An Introduction to Electrical Safety:
Substations and Switchgears

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1. SUBSTATION WORK.

1.1 PURPOSE OF SUBSTATION. A substation provides a protected area for switching power circuits and may include transforming power from one voltage to another. For the purposes of this discussion, substation refers to substations and switching stations. A substation presents an inherent safety hazard because usually only some portions of the substation apparatus can be deenergized for maintenance. For safe operation and maintenance, a thorough knowledge of the substation, including aerial and underground line connections, is necessary. Systems are designed to be safe to operate if maintained properly. Operating safely requires maintenance to be done in a manner that eliminates risks and requires knowledge of the work area, its hazards, and its design basis.

1.2 DIAGRAMS AND SCHEMATICS. Electrical diagrams and schematics of the substations must be available and up-to-date. Diagrams and schematics must be studied to understand the operation of the systems and the location and connections of all circuits. Protective devices, alarms, and interlocking circuits all are intended to protect the system. The electrical worker must understand where, why, how, and when blocking protective devices can maintain safe working conditions.

1.3 ENGINEERING GUIDANCE. Diagrams and schematics must be kept up to date under the supervision of the facility's engineering staff. Engineering staff guidance must be sought when performing maintenance on complex systems. Engineering input is mandatory if the maintenance work involves additions or changes to the power and control systems involved.

1.4 SYSTEM OPERATION. System single line diagrams must be permanently mounted at each substation. When Safe Clearance switching operations are performed, mimic buses on a switchgear can be helpful as a visual indication of the lines or equipment being operated.

1.4.1 PROTECTIVE DEVICES. Protective devices within the system, such as relays, circuit breakers, and fuses, must retain, respectively, their correct coordination settings or be of the proper size and type. Always record previous data so that unintended changes in system coordination are not made.

1.4.2 ALARMS. System alarms, if blocked during maintenance, must be returned to their correct operating condition at the completion of the maintenance.

1.4.3 INTERLOCKING. Interlocking is used to maintain proper electrical operation in the case of a circuit loss or switching change. Interlocking provisions must be fully understood so to eliminate the danger of electrical feedback from another source, possible paralleling of two unsynchronized sources, or other unsafe operations. Interlocks, if bypassed during maintenance, shall only be done by qualified persons and shall be returned to their correct operating condition at the completion of the maintenance.

1.5 ABNORMAL CONDITIONS. Maintenance accomplished after the occurrence of fault conditions that interrupted normal service imposes higher than usual maintenance risks. Faulty energized equipment and lines must always be placed in an electrically safe work condition before any work is done. All abnormal operating equipment and electrical components must be deenergized, locked and tagged tested, and grounded or isolated (whichever is applicable).

1.6 DEFECTIVE EQUIPMENT. Electrical apparatus found to be in a dangerous condition or not working properly must be removed from service immediately and tagged. Subsequently, a complete report on the defective equipment must be provided by the worker to the authorized individual-in-charge, the same day if feasible.

1.6.1 DEFECTIVE EQUIPMENT REMOVED FROM SERVICE, such as: distribution, potential, and current transformers; capacitors; and surge (lightning) arresters must be positively identified by an authorized and qualified individual before they are put in

storage. Existing defective equipment in storage or at any other location must also be clearly identifiable.

1.6.2 IDENTIFY DEFECTIVE EQUIPMENT by painting a large red “X” on the body (not on the top) of the equipment. The red X must remain on such equipment until it has been repaired or until it has been properly disposed of. Local policy may dictate use of their preferred defective equipment identification marking.

1.6.3 IT MUST BE CONSIDERED a serious neglect of duty and willful disobedience of instructions for a worker to deface in any way the identification marking on defective equipment or to place such equipment in service while so identified. The worker in charge of repairing any piece of defective equipment must be the only person authorized to remove the defective markings, and then only after all repairs have been made and the equipment has passed all required testing.

2. SWITCHING. Opening or closing a power switch can expose the electrical worker to some degree of hazard. A mishap might occur if a switch is closed when a fault is still present on the line. To prevent a mishap, the authorized individual must prepare a switching sequence and identify all load isolation requirements. All switches operated in the switching sequence must be correctly identified. The electrical worker will review the manufacturer's operation manual for any switch that is unfamiliar, and all safety steps listed in the operation manual will be accomplished before opening or closing the switch.

WARNING
Switches can fail during switching operations, creating arc flash hazards. Wear arc rated clothing and/or switching suits during these operations in accordance with Owner requirements.

Switching operations above 600 volts may require a Switching Order. Switching operations include changing the position of circuit breakers, fused equipment, switches, and other devices.

2.1 AIR SWITCHES. Many air switches cannot be opened if there is a load on the line, a large magnetizing current from a transformer, or a heavy charging current from an unloaded transmission line. Understand the interrupting capability of each switch being operated.

2.1.1 DISCONNECT SWITCHES. Disconnect switches of the non-load break-type must not be used to interrupt loads and magnetizing currents, unless an engineering review has determined the disconnect switch can safely interrupt the actual current. Switch sticks will be used when necessary to provide the minimum working and clear hot stick distances. Assume disconnect switches are of the non-load break-type unless you have positive proof otherwise. Operate non-load break-type switches on the following basis:

2.1.1.1 DISCONNECT SWITCHES can be used to open an energized line when not under load.

2.1.1.2 DISCONNECT SWITCHES can be used to open sections of deenergized lines where these lines parallel other high-voltage lines. Use caution because induced voltages can build up in the deenergized line and create dangerous switching conditions.

2.1.1.3 EVALUATE THE HAZARD before using disconnect switches to open a tie line or to break two parallel high-voltage lines.

2.1.2 AIRBREAK SWITCHES. Gang-operated airbreak switches equipped with arcing horns may be rated for load-break operation, or they may only be rated for interrupting the magnetizing current of transformers or the charging current of lines, or to make and break line parallels. Provide ground mats for the operator to stand on for all substation airbreak switches when operating. Either fixed or portable small iron-mesh mats must be used. The mats must be electrically connected to the operating rod and the substation ground grid to equalize the ground gradient and prevent any potential differences in case of insulation failure or flashover. Appropriate arc flash rated personal protective equipment, rubber gloves, and hot sticks must be used when operating airbreak switches.

2.1.2.1 THE HINGES OF AIRBREAK SWITCHES must be sufficiently stiff (and kept in this condition) so that after the blades have been turned into the open position, they will not accidentally fall back on their line-side energized clips.

2.1.2.2 THE SWITCH MUST BE INSPECTED after it has been opened to see that all blades have opened the proper distance. Single-throw airbreak switches must be opened to the maximum amount. Double-throw airbreak switches must be opened so that the blades clear both sides of the switch by the same amount.

2.1.2.3 INSTALL LOCKS on all airbreak switch-operating mechanisms. Airbreak switches will be kept locked except when opening or shutting the switch.

2.1.3 INTERRUPTER SWITCHES. Interrupter switches are designed to be opened under load. Metal-enclosed interrupter switches have sometimes been used in place of circuit breakers as a more economical switching method.

2.1.4 INCHING. The method of opening manually operated non-load break-type disconnects in a gradual manner is called inching, when the operator believes there is no load current. If a small arc occurs from the charging current, it has been assumed that a cautious opening would allow the arc to be broken; however, inching is dangerous and is prohibited.

2.2 OIL SWITCHES. The consequences of operating a faulty oil switch, or closing into a faulted circuit with an oil switch are likely to be catastrophic and, often fatal. Switching procedures will be used to make sure that no energized oil switch is operated while workers are in the vicinity. Unless the switch has been equipped for remote operation (at least 20 ft (6.1 m)) away, the switch must be completely deenergized by an upstream device before switching. The switch must be locked out and tagged out before allowing maintenance. In addition, do not operate any energized high-voltage oil switch unless routine maintenance has been performed within the past year. The switch must be deenergized at the nearest upstream device following the lockout/tagout procedures of Chapter 6 herein. Once maintenance has been performed on the switch, the switch shall be considered operational following the guidelines of this paragraph. Oil switches must incorporate a mechanical stop to prevent inadvertent operation to ground. Any abnormalities or defects discovered in any oil switch must be reported to an authorized individual.

2.3 SF_6 SWITCHES. Follow all precautions specified by the manufacturer. Inspect the switch before operating it for any signs of degradation, such as low SF_6 pressure or signs of SF_6 leakage (accumulation of powder around seals). Verify that the SF_6 pressure gauge is in the green zone before operating the switch; operating a switch with low SF_6 pressure can result in internal flashovers that will damage the equipment and cause personal injury. Before energizing the switchgear for first use, verify that the shipping

caps on all bushings and bushing wells have been replaced with elbows or insulated protective covers or plugs. The switchgear must be deenergized and grounded prior to conducting any maintenance, SF_6 sampling, or SF_6 filling procedures.

2.4 OIL-FILLED VACUUM SWITCHES. Follow all precautions specified by the manufacturer. Inspect the switch before operating it for any signs of degradation, such as oil leakage; operating a switch without oil can result in internal flashovers that will damage the equipment and cause personal injury. Before energizing the switchgear for first use, verify that the shipping caps on all bushings and bushing wells have been replaced with elbows or insulated protective covers or plugs. The switchgear must be in an electrically safe work condition prior to conducting any maintenance, oil sampling, or oil filling procedures.

3. FUSES

WARNING
Fuses might fail during handling if energized, creating arc flash hazards. Wear arc rated clothing or switching suits when changing energized fuses in accordance with Owner requirements.

3.1 CHARACTERISTICS. A fuse is a single-phase device. Fuses can be subject to partial melting or damage by currents that might not have been of sufficient magnitude to blow the fuse.

3.2 FUSE HANDLING. Fuses must normally not be handled, except when they need to be replaced. Pull them briskly, and remove completely. Use safety glasses and face shields when replacing fuses in primary fuse cutouts; do not use your free arm in an attempt to shield your eyes from possible flashes. The worker changing the fuses must stand firmly on a level surface. Where operating in an elevated position, the worker will be secured with a safety lanyard/harness to prevent a slip and fall if there is a flash. Use live-line tools to remove energized fuses. Whenever possible, deenergize the circuit before removing a fuse.

3.3 OPERATION OF ENERGIZED FUSES. Open all lines protected with energized fuses in the same manner as for air switches. Deenergize non-load-break type installations. For load-break installations, wait for a short time after fuse replacement in order to allow the fuse to interrupt any fault condition that might remain prior to the fuse replacement.

3.4 OPEN FUSE HOLDER. Do not leave outdoor fuse holders open for an extended period of time. Water damage/moisture or warping could make closing them dangerous, or degrade their protective ability.

3.5 CLOSED-POSITION FUSE LOCKING. Follow the fuse or switch manufacturer's instructions, as appropriate, to be sure that the fuse is securely locked, latched, and held fast in a closed position.

3.6 BYPASSING. Do not bridge fuses or fuse cutouts internally. Where it is necessary to bypass fused conductors, use plainly visible external jumpers and remove them as soon as possible.

4. ENERGY STORING PROTECTIVE DEVICES.

4.1 ELECTRICAL CHARGE.

WARNING

Protective devices such as surge arresters, choke coils, and capacitors store electrical charges as a byproduct of their protective mechanism. This stored charge must be discharged to ground before such devices can be considered deenergized. Always wear appropriately rated personal protective equipment, including eye/face protection when deenergizing or energizing these devices and use appropriate PPE in accordance with Owner requirements.

4.2 SURGE ARRESTERS. A surge arrester limits overvoltages and bypasses the related current surge to a ground system that absorbs most of the energy. An overvoltage condition can be caused by a fault in the electrical system, a lightning strike, or a surge voltage related to load switching. All surge arrester equipment must be considered as loaded to full circuit potential, unless it is positively disconnected from the circuit. Be sure the permanent ground conductor is intact before any work is performed.

4.2.1 HIGH-VOLTAGE SUBSTATION and at-grade surge arresters must always be provided with screens or fences to prevent possible contact while parts of the surge arresters may be live. The screen or fence must have a gate large enough to permit the removal of individual units. The gate must be provided with a lock and an authorized person must keep the key.

4.2.2 SURGE ARRESTERS must never be touched or approached, unless they are completely disconnected from all live lines and live equipment, and all parts have been discharged to ground and effectively grounded.

4.2.3 HORN GAP SWITCHES must be fully opened and completely separated from all live lines and equipment whenever it is necessary to work near a surge arrester.

4.2.4 IF THE FIRST ATTEMPT to disconnect a surge arrester is unsuccessful, wait 2 or 3 minutes before making another attempt so not to cause an internal fault.

4.3 CHOKE COILS. Choke coils are inductors that operate in a manner similar to surge arresters, except that they operate on over-frequency rather than over-voltage.

4.4 CAPACITORS. Capacitors consist of an electrical condenser housed in a suitable container. Power capacitors are used to provide power factor correction. Coupling capacitors are used for coupling communication circuits to metering circuits. Because capacitors can hold their charge, they are not electrically deenergized immediately after being disconnected from an energized line. Capacitors on electric lines must be provided with discharge devices to discharge the voltage to 50 V or less, within 5 minutes after the capacitors have been completely disconnected from the circuit. Wear appropriate levels of PPE.

4.4.1 DISCHARGE CIRCUITS are intended to discharge capacitors after the circuit is deenergized. Since there could be no indication that the circuit is burned out or otherwise not functioning, always assume capacitors are fully charged until tested.

4.4.2 LINE CAPACITORS removed from service for any purpose must be considered at full or higher voltage, until the terminals have been shorted together and discharged by an approved method. Do not short terminals until capacitors have been deenergized for at least 5 minutes to allow time for the voltage level to reduce.

4.4.3 IT IS NOT SAFE to use fuses or disconnect switches to disconnect large capacitor banks (above 60 kilovolt-reactive single-phase, or 180 kilovolt-reactive three-phase). Circuit breakers or switches designed specifically for this purpose must be used.

4.4.4 AFTER DISCONNECTING all capacitor banks, wait 5 minutes. Short together and ground all terminals; ensure the neutral is grounded. All operations must be performed using rubber gloves and a hot stick.

4.4.5 GROUNDS AND TERMINAL SHORTS on capacitors must be left on until the work is completed.

4.4.6 BARRICADE THE WORK AREA as a safety measure for other workers, when working on or testing capacitors in the shop.

4.4.7 CAPACITORS made before 1979 usually contain PCBs. Observe required precautions for hazardous materials if the case is ruptured or any liquid is visible on the outside of the case.

4.5 COUPLING CAPACITORS. These capacitors have a high impedance, which results in a long discharge period. This characteristic of coupling capacitors is typically overlooked, which makes them particularly hazardous to personnel if not properly grounded. To minimize shock hazard follow the precautions below:

4.5.1 A COUPLING CAPACITOR must always have a shorting wire installed.

4.5.2 DURING MAINTENANCE, a grounding wire must be connected to each exposed metal terminal that a worker could contact. Grounding wires must be left in place for the entire duration of maintenance.

5. INSTRUMENT TRANSFORMERS.

5.1 POTENTIAL (VOLTAGE) TRANSFORMERS (PT).

5.1.1 PTS PROVIDE a means of obtaining a low voltage from a higher voltage circuit. They are designed and selected to operate within certain accuracy limits and burdens.

5.1.2 REPLACEMENT TRANSFORMERS must have characteristics identical with the original units.

5.1.3 THE CASE and one of the windings of the low-voltage side of voltage transformers must always be grounded before energizing the transformer.

5.1.4 BE AWARE OF THE FOLLOWING HAZARDS inherent in the maintenance and removal of these units.

5.1.4.1 IF THE SECONDARY WINDINGS are inadvertently shorted together when the primary windings are energized, a very high current will flow causing the windings to quickly overheat. This may also create an arc flash hazard to anyone in the vicinity of the transformer.

5.1.4.2 ON MOST MODERN SWITCHGEAR, a drawout arrangement automatically disconnects and grounds the transformers when access to the fuses is necessary.

5.1.4.3 ON OLDER OBSOLETE SWITCHGEAR, fuse replacement is potentially dangerous when the primary circuit to the transformer remains energized. Follow these additional safety precautions.

5.1.4.3.1 THE AUTHORIZED INDIVIDUAL-IN-CHARGE will give specific instructions for replacing a blown primary winding fuse on a potential transformer located within the switchgear and whenever it is not possible to use a standard 6 ft (1.8 m) fuse puller.

5.1.4.3.2 IF A CIRCUIT BREAKER or sectionalizing switch is not installed to isolate a potential transformer, the worker must report the situation to the authorized individual-in-charge before replacing the fuse. The authorized individual-in-charge will arrange for deenergizing the primary circuit. Replacing a primary fuse when the potential transformer is not isolated is particularly hazardous, and requires specific approval.

5.1.4.3.3 WHEN DISCONNECTING the primary service to the transformer, verify the absence of voltage using a suitably rated voltmeter (a handheld test meter with a high voltage probe is not acceptable). Lamps can be used in addition; however, note that a non-illuminated lamp, connected on the low-voltage side of a voltage transformer, is not an adequate indication that the primary side of the transformer is deenergized.

5.1.4.3.4 THE SECONDARY FUSES must also be removed before replacing the primary fuse, and then reinstalled before the transformer is reenergized.

5.1.4.3.5 WHILE THE TRANSFORMER IS DEENERGIZED, the worker must visually inspect for obvious symptoms of trouble such as a smoked or burned case, a damaged bushing, or a damaged fuseholder.

5.2 CURRENT TRANSFORMERS (CT).

WARNING

The most serious hazard associated with the maintenance of CTs occurs when the secondary side is opened while the primary side is energized. This causes a very high voltage to develop in the secondary winding, which both stresses the insulation and presents an extreme personnel hazard. The secondary circuit of a current transformer must never be opened while the primary side is energized; however, the secondary leads can be shorted together without damage to the transformer.

5.2.1 BEFORE OPENING THE SECONDARY CIRCUITS of any energized current transformer, the secondary leads must be shorted together and grounded. The location of the short and ground is preferably located at the transformer secondary terminals, but

can be at any point between the current transformer and the location at which the secondary circuit is to be opened.

5.2.2 CURRENT TRANSFORMER CASES and secondary circuits must be grounded before energizing any current transformer.

6. POWER TRANSFORMERS AND REGULATORS.

6.1 TRANSFORMERS (POWER AND DISTRIBUTION).

6.1.1 CONSIDER ALL TRANSFORMERS ENERGIZED and at full voltage, unless they are disconnected from primary and secondary wires or disconnected from the primary wires and all phases shorted together and grounded. The secondary neutral is normally sufficient as a ground, provided that there is a grounding conductor interconnected with the common neutral, the transformer case, and the ground electrode. Always check continuity of the ground connection.

WARNING
Under no conditions should transformer covers or handhole plates be removed, nor should any work be done on the inside of transformers until the following instructions have been completed.

6.1.2 WHEN TRANSFORMERS are installed or replaced, the secondary terminals will be checked for correct voltage and for phase rotation (if applicable).

6.1.3 WHEN TRANSFORMERS ARE installed, and before they are energized, the ground connection must first be made to the case and to the neutral, when applicable.

6.1.4 WHEN REMOVING TRANSFORMERS, case and neutral grounds must be disconnected last.

6.1.5 WHEN WORKING on or near an energized three-phase, wye-connected transformer or transformer bank, verify the transformer neutral is properly grounded.

6.1.6 NEVER OPERATE no-load (or manual) tap changers when the transformer is energized. Only load-tap-changing (LTC) type tap changers can be operated when the transformer is energized. When reenergizing a transformer after changing the position of manual tap changers, maintain the minimum approach distances specified with all

required personal protective equipment until it is determined the internal switching was successful.

6.1.7 IF NECESSARY to relieve pressure on a transformer, the pipe plug, pressure relief device, or inspection cover plate must be loosened slowly so the internal pressure of the transformer can dissipate gradually.

6.1.8 PRESSURE RELIEF VALVES must never be opened when there is precipitation or high humidity, except on failed transformers and when re-fusing.

6.1.9 NEVER DRAW AN OIL SAMPLE, open a pressure relief valve, or otherwise open a transformer when there is an internal vacuum on an energized transformer. Doing so can cause an explosion.

6.1.10 TRANSFORMERS or tanks must not be entered unless forced ventilation or an air supply is used to maintain a minimum oxygen level of 19.5 percent by volume in the work area.

6.1.11 ENERGIZED PAD-MOUNTED TRANSFORMERS and associated equipment must be locked or otherwise secured when unattended.

6.2 VOLTAGE REGULATORS.

6.2.1 VOLTAGE REGULATORS are normally installed with bypass and disconnect switches. Never open or close a regulator bypass switch, unless the regulator is set on its neutral position and the control switch is open, or the automatic control feature is inactivated in accordance with the manufacturer's recommendations.

6.2.2 WHEN REGULATORS are maintained as spares in substations, their bushings must be short-circuited and grounded.

7. METALCLAD SWITCHGEAR.

7.1 OPERATE AND MAINTAIN metalclad switchgear according to manufacturer's instructions and the guidance provided in this section.

7.2 PERFORM THE FOLLOWING prior to drawout (rack out) of a circuit breaker operating mechanism. Always rack out the switchgear breaker whenever there is work on the circuit originating from that switchgear breaker.

7.2.1 IN A CONFINED SPACE, including pier vaults, the switchgear must be deenergized. Ground where possible. In other than confined spaces and vaults, the switchgear should be deenergized. Utilize remote racking devices (robots) when available, to rack breakers in and out. Wear appropriate PPE in accordance with Chapter 4 above.

7.2.2 OPEN the circuit breaker.

7.2.3 DISCHARGE the stored-energy mechanism, if provided.

7.2.4 CHECK that protective interlocks are functioning to protect against closed position circuit breaker rack out.

7.2.5 ENSURE that all workers in the vicinity know the circuit breaker is being racked out.

7.3 ACCESS TO SWITCHGEAR terminals, through portholes for maintenance in circuit breaker cells, is limited to the following.

- When both sets of terminals in a cell are deenergized (i.e., line and load, or bus to bus).

- After both sets of terminals are deenergized, access to switchgear terminals through the portholes is permitted for cleaning, inspecting, and routine maintenance of terminals and bushings.

7.4 A MANUFACTURER-APPROVED ground and test device can be used for access to terminals for procedures such as the application of protective grounds, phase identification on deenergized circuits, or phasing tests on live circuits. Use of this device avoids the hazardous operation of opening and shutting the shutters of a high voltage switchgear cell. It can be an extremely hazardous device if not used according to the manufacturer's instructions.

7.4.1 DO NOT install the device with ground cables already connected. Connect ground cables after installing the device.

7.4.2 Shut All Access Doors on the device while installing and removing the device. Use padlocks on any door where studs are intended to remain energized and access is not needed for testing.

7.4.3 AFTER INSTALLING THE device, verify by using a voltage detector that exposed studs are deenergized.

7.4.4 INSTALL THE GROUND cables, with the device end of the ground cables connected last (and disconnected first upon removal of the ground cables). For a stud-type device, the ground cables must be connected with the device in the "disconnect" position. For a bale-type device, the ground cables can be connected with the device in either the "disconnect" or the "engage" position.

7.5 FOR SOME OWNERS, a manufacturer-approved grounding breaker can be used for access to the terminals, for procedures of connecting temporary protective grounds to ground the main bus, ground the incoming lines or ground both the main bus and the incoming lines.

7.6 FOR SOME OWNERS, phasing tests on circuits must be accomplished by using ground ball studs on outgoing cable termination pads or synchronizing check controls in conjunction with ground ball studs on outgoing cable termination pads. It is no longer permissible to conduct phasing tests using the shutters of a high-voltage switchgear cell. Existing equipment should be retrofitted during preventive maintenance cycles.

8. STATIONARY BATTERIES.

8.1 BASIS FOR SAFETY REQUIREMENTS.

8.1.1 BATTERIES AND DC SYSTEM components are different from AC electrical system equipment. Batteries contain acid, which is harmful to skin and eyes, and the electrical shock hazards associated with DC power can be more severe than those associated with AC power for equivalent voltages and currents.

8.1.2 ONLY AUTHORIZED PERSONNEL who have been familiarized, trained, and qualified on battery fundamentals and maintenance procedures are allowed to perform maintenance-related activities on a battery.

8.1.3 THE FOLLOWING INDUSTRY STANDARDS provide the most complete safety standards for stationary batteries and DC systems. Refer to the appropriate document for the type of battery used in a particular application.

- ANSI/IEEE 450, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*.

- ANSI/IEEE 484, *IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications*.

- ANSI/IEEE 1106, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications*.

- IEEE 1187, *IEEE Recommended Practice for Installation Design and Installation of Valve Regulated Lead-Acid Batteries for Stationary Applications*.

- IEEE 1188, *IEEE Recommended Practice for Maintenance, Testing and Replacement of Valve Regulated Lead-Acid Batteries for Stationary Applications*.

- NFPA 70E, *Standard for Electrical Safety in the Workplace*, Chapter 2, Article 320, *Safety Requirements Related to Batteries and Battery Rooms.*

- *NFPA 70B, Recommended Practice for Electrical Equipment Maintenance,* Chapter 9, Section 9.9.4 *Stationary Batteries and Battery Chargers*.

8.1.4 IN ADDITION to substation applications, the requirements of this section apply to all stationary battery applications, including engine starting, UPS, and other backup power applications.

8.2 PROTECTIVE EQUIPMENT. The following equipment must be available for the safe handling of the battery and protection of personnel:

- Safety glasses with side shields, goggles, and/or face shields

- Acid-resistant gloves

- Protective aprons and safety shoes

- Portable or stationary water facilities for rinsing eyes and skin in case of contact with acid electrolyte

- Class C fire extinguisher
- For lead acid batteries, bicarbonate of soda to neutralize any acid spillage (1 lb/gal or 0.1 kg/L of water)
- Adequately insulated tools
- Lifting devices of adequate capacity, when required

8.3 SAFETY PRECAUTIONS.

WARNING
Stationary batteries generate a direct current (DC) voltage, which is particularly dangerous with respect to electrical safety. Exercise extreme caution whenever working on battery systems.

8.3.1 WEAR PROPER SAFETY clothing to prevent contact with acid or live electrical connections. Whenever working on or near batteries, wear a rubber apron and rubber gloves. Ensure goggles and face shields are available for personnel.

8.3.2 USE ONLY INSULATED TOOLS in the battery area to prevent accidental shorting across battery connections. Never lay tools or other metal objects on cells; shorting, explosion, or personal injury could result. As a general rule, the length of the exposed metal for any tool should be less than the distance between the positive and negative posts of each cell.

8.3.3 WEAR ONLY NONCONDUCTIVE hard hats near batteries. Metal hard hats can fall across the battery terminals or connections and create short circuits.

8.3.4 REMOVE ALL JEWELRY, wristwatches, or clothing with metal parts that could come into contact with the battery terminals.

8.3.5 DO NOT MAKE or break series connections within an operating group of cells. Before proceeding, open the battery system circuit breaker to minimize the possibility of arcing.

8.3.6 VENTED LEAD ACID, vented nickel cadmium batteries and valve-regulated lead acid (VRLA) batteries can generate hydrogen gas that, in sufficient concentrations, can be explosive if ignited. Never bring burning materials such as lighted matches, cigarettes, or sparks of any kind near the battery. Avoid the use of spark-producing equipment near batteries. Residual gases can remain within cells during storage and shipment. Smoking is not permitted in battery rooms or near stationary batteries. Take these precautions at all times while handling batteries.

8.3.7 ENSURE that the exit from the battery area is unobstructed.

8.3.8 MINIMIZE access to the battery by personnel unaware of battery safety precautions.

8.3.9 ENSURE that the battery area is suitably illuminated.

8.3.10 KEEP THE BATTERY and adjacent area clear of all tools and other foreign objects.

8.3.11 AVOID STATIC BUILDUP by having personnel contact the ground periodically while working on batteries.

9. INSULATING OIL HANDLING OPERATIONS. Place oil insulating equipment in an electrically safe work condition before starting any oil handling procedure. Observe the following additional precautions during oil filtering, oil reclaiming, and other oil-handling operations:

9.1 ALWAYS PLACE potential and current transformers in an electrically safe work condition before taking oil samples.

9.2 HAVE APPROPRIATE types and sizes of fire extinguishers readily available.

9.3 ONCE ALL EQUIPMENT has been placed in an electrically safe work condition and insulating oil handling operations is to begin, employees shall don an approved disposable coverall. Employees shall use extreme caution to ensure that oil does not contaminate arc-rated PPE. Arc-rated PPE that has become contaminated shall be immediately removed from service.