, and protective functions. Examples of transduced data include:

- Bearing oil level or temperature read by a meter or scanning equipment
- Megawatt or megavars as input to the SCADA system

Meters indicate, and sometimes record, electrical and mechanical quantities. Some meters also transmit stored data to SCADA or other systems. The accuracy and reliability of meter indication are important to ensure correct power and water systems operation.

Switches can be actuated by a number of different devices including, but not limited to, pressure, flow, temperature, position, etc. These switches can be used in protection, control, or alarm circuits. The accuracy and reliability of these switches are important to ensure correct power and water systems operation.

33.2 Maintenance Schedule for Transducers/Meters/Switches

Maintenance or Test	Recommended Interval	Reference
[Test and calibrate]	**[3 years]**	Reclamation Standard Practice

34. Transformers

34.1 General

Transformers convert electrical power from one voltage level to another. Transformer reliability is essential to the continued delivery of the facility's services.

34.2 Instrument Transformers

34.2.1 General

Instrument transformers convert power system level voltages and currents to levels safe to feed meters and other low voltage and current devices. Voltage or potential transformers generally have output in the 240/120-Vac range, while current transformers have output in the 1- to 5-ampere range. Voltage transformers may be integral to other equipment or stand alone. Typically, current transformers are integral to other equipment (circuit breakers, transformers) but occasionally may be stand alone (e.g., 500-kV switchyard at Grand Coulee).

Over the course of time, instrument transformers (particularly current transformers) may become overburdened with the addition of more devices in the secondary circuit. This may lead to saturation during a fault that may cause the relay to misoperate. Periodical measuring of the secondary burden and comparing it to the rated burden will indicate if this is a problem.

Instrument transformer secondary wiring always should be checked for integrity after any work that may have disrupted these circuits.

Oil-filled instrument transformers may fail catastrophically and cause hazards to workers if not maintained properly. Any oil leak should trigger immediate Doble testing and replacement planning.

34.2.2 Maintenance Schedule for Instrument Transformers

Maintenance or Test	Recommended Interval	Reference
[Visual inspection]	**[Annually]**	Reclamation Standard Practice
[Burden measurements]	**[6 years]**	FIST 3-8, section 5.1
[Insulation test if oil-filled] (Doble test – power frequency dielectric loss, dc insulation resistance, power factor)	**[6 years]**	Reclamation Standard Practice
[Current transformer excitation test]	**[6 years]**	FIST 3-8, section 6

Maintenance Schedule for Instrument Transformers (continued)

Maintenance or Test	Recommended Interval	Reference
[Verify that acceptable instrument transformer output signals are received at the protective relay]	**[6 years]**	FIST 3-8
[Instrument transformer secondary grounding and insulation resistance tests]	**[6 years]**	FIST 3-8, sections 5.2 and 5.3

34.3 Transformers Rated Less Than 500 kVA

34.3.1 General

Station and distribution transformers generally operate at relatively low voltages and power ratings. They provide step-down power to supply plant auxiliary loads—for example, a 480- to 240/120-Vac transformer that supplies power to auxiliary lighting panels.

The maintenance schedule for transformers rated less than 500 kVA only pertains to transformers associated with critical equipment as defined in section 1.2 of this document.

34.3.2 Maintenance Schedule for Transformers Rated Less Than 500 kVA

Maintenance or Test	Recommended Interval	Reference
[Insulation test if oil-filled] (Doble test – power frequency dielectric loss, dc insulation resistance, power factor)	**[5 years]**	FIST 3-30
[DGA if oil-filled]	**[Annually]**	FIST 3-30

34.4 Dry-Type Power Transformers Rated 500 kVA and Larger

34.4.1 General

Dry-type power transformers are air cooled and have no liquid insulation. Typical applications include station service and excitation system transformers.

The maintenance schedule for dry-type power transformers rated 500 kVA and larger only pertains to transformers associated with critical equipment as defined in section 1.2 of this document.

34.4.2 Maintenance Schedule for Dry-Type Power Transformers

Maintenance or Test	Recommended Interval	Reference
[Visual inspection/cleaning]	**[Annually]**	FIST 3-30
[Check fan operation]	**[Annually]**	FIST 3-30
[Clean fans and filters]	**[Annually]**	FIST 3-30
[Insulation test] (Megger® or hipot test)	**[5 years]**	Reclamation Standard Practice

34.5 Oil-Filled Power Transformers Rated 500 kVA and Larger

34.5.1 General

Oil-filled power transformers rated 500 kVA and above generally deliver power to and from the main units of the facility—for example, generator step-up transformers. These transformers usually are located outside the building in a transformer bay or in a switchyard.

34.5.2 Maintenance Schedule for Oil-Filled Power Transformers

Maintenance or Test	Recommended Interval	Reference
[Transformer physical inspection]	**[Annually]**	FIST 3-30
[Bushings – visual inspection]	**[Quarterly]**	FIST 3-30
[Bushings – visual inspection]	**[5 years]**	FIST 3-30
[Bushings – check oil level]	**[Weekly]**	FIST 3-30
[Bushings – cleaning]	**[5 years]**	FIST 3-30
[Transformer and bushings – Insulation test] (Doble test – power frequency dielectric loss, dc insulation resistance, power factor)	**[5 years]**	FIST 3-2 FIST 3-30
[Transformer excitation current test]	**[5 years]**	FIST 3-30

Maintenance Schedule for Oil-Filled Power Transformers (continued)

Maintenance or Test	Recommended Interval	Reference
[Insulating oil – DGA, physical, and chemical tests]	**[Annually]**	FIST 3-30
[Cooling fans – inspect and test]	**[Annually]**	FIST 3-30
[Oil pumps and motors – inspect and test]	**[Annually]**	FIST 3-30
[Heat exchangers – inspect]	**[Annually]**	FIST 3-30
[Conservator and bladder – inspect]	**[5 years]**	FIST 3-30
[Top oil and winding thermometer inspection]	**[Annually]**	FIST 3-30
[Top oil and winding thermometers calibration]	**[5 years]**	FIST 3-30
[Oil level indicator operation]	**[5 years]**	FIST 3-30
[Pressure relief device]	**[5 years]**	FIST 3-30
[Sudden pressure relay]	**[5 years]**	FIST 3-30

35. Transformer Fire Suppression Systems

35.1 General

Reclamation generator step-up (GSU) transformers normally contain thousands of gallons of flammable transformer oil. Reclamation requires fire suppression for mineral oil-filled GSU transformers.

35.2 Maintenance Schedule for Transformer Fire Suppression Systems

Maintenance or Test	Recommended Interval	Reference
[Visual inspection]	**[Annually]**	FIST 3-32, section 10
[Functional test fire suppression system]	**[Annually]**	FIST 3-32, section 10

36. Calibration of Test Equipment

36.1 General

It is critical to ensure the proper operation and calibration of test equipment per the manufacturer's recommended schedule. If test equipment has not been calibrated to ensure accurate performance, then it may not be reliable to perform these critical functions accurately. Test equipment includes all equipment that is used to check the calibration or proper operation of other equipment. Calibration is required per the recommended interval in table 36.2 for equipment used to take measurements for test results to show compliance with regulatory requirements. These measurements need to be traceable to National Institute of Science and Technology (NIST) standards. Best practice recommends that instruments used to verify accuracy of plant equipment should be calibrated in accordance with the manufacturer's recommendations.

Most manufactures recommend sending test equipment back to the manufacturer for calibration. However, this may not be necessary. For example, a craftsman can verify the accuracy of a relay test set with a calibrated multimeter or similar device to compare the output voltages and currents of the relay test set to the reading of the meter. The craftsman must use a multimeter or similar device that has been calibrated within the required interval. Such test procedures and/or equipment calibration certificates should be documented and filed for future reference.

36.2 Maintenance Schedule for Calibration of Test Equipment

Maintenance or Test	Recommended Interval	Reference
[Calibrate test equipment[1]]	**[Annually[2]]**	Reclamation Standard Practice
[Verify accuracy of test equipment]	**[Annually]**	Reclamation Standard Practice

[1] It is only necessary to calibrate equipment required to verify the accuracy of a test instrument. A test instrument that cannot be verified as accurate by other equipment must be calibrated according to table 36.2.

[2] If the equipment manufacturer recommends a longer interval, a variance documenting this fact can be put in place to extend the calibration interval.