BY ORDER OF THE SECRETARY OF THE AIR FORCE

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Civil Engineering

ELECTRICAL WORKER FIELD SAFETY GUIDE

This handbook summarizes safety requirements for electrical workers in the field. The use of the name or mark of any specific manufacturer, commercial product, commodity, or service in this publication does not imply endorsement by the Air Force.

Chapter 1 Electrical Hazards and Mishaps

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CHAPTER 1. ELECTRICAL HAZARDS AND MISHAPS

1-1. Scope. This handbook provides safety requirements and rules pertinent to electrical work in the field as performed by electrical supervisors, foremen, and crew members involved in inspection, switching, maintenance, line clearance, testing, and fault-locating. No phase of electrical operations and maintenance is of greater importance than mishap prevention. Your safety will be in direct proportion to your adherence to Air Force safety directions.

a. Use. Use this handbook as a safety reminder. It has been sized to be carried on your person. Rules are limited to reminders of safe working practices with no attempt to explain the reasons for such practices unless they touch on major safety concerns. Such concerns are the damaging effects of electricity on the human body and the ever-present possibility of voltage differences occurring on de-energized electrical lines. Major causes of electrical mishaps are carelessness around electrical hazards, ignorance of the dangerous potentials that can occur on de-energized lines, and lack of suitable fall protection.

b. Supplementary Information. Additional safe performance of work directions are given in *AFMAN 32-1185 (Electrical Worker Safety)* which amplifies and complements this handbook. Reference is provided, where appropriate, to *AFMAN 32-1185* and to various Air Force occupational, safety and health *(AFOSH)* standards.

1-2. Reminder of Electrical Hazards in the Field. Always identify the electrical hazards applying to the work being done. Rules, apparel, tools, and tests, if correctly used, will protect you from the destructive effects of electric shocks, arcs, and blasts and the hazards of elevated and confined workplaces.

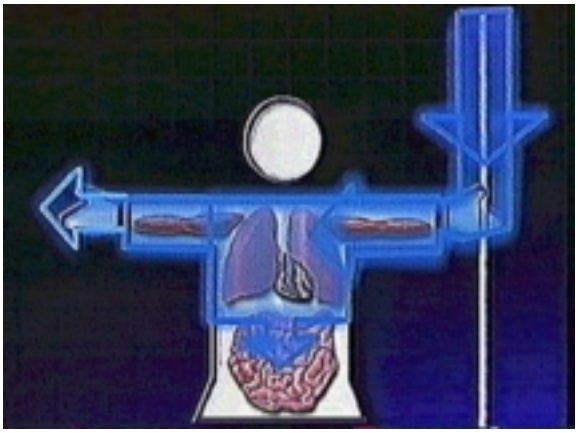
a. Dangers From Electric Shock. Electric shock results from setting up an electric current path within the human body. The current flows because there is a potential gradient (voltage difference) between an energized object and the grounded worker. *Pictures 1-1, 1-2, 1-3, and 1-4* indicate graphically shock, arc, and blast, and their effect on the human body. *Figure 1-1* shows potential gradients and the safe area or equipotential zone which has no potential gradient. *Figure 1-2* indicates current flow paths. *Table 1-1* indicates the effects of 60-hertz current on humans.

b. Danger from Arcs And Blasts. Arcs result from the passage of electric current through air; the air failing as an insulator but serving as a conducting medium for ionized gases. Blasts result when the metal at the arc site expands and vaporizes. Arcs can reach temperatures up to four times the temperature of the sun's surface. Water expands 1,670 times when it becomes steam; copper expands 67,000 times when it vaporizes. High energy arcs can be fatal even at distances of 10 feet (3 meters).

Picture 1-1
Shock

Picture 1-2
Arc

Picture 1-3
Blast



Picture 1-4
Effect on Human Body

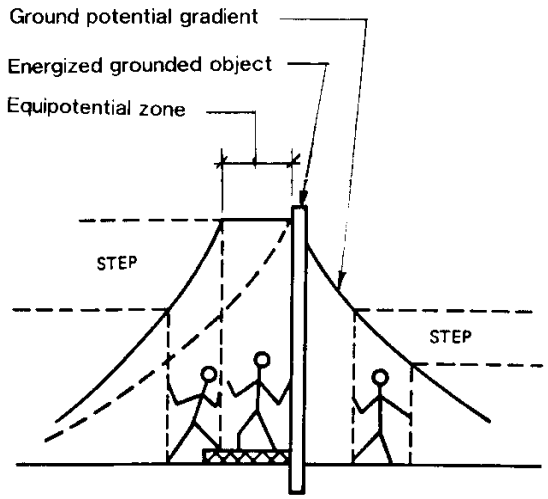
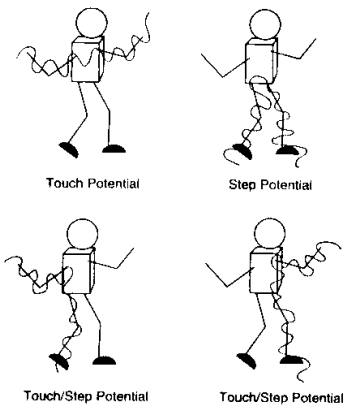


Figure 1-1
Ground potential gradient



The current path will determine which tissues and organs will be damaged or destroyed. The pathway is differentiated into three groups: touch potential, step potential, and touch/step potential.

Figure 1-2
Current path flow

Table 1-1. Effects of 60-hertz current on humans

	Effect	Milliamperes	
		Men	Women[1]
1.	Slight sensation on hand	0.4	0.3
2.	Perception threshold	1.1	0.7
3.	Shock, not painful and muscular control not lost	1.8	1.2
4.	Painful shock, painful but muscular control not lost	9	6
5.	Painful shock let-go threshold	16	10.5
6.	Painful severe shock, muscular contractions, breathing difficult	23	15
7.	Ventricular fibrillation, threshold	75	75
8.	Ventricular fibrillation, fatal (usually fatal for shock duration of 5 seconds or longer)	235	235
9.	Heart paralysis (no ventricular fibrillation), threshold (usually not fatal; heart often restarts after short shocks)	4,000	4,000
10.	Tissue burning (usually not fatal unless vital organs are damaged)	5,000	5,000

[1]The current values for women are lower because women typically have less body mass than men.

c. Dangers from Workplaces. The dangers of a fall from an elevated workplace are self-evident. *Table 1-2* indicates typical hazardous materials which may be found in enclosures or confined work spaces. Check the applicable material safety data sheets (MSDS).

Table 1-2. Hazardous materials

Material	Source
Asbestos	Old electric equipment, fire protecting tape, duct banks, arc chutes
Polychlorinated biphenyl (PCB)	Old liquid-filled transformers, capacitors, ballasts, lead-sheathed cables
Sulfur hexofluoride (SF_6)	Toxic decomposition products from electric arcs or faults acting on SF_6 insulation
Combustible gases	Sewer or natural gas accumulations or from outgassing of lead-acid batteries
Carbon monoxide	Cable faults, combustion engine exhausts
Hydrogen chloride	Faults or fires involving polyvinyl chloride (PVC) conduits or PCB oils.
Inadequate oxygen	Displaced by heavier-than-air gases

MSDS should be available on site, however, manufacturers & retailers can provide them.

1-3. Mishap Handling. Each worker must know what to do when a mishap occurs. Additionally, each worker must know how to report injuries and other mishaps.

a. Knowing What To Do. Refer to *AFMAN 32-1185* for first aid treatment and pointers which indicate the need for immediate hospitalization of electric shock victims. *Table 1-3* summarizes the first aid knowledge required of each worker. An emergency telephone number list must be prepared and kept readily available to include as applicable the location and telephone numbers of the nearest ambulance or emergency medical treatment responders, the nearest hospital with an emergency room, the nearest helicopter evacuation service, and the nearest burn trauma center. (Keep form *AF 1608, Emergency Numbers* readily available.*)*

Table 1-3. Knowing what to do

Item	Instructions/training
First aid	How to control bleeding and apply artificial respiration and cardiopulmonary resuscitation (CPR). How to provide pole top and manhole rescues of mishap victims. Familiarity with electric shock symptoms.
Medical provisions	Location, contents, and use of first aid kits and where located in electric line and aerial lift vehicles. How to get medical assistance.

b. Work Injuries and Mishap Reports. Report injuries, even minor ones, to your immediate supervisor in accordance with *AFI 91-202 (The U.S. Air Force Mishap Prevention Program).* Additionally, every mishap involving personnel injury, property damage, or near misses must be investigated to determine the cause and the corrective action needed to prevent recurrence. Base safety personnel conduct investigations. The wing or installation safety staff must be notified of all mishaps that involve personnel injuries or property damage. Certain mishaps must be investigated and reported through safety channels according to *AFI 91-204 (Safety Investigations and Reports)*.

CHAPTER 2. WORKER/CREW RESPONSIBILITIES

2-1. Levels of Responsibility. Operation and maintenance of electrical distribution systems are a single work group responsibility. The same personnel will frequently perform both functions. All personnel are responsible for safety at all times. The safety accountability duties are given in *Table 2-1* from the top down.

Table 2-1. Levels of safety accountability

Title	Electric safety accountability
Installation commander	Ultimate safety responsibility
Base civil engineer	Base systems safety responsibility
Electric supervisor (if assigned)	Systems safety responsibility
Foreman/lead electrician	Systems safety and specific work task safety responsibilities
Crew members	Crew members' safety responsibility is limited to doing only work for which they are qualified

2-2. Electrical Work Qualifications. Qualifications for electrical workers are normally established locally. Refer to *AFMAN 32-1185* for typical qualification requirements. Workers are classified as Qualified or Unqualified.

a. Qualified Workers. Persons who by training and demonstration are familiar with the skills and techniques for: (1) distinguishing exposed live parts from other parts of electric equipment; (2) determining the nominal voltage of exposed live parts; and (3) maintaining minimum clearance distances corresponding to the voltages to which that person will be exposed.

b. Unqualified Workers. Persons not meeting the requirements for Qualified Worker. However, to be on the job these persons must be trained in all electrically related practices that are necessary for their safety.

2-3. Safety Observances.

Avoid prohibited actions (*Table 2-2*) and report unsafe worker indications (*Table 2-3*). Meet presite requirements (*Table 2-4*). Significant unsafe actions and conditions are given in *Table 2-5*.

Table 2-2. Prohibited actions

Taking chances
Playing jokes
Carelessness
Smoking
Use of intoxicants or drugs
Throwing material
Quarreling
Disobedience
Unnecessary talking or noise
Working while ill or under emotional stress

Table 2-3. Unsafe worker indications

Lacks information
Lacks skills
Lacks experience
Unaware of safe practices
Doesn't realize danger

Table 2-4. Presite job requirements

Regular safety meetings
Job hazard analysis if safe clearance (*Chapter 6*) requires it or energized line work (*Chapter 8*) will be done
Written work procedures covering existing conditions
Tailgate briefings

Table 2-5. Significant unsafe actions and conditions

	Unsafe actions
1.	Operating without authority; failure to secure or warn others
2.	Operating or working at unsafe speeds
3.	Making safety devices inoperative without proper authorization
4.	Using unsafe equipment (hands instead of equipment) or equipment unsafely
5.	Taking unsafe positions or postures
6.	Working on moving or dangerous equipment
7.	Distracting, teasing, abusing, startling
8.	Failing to use safe attire or personal protective devices
9.	Failing to lock-out energized circuits
	Unsafe conditions
10.	Improperly guarded facilities
11.	Defects of facilities
12.	Hazardous arrangement or procedure
13.	Improper ventilation
14.	Improper illumination
15.	Unsafe dress or apparel

2-4. Compliance with Safety Rules. A requirement of employment is compliance with and knowledge of the rules in this handbook.

a. Enforcement. Supervisors and foremen are responsible for enforcing safety rules and are subject to penalties for violations as are crew members.

b. Interpretation. Always ask the foreman or supervisor for an interpretation In any case where rules are not clear.

c. Violations. The severity of the penalty must be related to the seriousness of the offense. Violations can range from a reprimand, layoff without pay, demotion, or discharge. Discharge is applicable to cases of deliberate or willful failure to observe written regulations whenever such failure endangers the safety of persons or property.

CHAPTER 3. PRESITE SAFETY MANAGEMENT

3-1. Work Area Aspects Affecting Safety. The location and the public's access to the work site impose additional protective or regulatory requirements.

a. Location of Work. The location of the work will determine whether climbing or confined space training along with fall and/or respiratory protection are mandatory (see *Chapter 4*). Safety standards require protection from excessive noise and provision of minimum illumination at any applicable work site.

(1) Noise. *AFOSH Standard 48-9 (Hazardous Noise Program)* requires a listing of hazardous noise areas, physical boundaries, and conditions of required hearing protection. A monitoring program is mandated by *AFOSH Standard 161-20 (Hearing Conservation Program).* Where hazardous noise area signs are posted, hearing protection must be used as prescribed.

(2) Minimum Illumination. The minimum illumination for area safety is given in *Table 3-1*. Additional illumination may be necessary dependent upon the work required. Generally additional illumination should only be needed for work in confined spaces and for work approved for nondaylight hours.

Table 3-1. Minimum illumination requirements

Foot-candles	Location
10	Exitways, walkways, ladders, and mechanical/electrical rooms
5	Indoor construction areas, accessways, and outdoor field maintenance areas
3	Parking areas and general outdoors

b. Public Safety. Protect the public around the work area by safely guiding traffic away from workers, equipment, and excavations.

(1) Warning Devices. Locate appropriate barriers, warning signs, traffic cones, and lights at approaches to and at work areas, excavations, open manholes, parked equipment, and other hazards. Take special precautions for any areas where reduced visibility occurs, such as night operations or in fog. Immediately remove warning devices after removal of hazards and equipment. Provide flagmen if there is any doubt as to whether the warning devices will be adequate as controls, such as in areas with obstructed vehicular traffic.

(2) Excavations. Provide barricades around every excavation area. Keep warning barricade (cones, tape, and other items providing no physical protection) 5 feet (1.5 meters) from the excavation. A protective barricade may be placed closer since it provides both a warning and physical protection. Protective barricades must have a withstand rating of at least 200 pounds (90 kilograms) in any direction with minimal deflection. Never enter an excavation which does not have a safe accessway, which has not been inspected before allowing an entrance, or which has equipment working next to the edge.

3-2. Electrical Aspects Affecting Safety. Working on or near normally energized lines or parts requires observance of rules applying to safe working distances, work methods related to whether the line has been de-energized or left hot, and recognition of work hazards which require more than one worker for safety.

a. Safe Working Distances. Only workers qualified by electrical training may work in areas on or with unguarded, uninsulated energized lines or parts of equipment operating at 50 volts or more (see *paragraph 2-2*). All electric lines and equipment must be treated as energized unless de-energized and grounded. Maintain the minimum clearances of *Tables 3-2* and *3-3* based on the voltage range. See *paragraph 8-3* for approved work methods by voltage level.

Table 3-2. Qualified worker minimum working distances

Voltage Range	Minimum working distance (Between energized parts and grounded objects without insulation, isolation, or guards)		Clear Hot Stick Distance (Between worker's hand and working end of stick)
	Phase-to-ground (That is, work on single phase systems, and work on one phase only of 3-phase wye systems)	**Phase-to-phase** (That is, work on 3-phase delta systems, and on more than one phase of 3-phase wye systems)	**Phase-to-ground and Phase-to-phase**
50-V to 300-V	Avoid contact	Avoid contact	Not Applicable
301-V to 750-V	1 ft 0 in (0.31 m)	1 ft 0 in (0.31 m)	Same as minimum working distance
751-V to 15-kV	2 ft 2 in (0.66 m)	2 ft 3 in (0.69 m)	Same as minimum working distance
15.1-kV to 36-kV	2 ft 7 in (0.79 m)	2 ft 10 in (0.86 m)	Same as minimum working distance

Table 3-3. Unqualified worker minimum approach distances

Voltage to ground	Distance
50 kV or below	10 ft (3 m)

b. Work Methods In Relation To Workers' Safety. All work must be done de-energized unless energized line work has been specifically authorized.

(1) De-energized Electrical Line Work. Follow the safe clearance (lockout/tagout) procedures given in *Chapter 6*. Remember lines are considered energized if the de-energized systems have not been provided with proper protective grounding (see *Chapter 7*).

(2) Energized Electrical Line Work. Work on energized lines and equipment only when authorized by the Base Civil Engineer, the Chief of Operations Flight, or other designated authority (per local organization) based on the need to support a critical mission, to prevent injury to persons, or to protect property. Insulating means must be provided to isolate workers from a source of potential difference. When authorized, perform energized line work per *Chapter 8*. **Barehand live-line work is prohibited.**

c. Number of Qualified Workers Per Hazard Exposure. *29 CFR 1910.269 (Electrical power generation, transmission, and distribution)* requires more than one worker where the hazard exposure of the work is considered to be significantly reduced by the presence of additional workers. *Tables 3-4* and *3-5* cover these requirements. *Table 3-6* indicates acceptable work where only one worker is needed. These tables indicate the minimum number of workers required. More workers may be necessary to provide safe working conditions in some circumstances.

Table 3-4. Jobs requiring two electrical workers

Hazard exposure	Working on
Installation, removal, or repair when working on or near lines or parts energized at more than 600 volts ac or 250 volts dc	1. Energized lines 2. De-energized lines with possible energized parts contact 3. Equipment with possible energized line contact 4. Mechanical equipment operation (except insulated aerial lifts) near energized parts 5. Other work with equal or greater hazard exposure

Table 3-5. Jobs working in confined spaces requiring additional workers

Hazard exposure	Additional worker requirement
Installation, removal, or repair when working in a confined space. Manhole or vault requirements are generally classified as confined spaces.	1. An attendant with first-aid and CPR training must be available on the surface in the immediate vicinity. 2. If a hazard exists within the space, or a hazard exists or is created because of traffic patterns outside the space, the attendant may not enter the confined space. 3. If the restrictions of Item 2 above do not apply, the attendant may enter the confined space to provide assistance, but only for a brief period (other than in an emergency). For extended periods of assistance, a second worker in addition to the attendant is required.

Table 3-6. Jobs generally acceptable for one electrical worker

- Work on de-energized systems with nominal system voltages of 600 volts ac or 250 volts dc, or less.
- Routine electrical measurements on energized systems with nominal system voltages of 600 volts ac or 250 volts dc, or less.
- Routine operation of metal-enclosed or metal-clad switchgear with nominal system voltages of 600 volts ac or 250 volts dc, or less.
- Routine electrical measurements or switching using gloves and live-line tools if the worker is positioned out of reach or possible contact with energized parts.
- Emergency repair work to safeguard the general public, if previously authorized.

3-3. Verifying System and Equipment Provisions. Be familiar with the electrical system you are working on by reviewing the system's one line diagrams & schematics. Check out the equipment needed such as insulating tools, hot sticks, and grounding cables. *Pictures 3-1, 3-2, 3-3*, and *3-4* are illustrative of the above items.

Picture 3-1
Reviewing the single line

Picture 3-2
Insulating tools

Picture 3-3
Use of rubber gloves with hot sticks

Picture 3-4
Grounding cables

CHAPTER 4. PERSONAL PROTECTIVE EQUIPMENT

4-1. General Body Protection. Always wear personal protective clothing as required by your supervisor and as appropriate to the work area, work methods, and site hazards. Wear these items because it is impossible or impractical to totally eliminate all work site hazards and they will reduce your chance of injury or illness. *AFOSH Standard 48-1 (Respiratory Protection Program)* applies where confined spaces or hazardous gases mandate respirators. Restrictions on the wearing of jewelry are covered in *AFOSH Standard 91-66 (General Industrial Operations)*. Items appropriate for work on a wood pole are shown in *Figure 4-1.* A summary of apparel requirements is given in *Table 4-1.* A flash-resistant clothing kit is shown in *Picture 4-1.*

4-2. Additional Worker Protection For Pole/Tree Climbing and for Fall Protection. Pole and tree climbing requires additional personal protective equipment to prevent falls.

a. Climbing Protection. Use climbers only when engaged in work requiring their use. Never wear climbers: when working in trees, on ladders, or in aerial lifts; when in vehicles; when setting, removing or handling poles; when working on the ground or inside buildings; or while working on roofs.

(1) Fall Protection. Climbers provide the only fall protection when ascending or descending poles.

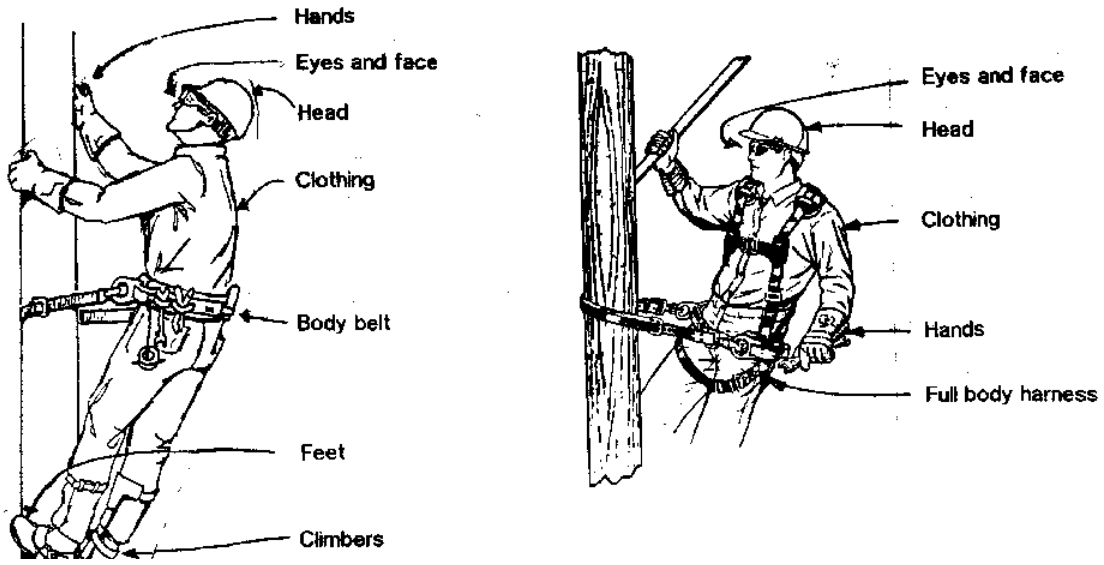


Figure 4-1
Personal protection for working on a pole

Table 4-1. Apparel and body protection requirements

Clothing - general
1. Nonelectrical industrial activities wear
Full length pants
Shirts with at least short sleeves
2. Around machinery you may not wear or have
Dangling sleeves
Neckties
Unsecured long hair
3. Around vehicular traffic or on the flightline wear
Safety color fluorescent clothing with approximately 3.5 square feet (0.33 square meters) of reflective area above the waist
4. On or near energized lines/equipment wear
Long-sleeved apparel with
No acetate, nylon, polyester, or rayon alone or in blends
No metallic items (fasteners)
No jewelry items
No celluloid items

Table 4-1. Apparel and body protection requirements (cont.)

Head	
	Wear a *ANSI Z89.1 (Protective Headware for Industrial Workers)* type B **hard hat** which has a rating of 20,000 volts, 60 hertz for 3 minutes, provides a suspension to 1.5 inches (38 millimeters) above the head, and can include an optional cold weather liner and chin strap. Wear where exposed to energized lines/equipment and falling objects such as exterior substations, overhead and underground lines, construction sites, fuse changing, voltage readings, and maintenance of batteries and medium-voltage equipment.
Eyes and face	
	Wear *ANSI Z87.1 (Occupational and Educational Eye and Face Protection)* eye and face protection with impact-resistant lenses and side shields. Contact lenses do not provide eye protection. Face shields do not provide impact eye protection. Filter lenses are required for radiant energy protection.

Table 4-1. Apparel and body protection requirements (cont.)

Skin	
	Apply appropriate protective ointment if needed for exposed areas. Ointment must not be damaging to rubber goods.
Hands	
	Use rubber gloves where required in other chapters of this handbook. Use leather palm gloves for protection when rubber gloves are not required. Use welders' gloves when welding.
Feet	
	Wear *ANSI Z41 (Protective Footwear),* P591, C75 or I75 shoes rated for 75 pounds (34 kilograms) crushing strength and having **no heel or toe plates or hobnails**. Use electrically insulated shoes for de-energized line work within 10 feet (3 meters) of grounded items. Use conductive shoes where needed for protection from static discharges.

Table 4-1. Apparel and body protection requirements (cont.)

Hearing	Ear plugs or inserts go in ear canals and provide 25 to 30 decibel attenuation. Ear caps and muffs or muffs go over ear canals and provide 35 to 45 decibel attenuation. A combination of both can provide up to a maximum of 50 decibel attenuation. All need careful fitting.
Respiratory	Provide per the confined space entry plan and/or the hazardous material regulated area requirement. Use *NIOSH-MESA* certified device if the hazard type has a *NIOSH-MESA* performance requirement. Use for emergencies only; correct hazardous atmospheric conditions with ventilation. Requires special training and fitting.

(2) Training. Climb only if qualified to climb, or if in training and under direct supervision and observation as covered in *Table 4-2*. Use climbers meeting *ASTM F 887 (Specifications for Personal Climbing Equipment).*

Table 4-2. Qualifications for climbing

1. Current annual physical fitness examination (when locally required) plus continuing supervisor's observation of satisfactory performance.
2. Two years of documented climbing training including
   - Hazard recognition
   - Hands on climbing
   - Hands on rescue
3. Has routinely climbed structures within the last 5 years, which are similar to facility structures.
4. Can be a worker in training under the direct supervision and observation of a worker who meets the first three qualifications.

(3) Climber Gaff Field Check. Always perform a pole cutout test *(Table 4-3* along with *Pictures 4-2, 4-3,* and *4-4)* before climbing. Check failed gaffs with your gaff gauge to determine the reason for failure and correct the deficiency.

Table 4-3. In-use check of pole climber gaffs

Picture	Check
4-2	Initial placement. Place the climber on the leg, holding the sleeve with the hand, palm facing the pole. With the leg at about a 30 degree angle to the pole and the foot about 12 inches (0.3 meters) off the ground, lightly jab the gaff into the pole to a distance of approximately 1/4 inch (6 millimeters).
4-3	Intermediate action. Keeping enough pressure on the stirrup to keep the gaff in the pole but not so much as to cause the gaff to penetrate any deeper, push the climber and the hand toward the pole by moving the knee until the strap loop of the sleeve is against the pole.
4-4	Full pressure. Making certain that the strap loop is held against the pole with pressure from the leg, gradually exert full pressure of the foot straight down on the stirrup without raising the other foot off the ground (to maintain balance if the gaff does not hold).

Picture 4-1
Flash resistant clothing kit

Picture 4-2
Initial gaff action

Picture 4-3
Intermediate gaff action

Picture 4-4
Gaff full pressure

(4) Restrictions on Pole Climbing. Do not climb a pole unless you are sure it can safely hold your weight. Be sure to inspect for rotted areas, knots, and nails. Check for proper pole support. Discontinue work during adverse weather conditions such as thunderstorms, rain, high winds, and icy conditions. In bad weather, do not climb poles except for emergency restoration work.

b. Fall Protection. Use of fall protection equipment is not required by OSHA while climbing or changing positions on poles or towers unless adverse weather makes it unsafe to do so without such equipment. In such cases, use fall protection such as belts or harnesses. Four types of fall protection are used to handle various fall situations as shown in *Figure 4-2.* Fall arrest equipment is effective only if adequate anchoring has been identified by a qualified person. Use of the full body harness is preferred over the body belt as discussed in *Figure 4-3.*

(1) Positioning, Retrieval, and Suspension Fall Protection. Must support worker's weight plus any additional load. Does not provide fall arrest. Fall arrest must be added if it is determined that there is a fall arrest anchor point capable of meeting fall arrest requirements.

(2) Fall Arrest Protection. Needs an anchor point capable of supporting 5,000 pounds (2,250 kilograms) plus a connection device. Protection must provide an adequate free fall distance of 6 feet (1.8 meters) or with a deceleration unit a fall distance of 9.5 feet (2.8 meters).

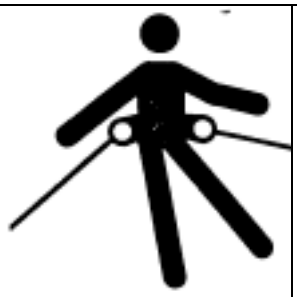
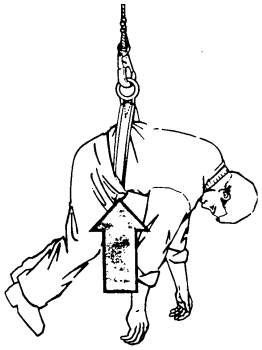
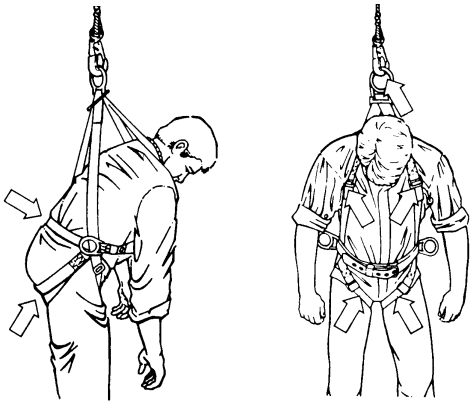
			
Positioning	Retrieval	Suspension	Fall arrest
Leaves hands free while positioning a worker.	Allows emergency retrieval from a confined space.	Leaves hands free and supports a worker.	For arresting a fall from an elevated position.
Use on wood pole.	Use in a manhole.	Use on structures.	With anchor points.

Figure 4-2
Fall protection types



BODY BELT
All forces concentrated on the abdomen. Fall impact force cannot exceed 900 pounds (400 kilograms)



FULL BODY HARNESS
Forces distributed over the body. Sliding back rings keep body upright. Fall impact force permitted is twice that of the body belt.

Figure 4-3
Advantages of body harness use over body belt use

CHAPTER 5. WORK AREA PROTECTIVE EQUIPMENT

5-1. Temporary Protective Electrical Insulation. The qualified worker must be protected from electrical energy exposure while either de-energizing (isolating and grounding) the line or working on a live-line. Temporary protective insulation is provided by using the insulating properties of rubber goods, plastic guard equipment, and live-line tools. Platforms and aerial lift trucks provide insulated supports for positioning a worker.

a. Rubber Protective Equipment. Equipment consists of gloves, sleeves, blankets, covers, and line hose. All items must meet or exceed requirements of the applicable *ASTM F 18* series specification and be suitable for the working voltage level *(Table 5-1).* Visually inspect rubber goods before use.

(1) Air Tests and Visual Inspections. An air test of gloves is also required. *Pictures 5-1* and *5-2* show the air test and a visual inspection. Workers should periodically review *ASTM F 1236 (Guide for Visual Inspection of Protective Rubber Products).*

(2) Electrical Retesting. Electrically retest rubber goods issued for service based on work practice and test experience intervals. Retesting intervals shall not exceed 6 months for rubber gloves and 12 months for rubber sleeves and blankets. Retest any rubber goods where there may be a reason to suspect the electrical integrity of the equipment. Electrically retest items that have been removed from storage for issue for service, unless they were electrically tested at the time of placement into storage and storage time does not exceed 12 months. See AFOSH Standard 91-31 *(Personal Protective Equipment).*

Table 5-1. ASTM F 18 rubber goods[1]

Maximum use, ac volts	Class	Color label	Proof test ac volts	Minimum distance[2] inches(millimeters)
1,000	0	Red	5,000	1 (25)
7,500	1	White	10,000	1 (25)
17,000	2	Yellow	20,000	2 (50)
26,500	3	Green	30,000	3 (75)
36,000	4	Orange	40,000	4 (100)

[1]Wear leather protectors over rubber gloves.
[2]Minimum length of exposed rubber glove above the leather protector.

b. Plastic Guard Equipment. This equipment is rated for momentary (brush) contact protection (see *Table 8-4*). Guards include conductor guards; connecting covers used over lines, insulators, buses, and structures; and apparatus guards used over poles, crossarms, cutouts, and switchblades. Electrically retest plastic guard equipment based on work practice and test experience. Electrically retest items where there may be a reason to suspect the electrical integrity of the equipment.

c. Live-Line Tools. *ANSI/IEEE 935 (Guide on Terminology for Tools and Equipment to be Used in Live-Line Working)* covers the live-line tools used to hold, move, operate, and test equipment. Tools are only as safe as their continued care and inspection make them. Try to always use a fiberglass tool as it is impervious to oil-borne materials and solvents, is stronger, and is a better insulator than wood. Live-line tools must be wiped clean and visually inspected before use each day. Do not use tools in rain or heavy fog, except in an emergency where directed by your foreman/lead electrician. In any case, never use tools when weather conditions allow formation of rivulets of water along the tool. Hang tools on hand lines or approved tool hangers, never on conductors or ground (bond) wires. See *Pictures 5-3 and 5-4* for live-line tool use. See *paragraph 8-3* for further information.

d. Equipment for Positioning a Worker. Body harnesses and belts, platforms, and aerial lift buckets are used to position workers performing elevated electrical maintenance. See *Figure 4-3* for the advantages of body harnesses over body belts. Always use fiberglass ladders and platforms. Review the safety rules given in *AFMAN 32-1185* when using aerial lifts (insulated buckets) and *AFOSH Standard 91-2 (Vehicle-Mounted Elevating and Rotating Work Platforms, Manually-Propelled Mobile Work Platforms, and Scaffolds (Towers))*. Body harnesses or belts must be worn with a lanyard attached to the boom or bucket. Climbers must not be worn by workers when in an aerial lift bucket. Only one energized conductor may be worked at a time regardless of the number of workers on the pole and/or in the bucket. See *Pictures 5-5, 5-6, 5-7, and 5-8.*

Picture 5-1
Air testing a rubber glove

Picture 5-2
Inspecting a rubber-glove protector

Picture 5-3
Installing rigid coverup

Picture 5-4
Placing a hot-line jumper

Picture 5-5
Worker on a pole platform

Picture 5-6
A secured aerial lift truck area

Picture 5-7
Aerial lift truck pre-use inspection

Picture 5-8
Workers in an aerial lift truck

5-2. Energy Hazard Detection. Potential differences, induced voltages on lines, accidental short circuiting, leakage current across insulated protective equipment, and combustible gas accumulation can create safety hazards if not detected by the use of proper test devices. Typical test devices include:

a. Potential Differences. Voltage detectors are used to determine whether the line or device is energized. Low-voltage detectors often use neon glow lamps or solenoid plunger testers. Medium- and high-voltage detectors are proximity and direct-contact types. Direct-contact type detectors may not be effective on circuits not connected to ground, and proximity-type detectors may not be effective where magnetic fields can cancel (such as cable potheads). Proximity-type detectors cannot detect nonalternating (dc) voltages. Never use portable multimeters for measurements on medium- and high-voltage systems. Always check a voltage detector for proper operation using the "hot-dead-hot" method: first, check the detector on a known energized circuit, then check the desired line or device for voltage, and last, check the detector on a known energized circuit.

b. Phasing Testers. Phasing testers are used to determine the phase relationship of energized lines. Short circuits occur when different phases are tied together. A phasing tester can use two high-resistance units on hot sticks connected by a phasing-out voltmeter. Where voltage transformers are available, a voltmeter can be connected between one side to the other side. If lines are in phase, the voltmeter will register zero. If performing a phasing check at a generator disconnect, the maximum voltage rating of the phasing tester must be at least two times the nominal rated voltage of the circuit to be tested.

c. Combustible Gas/Oxygen Detectors. Portable monitors provide visual and audible warnings of explosive atmospheres and/or low oxygen levels which often occur in confined spaces. A continuous reading is given of any gas concentration ranging from 0 to 100 percent of the lower explosive level (LEL) and 0 to 25 percent of the oxygen level. A detector can be used to check battery rooms where ventilation is suspect. Determine if a hazardous atmosphere exists before entering a confined space. Hazardous atmosopheres include: a contaminant concentration 10 percent or more of its lower flammability limit; oxygen concentration less than 19.5 percent by volume; contaminant concentrations exceeding specific OSHA standards (lead, asbestos, cadmium, and like substances); and oxygen concentration more than 23 percent by volume, particularly if oil mist or other combustible materials are present. (See *AFOSH Standard 48-1, Respiratory Protection Program,* and *AFOSH Standard 91-25, Confined Spaces)*.

d. Aerial-Lift Leakage-Current Monitoring. Leakage current flows along the surface of tools or equipment due to the properties of the device's surface and surface deposits. The permissible leakage current on aerial lifts is one microampere per kilovolt ac or 0.5 microamperes per kilovolt dc. Adverse weather conditions derate the normal dielectric quality of air which results in a greater leakage current. Periodic testing is required. The use of a monitor on an aerial lift providing a continuous display of leakage current is recommended. The monitor should sound an alarm at a pre-set leakage current level to alert workers to danger.

e. Examples of Detection Devices. *Pictures 5-9, 5-10*, 5-*11,* and *5-12* are examples of the use of detection devices.

Picture 5-9
Voltage tests

Picture 5-10
Testing a cable with a pocket statiscope

Picture 5-11
A phasing tool testing an energized transformer bushing

Picture 5-12
Testing for potential

CHAPTER 6. DE-ENERGIZED LINE CLEARANCE

6-1. Safe Clearance Procedures. Sample lockout/tagout procedures for isolating machines or equipment from energy sources are given in *AFOSH Standard 91-66, Chapter 4 (General Industrial Operations)*, along with descriptions of the Air Force forms and their use.

a. Safe Clearance Provisions. A Safe Clearance provides lockout/tagout directions for the safe blocking, tagging, and grounding of electrical switching and controlling devices to clear lines and equipment for the safe accomplishment of work in the de-energized condition.

b. Preparation Responsibility. A lockout/tagout procedure must be developed by certified individuals authorized to do so. Required information is discussed in *AFMAN 32-1185 and AFOSH Standard 91-66, Chapter 4.*

c. Tag Recognition. In the process of lockout/tagout, three of the forms described in *Table 6-1* must be used. Spaces on the tags are provided for defining the hazard and the control measure to be used. They must be filled in. The reverse side contains additional data, including the names of the individual responsible for the tag and the functional manager.

Table 6-1. Tag forms

AF form no.	Warning	Hazard	Tag identification	
			Tag Color	Symbol
979	Danger	Immediate	White	Red ellipse on black square
980	Caution	Possible	Yellow	Black rectangle
981[1]	Out of order	If used	White	Black square
982	Do not start	If started	White	Red oval on black square

[1]Not to be used for Safe Clearance provisions of lockout/tagout instructions.

6-2. Lockout/Tagout Instructions. Each lockout/tagout instruction for a specific job must cover all the steps given in *Table 6-2.*

Table 6-2. Sequence of lockout/tagout steps

De-energizing steps
1. Notify all affected workers of the hazard source, control, and possible stored energy. (See *Table 6-3.)*
2. Shut down the system by isolation of energy sources. System is rendered inoperative.
3. Secure all energy source shutdowns by lockout/tagout of controls.
4. Release all stored energy and verify such release. *(See Table 6-3.)*
5. Verify by testing there is no voltage.
6. Provide temporary grounding *(Chapter 7).*
Re-energizing steps
7. Inspect the work area for an operationally intact system and remove nonessential items.
8. Notify workers that the system is to be re-energized and warn them to stand clear.
9. Remove temporary grounding *(Chapter 7).*
10. Remove the lockout/tagout devices.
11. Visually determine that all affected workers are clear of the circuit.
12. Proceed with restoring service.

6-3. Hazardous Energy Elimination. Eliminate any source of hazardous energy affecting the work by controlling electrical and nonelectrical energy hazards as shown *in Table 6-3.*

Table 6-3. Hazardous energy control

	Electrical systems/equipment
1.	Isolating by control operation: • Open switching devices; lockout if possible • Pull plugs or fuses • Block interlock feedbacks
2.	Stored or other energy release: • Disconnect and discharge capacitors, choke coils, and surge arresters. • Discharge static electricity. • Temporarily short to ground induced voltage from adjacent lines, static charges, accidental connections, and incorrect disconnections. • Provide shielding for possible contact with energized parts
3.	Verify by testing there is no voltage on de-energized system/equipment.
	Nonelectric energy hazards
4.	Check for chemical, electromagnetic, mechanical, pneumatic, thermal, and ultraviolet energy.
5.	Isolate by blocking valve operations or other control operations for the above systems.
6.	Discharge trapped energy by releasing pressure or by draining/purging lines and verify lack of rotation or dangerous temperatures.

CHAPTER 7. DE-ENERGIZED LINE GROUNDING

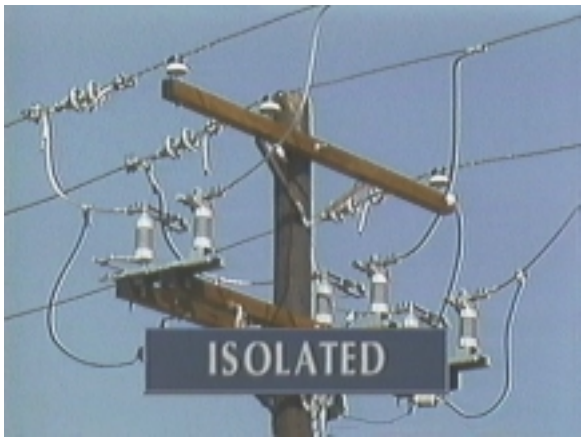
7-1. Grounding Provision. Grounding must be used to limit dangerous potentials. Permanent grounding is provided as a part of any electrical system to meet safety and system requirements. A ground system consists of a grounding connection, a grounding conductor, a grounding electrode, and the earth (soil) that surrounds the electrode or some conductive body which serves instead of the earth (an airplane's frame) as a minimum impedance return path for fault current. A jumper is to connect conductors so that continuity is maintained. Bonding is the joining of metallic parts to form a conductive path. Temporary grounds must be used so that work may be safely done on parts of the system that are temporarily isolated and cleared (de-energized).

7-2. Why Temporary Grounds Are Necessary. Energized lines over 50 volts which have been opened and checked as showing no voltage must be considered as hot if they have not been grounded. Potential differences can occur on de-energized lines from any of the factors described in *Table 7-1*. Temporary grounding is essential for safety. *Pictures 7-1, 7-2,* and *7-3*, indicate the steps to ensure that an energized line is de-energized. *Picture 7-4* shows a tester used to check the resistance of temporary grounding sets.

Table 7-1. Causes of hazardous induced potential differences

1.	Potential differences caused by various line effects (such as induced voltages from adjacent energized lines and electrostatic build-up from wind action).
2.	Lightning strikes anywhere in the circuit.
3.	Fault-current feed-over from adjacent energized lines.
4.	Connection to an energized source through switching equipment, either by equipment malfunction or human error.
5.	Accidental contact of the de-energized line with adjacent energized lines.
6.	Residual charge from power-factor correction capacitors or surge arresters.

Picture 7-1
Energized line



Picture 7-2
Isolated line

Picture 7-3
Grounded line

Picture 7-4
A protective grounding set tester

7-3. Equipotential Ground Zone. Whenever possible install temporary grounding to provide an equipotential zone at the work site. An equipotential zone provides a zero ground potential gradient across a worker's body, thus preventing a harmful electrical current through the worker. *Figure 1-1* shows the voltage gradient around a grounded energized object when a ground fault occurs. *Figure 1-2* shows the current path across the worker's body which flows when there is a potential difference between two different points or an individual's contact with the ground or a grounded structure. *Table 6-2* indicates where grounds are provided in the sequence of de-energized lockout/tagout steps.

7-4. Placement of Grounds. Temporary grounds must be installed as close as possible to the work. Temporary grounding connection/removal procedures must be in accordance with *Table 7-2*. Never approach closer than working distances given in *Table 3-2* until after the line/equipment has been isolated, de-energized, tested, and properly grounded. Afterwards, avoid coming closer than 10 feet (3 meters) to minimize the hazard from step and touch potentials. This minimizes step and touch potential differences. Such potential differences occur from items such as down guys, ground rods, maintenance vehicles, and structure legs or ground wires during the period in which they are bonded to temporary grounds. When it is absolutely necessary to work on or near these features, workers should use bonded conductive or insulated platforms, or approved insulated shoes to minimize the hazard from step and touch potentials. Bond separately grounded systems together if they can be simultaneously contacted.

Table 7-2. Temporary grounding connection/removal procedures

1.	Select a ground electrode using either an established ground at the structure or a temporarily driven ground rod (see *Picture 7*-7). The selection should minimize impedance and not introduce a hazardous potential difference.
2.	Test the de-energized line/equipment for voltage by an approved tester, verified immediately before and after use as to its good working condition (see *Picture 5-12).*
3.	Visually inspect ground equipment. Check mechanical connections for tightness. Clean clamp jaws and conductor surfaces. Clean not earlier than 5 minutes before connection using a wire brush attached to a hot-line tool. Use of self-cleaning equipment is also acceptable.
4.	The ground end clamp of each grounding cable should always be the first connection made and the last to be removed. Hot sticks must be used if the grounded system and worker are at different potentials.
5.	The conductor-end clamps of each grounding cable must always be connected last and removed first by hot sticks. Apply to the nearest conductor first and proceed outward and/or upward until all phases have been connected. Remove in reverse order. The practice of holding the cable near the base of the hot stick to lighten the load on the head of the stick is strictly prohibited. Instead, a co-worker should assist in installing heavy cables by holding the cable with another hot stick, or by using a “shepherd hook” with a pulley and a nonconductive rope to hoist the grounding cable into position.

7-5. Temporary Grounding System Components. Use system application (overhead, underground, substation) sets with *ASTM F 855 (Temporary Grounding Systems to be Used on De-Energized Electric Power Lines and Equipment)* grounding jumpers (clamps, ferrules, and clear 600-volt jacketed elastomer flexible cable) to the maximum possible extent.

a. Clamps. Use the alloy (copper or aluminum) matching the conductor or device to which it is attached and meeting or exceeding the current-carrying capacity of the associated cable. Use smooth jaw clamps on buses to avoid surface marring. Use serrated clamp jaws to bite through corrosion products for attachment to conductors or metal products. Self-cleaning jaws are recommended for use on aluminum (see *Picture 7-5*). Never use hot-line clamps for grounding.

b. Cable. Cables should be preferably *ASTM F 855, Type I* of a minimum 2/0 AWG copper selected to meet the fault current necessary as given for 15-cycle substation duty and 30-cycle line use. See *Table 7-3*.

(1) Derating. Derate these fault current by 10 percent when using multiple ground cables (which must all be of the same size and length).

(2) Handling. Handle cables to avoid conductor strand breakage from sharp bends or excessive continuous flexing. Avoid excessive cable length because an increased resistance can elevate potential differences and twisting or coiling reduces their current-carrying capacity. Avoid very low temperatures; the clear jacket which allows checking for strand breakage will stiffen at low temperatures and split or shatter.

(3) Facility-Prepared Cable. Cables prepared by facility personnel for grounding applications should be highly flexible but rugged. (Specialty multi-stranded cables intended for electric welders or for railroad locomotives are typically used.)

Table 7-3. Maximum fault current capability for grounding cables[1]

Cable size (AWG)	Fault time (cycles)	RMS amperes (copper)
2/0	15	27,000
	30	20,000
3/0	15	36,000
	30	25,000
4/0	15	43,000
	30	30,000

[1]These current values are the "withstand rating" currents for grounding cables and cables as per *ASTM F 855*. These values are about 70 percent of the fusing (melting) currents for new copper conductors. They represent a current that a cable should be capable of conducting without being damaged sufficiently to prevent reuse.

c. Ferrules. Use *ASTM F 855*, Type IV (threaded stud copper base compression type) when installed on grounding cables by facility personnel. (See *Picture 7-6*.) Ferrules should have the filler compound vent hole at the bottom of the cable so that employees can visually check that the cable is fully inserted into the ferrule. Heat shrink or springs should be installed over a portion of the ferrule to minimize strand breakage caused by bending. In all cases, the manufacturer's recommendations should be followed. Do not use aluminum alloy ferrules as they will not provide a lasting snug fit. Check for tightness periodically.

d. Grounding Cluster Bars. Use to connect phase and neutral conductor jumper cables to the selected method of providing a ground electrode (pole ground wire, temporary ground rods, substation ground grid). Cluster bars must have an attached bonding lead. Provide temporary ground rods as given in *Table 7-4*. See *Pictures 7-7* and *7-8.*

Table 7-4. Temporary ground rod minimum requirements

1. Single rod installed to a depth of 5 feet (1.5 meters) below grade. • A minimum 5/8-inch (16-millimeter) diameter bronze, copper, or copper-weld rod at least 6 feet (1.8 meters) long. • A 6-foot (1.8-meter), screw-type ground rod, consisting of a minimum 5/8-inch (16-millimeter) diameter copper-weld shaft with a bronze auger bit and bronze T-handle, tightly connected to the rod.
2. Additional rods to provide a total of 5 feet (1.5 meters) below grade where required. • Install 6 to 8 feet (1.8 to 2.4 meters) apart while maintaining the 10-foot (3-meter) step and touch potential clearance. • Bond all rods together prior to installing other electrode connections.

7-6. Temporary Grounding of Aerial Lines. Ground by installing an overhead distribution grounding set as shown on *Picture 7-9.* The grounding set provides a parallel low-level (milliohm) resistance path which limits the current flow through the worker to a very low (safe) value (milliamperes) thus limiting the potential across the worker to a safe value. If the ground resistance were in series with the worker life-endangering currents could flow through the worker under fault conditions. Avoid any ground connection which could provide violent whipping from wind action. *Picture 7-10* shows a single-point ground. Double-point grounds are sometimes utilized but single-point grounding is the preferred method. If double-point grounding is necessary, install the temporary grounds at least one span away from the work site because the grounding cables may violently move during a fault condition. An incorrect multi-point ground is shown on *Picture 7-11. Picture 7-12* shows the proper method of holding a ground cable.

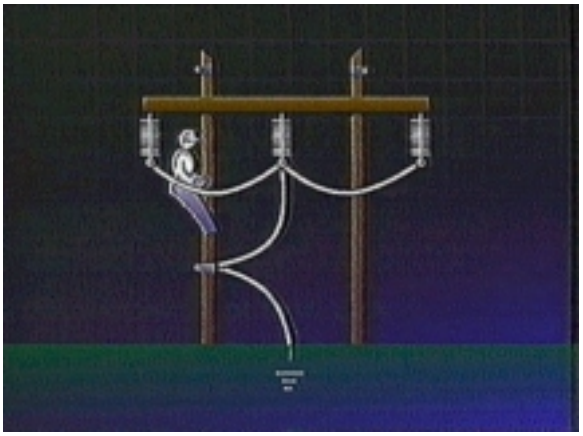
Picture 7-5
Grounding clamps

Picture 7-6
Grounding ferrules

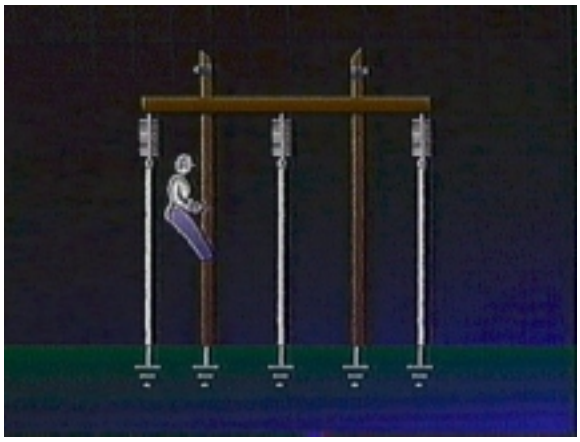
Picture 7-7
Driving a ground rod

Picture 7-8
Cleaning the cluster bar with a wire brush

Picture 7-9
Proper temporary grounding connections



Picture 7-10
Correct Multi-Bonding, with single-point to ground



Picture 7-11
Incorrect (No bonding) single-point grounds

Picture 7-12
Proper method of holding a ground cable

7-7. Temporary Grounding of Substation Current-Carrying Equipment Components. Ground de-energized current-carrying components of substation equipment before approaching them within working clearance distances given in *Table 3-2*. Grounds should be placed as close to the equipment as practical *(see distance D1 on Figure 7-1)* to minimize the inductive voltage loop (*see distance D2 on Figure 7-1)* formed by the ground cable and the worker. See *Tables 7-5* and *7-6*. Special precautions are needed during oil handling *(Table 7-7).*

Table 7-5. Substation protective grounding procedures

1.	Check validity of permanent equipment grounds.
2.	Install a protective ground cable and bond to a grounded structure member or to a common copper equipment bushing lead for equipment being worked on.
3.	Apply personal protective grounds before working within *Table 3-2* clearance distances on substation equipment including:
	• Bushings • Buses • Capacitors • Circuit breakers • Instrument transformers • Power transformers • Switches • Surge arresters

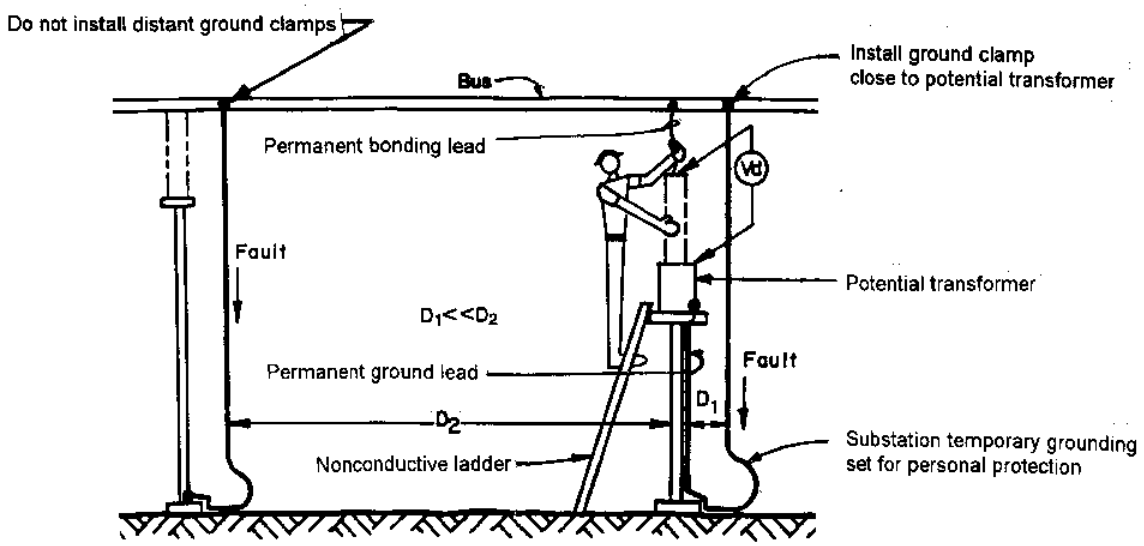


Figure 7-1
Substation temporary grounding

Table 7-6. Grounding of substation equipment

1. Grounds must be in place (see Table 7-7) before a tank is opened and the insulating medium (oil/gas) is changed. This does not apply to sampling.
2. No type of switch may be used to maintain personal ground continuity.
3. Allow at least 5 minutes between opening of the capacitor switching devices and the closing of the ground switch on a fully charged capacitor bank. At least 5 minutes must be allowed after the ground switch is closed before installing protective grounds. A capacitor bank must remain de-energized for at least 5 minutes before it is re-energized. The time required for these maneuvers must be explicitly expressed in switching orders involving capacitor banks.
4. Surge arresters must be disconnected and discharged using grounding cables.
5. Grounding transformers mustl not be worked on unless de-energized and properly grounded. Phase reactors must be isolated from all energized sources and grounded before being worked on.
6. Bushing leads may be disconnected from bushing terminals as necessary to permit equipment testing that requires the equipment to be ungrounded. Use a hot stick to connect test equipment and re-establish the ground as soon as the test is completed. Following an applied potential test (“Hi-Pot”), ensure the ground remains in place for a period at least two times the duration of the test period. Work clearances and grounding instructions for the test equipment must be in accordance with the manufacturer’s recommendations.
7. Install separate grounds for each isolated section of the de-energized circuit if a hazard exists when working in a de-energized area of a substation where there are one or more physical breaks in the electrical circuit.

Table 7-7. Grounding of equipment during oil handling

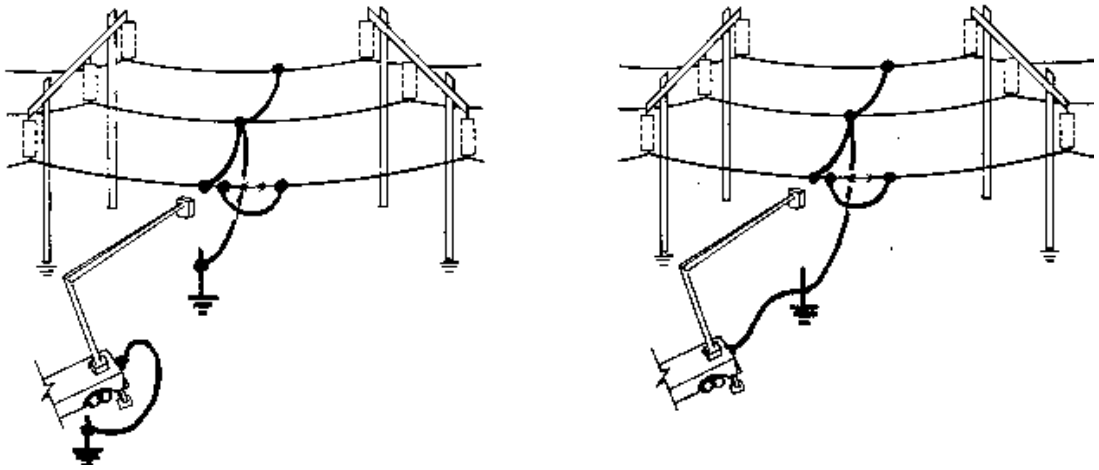
Observe the following precautions to prevent the buildup of a hazardous electrical charge:

1. Bond apparatus tanks, conductive hoses, pumping or filtering equipment, drums, tank cars, trucks, and portable storage tanks to the station ground mat. Connect the vehicle end first and disconnect it last to prevent possible arcs near the vehicle.
2. Bond exposed conductors, such as transformer or circuit breaker bushings, or coil ends or transformers where bushings have been physically removed, to the same grounding point.

7-8. Aerial Lift Truck Vehicle Grounding. Ground vehicles prior to conductor bonding, if at all possible. If not, use a hot stick to remove or install vehicle grounds on a grounded system bonded to the conductor. Ground in accordance with *Table 7-8* and *Figure 7-2.*

Table 7-8. Procedures for grounding insulated and uninsulated aerial lift trucks

Grounding	Procedure
Insulated boom vehicles	Bond the vehicle to a separate driven ground rod located about midway on one side and as close to the vehicle as practical. If possible, keep insulated vehicles and their ground rods at least 10 feet (3 meters) away from the structure grounding system to minimize step and touch potentials. If workers can simultaneously contact two or more separately grounded systems, the systems must be bonded together.
Uninsulated boom and other electrical work vehicles	Bond the uninsulated boom and all other vehicles directly involved in electrical work to the grounded system using a grounding cable rated for the maximum available fault current.
Tensioning vehicles	Vehicles used to pull and hold tension on the conductor or overhead ground wire must be properly bonded to a structure ground or a temporary ground rod. Stay on the vehicle or at least 10 feet (3 meters) away from the vehicle ground when possible.



Insulated aerial lift

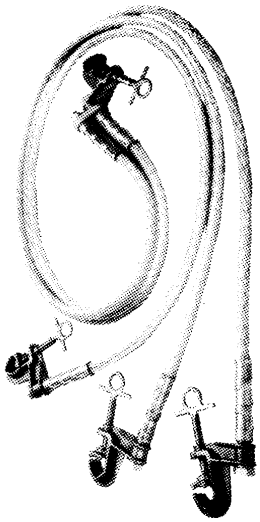
Uninsulated aerial lift

Figure 7-2
Insulated and uninsulated aerial lift vehicle grounding connections

7-9. Temporary Grounding of Underground Lines. Ground all possible sources of power (including transformer backfeed). Omission of grounds may be permitted only if their omission decreases the work hazard. Install protective grounds at equipment terminations or ground by spiking cable (using an approved tool) prior to work on the cable. Use approved ground sets of the type shown on *Figure 7-3.*

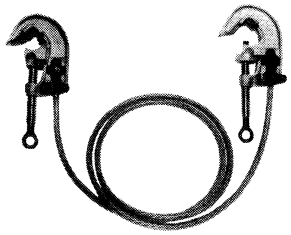
7-10. Opening or Splicing De-Energized Conductors. Conductors may be spliced at ground level, from aerial lift equipment utilizing ground mats (uninsulated aerial lifts), or from insulating platforms (insulated aerial lifts). Grounding for conductive or insulating platforms is shown on *Figure 7-4.* Install all grounding jumpers with hot sticks. Steps in providing safe grounds are given in *Table 7-2.* Remove in reverse order as installed. Ground any mobile equipment. Stay 10 feet (3 meters) away from grounded items and step onto equipment or platforms as quickly as possible to minimize any adverse step and touch potentials.

7-11. Grounding for Stringing and Removing Lines. Locate grounds to meet requirements of *Table 7-9* and *Figure 7-5*. After conductor pulling, locate grounds in accordance with *Table 7-10.*

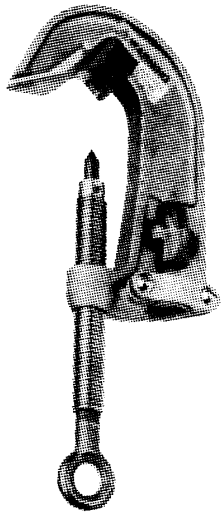


Live-front pad-mount equipment grounding set

Elbow grounding set

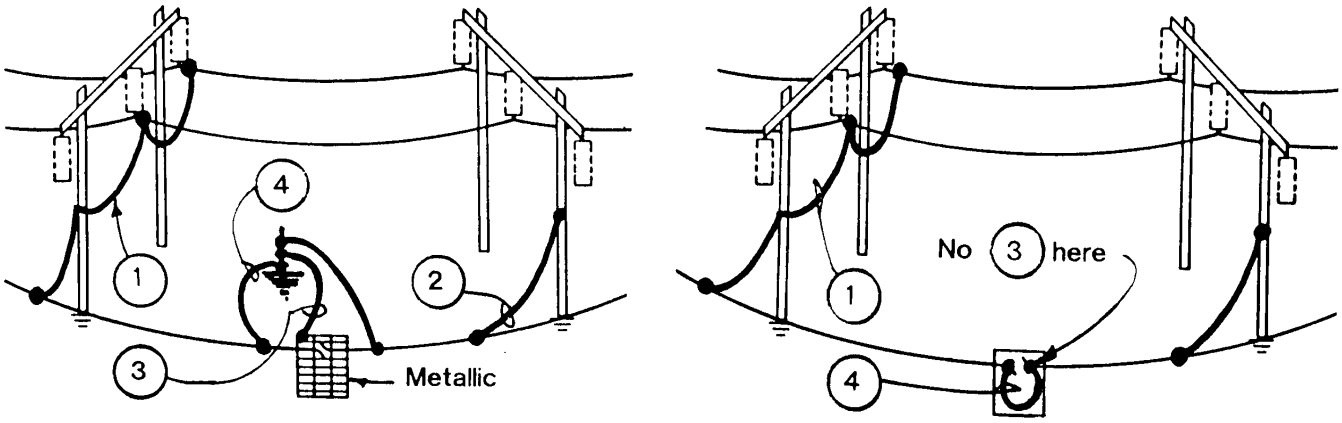


Cable spiking grounding jumper



Cable clamps with a penetrating grounding spike

Figure 7-3
Underground system grounding sets



Conductive platform Insulating platform

1. Three-phase ground all conductors and structure on one side of the work.
2. Single-phase ground work on conductor and structure on the other side of the work.
3. Ground conductive platform but not insulating platform.
4. Maintain integrity of conductor connection.

Figure 7-4

Using a conductive or insulating platform for opening/closing de-energized overhead conductors

Table 7-9. Stringing/removing conductor ground locations

1. Ground all stringing equipment such as reel stands, pullers, tensioners, and other devices.
2. Provide a safety barrier around the equipment.
3. Install a running ground between pulling and tensioning equipment and their adjacent structures.
4. Ground stringing blocks at first and last structures, and at least every 2 miles (3.2 kilometers) in between.
5. Ground stringing blocks at each structure on both sides of an energized circuit being crossed. If the design of the circuit interrupting devices protecting the lines so permits, the automated reclosing feature of those devices shall be made inoperative.

Table 7-10. Conductor ground location after pulling

1. Ground at each structure next to intermediate deadends of the stringing operation.
2. Ground at each structure where and while work (including clipping-in) is being performed on or near the conductor.
3. Remove grounds as the last phase of finished aerial installation.

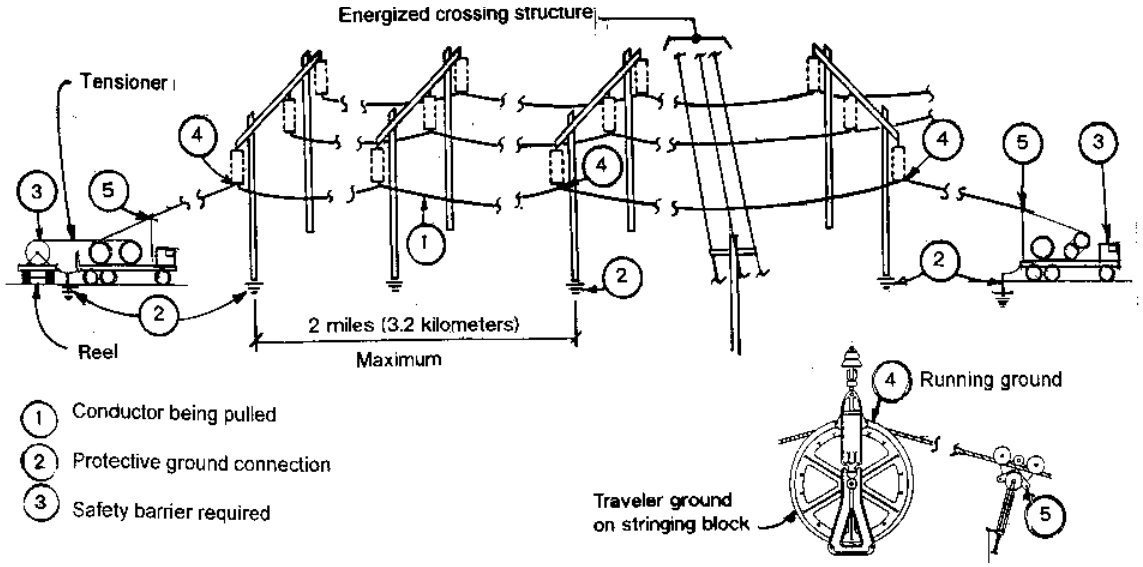


Figure 7-5

Composite stringing/removing the temporary protective grounds on overhead conductor lines

CHAPTER 8. ENERGIZED LINE WORK

8-1. Normal Work Methods. Lines shall be worked de-energized, except where energized line maintenance has been approved by the Base Civil Engineer, the Chief of Operations Flight, or other designated authority (per local designation) and considered necessary to support a critical mission, prevent human injury, or protect property. Observe approved work methods, equipment prework procedures, and general job-in-progress procedures. No work may be performed during adverse weather conditions (ice storms, high winds, electric storms) unless there is an emergency and the work has been approved. See *Tables 3-4, 3-5,* and *3-6* for number of qualified workers.

8-2. Permitted Energized Line Work Methods. Only the approved methods given in *Table 8-1* may be used by facility workers in performing energized line maintenance.

Table 8-1. Categories of energized line maintenance work

Line potential	Worker insulation	Energized line clearances	Approved for use
Ground	None	Use lockout/tagout and temporary grounding	Always
Intermediate	Isolated by aerial lifts/ insulating supports	Use insulated equipment and tools on energized lines	Requires specific approval
Line	Insulated from ground	Bonded to energized line for barehand work	Prohibited

8-3. Voltage Levels and Approved Work Methods and Equipment. Use the approved energized work methods given in *Table 8-2* while maintaining the working distance requirements given in *Table 3-2.* Use insulating (rubber) goods meeting the requirements of *ASTM F 18* standards with color coding meeting the requirements of *Table 5-1*. Use leather protectors over rubber gloves. Use insulating tools meeting the requirements of *Table 8-3* and insulating plastic guard equipment meeting the requirements of *Table 8-4*. Use approved gloves and rubber insulating sleeves with hot-line tools. The use of hot-line tools without gloves to detect tool deterioration is discouraged. Complete instructions and regulations detailing correct use and maintenance of such tools/equipment should be available and reviewed as a part of the work procedures. At least two workers, fully qualified for the voltage range (including other conductors within reach) must be available.

Table 8-2. Approved energized work methods by voltage class

Nominal ac voltage level	Work method
Up to 600 volts	Gloving by conventional work position or by structure mounting (ground potential)
0.601 to 7.5 kilovolts	Gloving from structure mounting or in an aerial lift bucket (ground potential)
7.6 to 15 kilovolts	Gloving from electrically insulated aerial lift bucket or platform (intermediate protection) or gloving and use of live-line tools from structure mounting or an aerial lift bucket (ground potential)
15.1 to 36 kilovolts	Gloving and use of live-line tools from an electrically insulated aerial lift bucket (intermediate potential)

Table 8-3. Insulating tools for electrical workers

Standards			
ASTM F711, Specification for Fiberglass Reinforced Plastic (FRP) Rod and Tube Used in Live-Line Tools.			
IEEE Std 978, Guide for In-Service Maintenance and Electrical Testing of Live-Line Tools.			
Minimum test values			
Tool material	OSHA acceptance[1]	IEEE in-service[2]	Use
Fiberglass reinforced plastic (FRP)	100 kV/foot (0.3 meters)	75 kV/foot (0.3 meters)	Preferred[3]
Wood	75 kV/foot (0.3 meters)	50 kV/foot (0.3 meters)	Phase-out[4]

[1]Test values manufacturers must certify for acceptance by buyer.
[2]Test values required after acceptance and tested after use in the field. Electrically test at intervals of not more than 6 months for tools in frequent use. Electrically test at intervals of not more than one year for tools stored for long periods of time. See *AFMAN 32-1185 (Electrical worker Safety)* for electrical test methods.
[3]All new tools must be FRP.
[4]Replace wood hot line tools with FRP tools.

Table 8-4. Insulating plastic guards/platforms for electrical workers

Standards			
ASTM F 712, Test Methods for Electrically Insulating Plastic Guard Equipment for Protection of Workers			
ASTM F 968, Specification for Electrically Insulating Plastic Guard Equipment for Protection of Workers			
ASTM F 1564, Specification for Structure Mounted Insulating Work Platforms for Electrical Workers			
Common classifications for plastic guards			
Installation	**Conductors**	**Structure/apparatus**	**Special**
✎ Attached hot stick ✎ Eye for removable hot stick ✎ Rope loop or equivalent for gloving or hot stick	✎ Line guards ✎ Line guard connectors ✎ Insulator covers ✎ Deadend covers ✎ Bus guards ✎ Bus “T” guards	✎ Pole guards ✎ Ridge pin covers ✎ Switchblade covers ✎ Arm guards ✎ Cutout covers ✎ Crossarm guards	✎ Shape ✎ Size ✎ Attachment ✎ More stringent electrical requirements

Table 8-4. Insulating plastic guards/platforms for electrical workers (cont.)

Class	Guard rating for accidental brush contact: Maximum use rating kV (60 Hz)		Proof test withstand voltage (in-service testing)			Criteria
	Phase-to-phase[1]	Phase-to-ground	Phase-to-ground kV 60 Hz	dc	Duration, minutes	
2	14.6	8.4	13.0	18	1	No flashover other than momentary as a result of too close spacing of electrode
3	26.4	15.3	24.0	34	1	
4	36.6	21.1	32.0	45	1	
5	48.3	27.0	42.0	60	0.5	
6	72.5	41.8	64.0	91	0.25	

[1]Cover-up materials are tested at values greater than the 60 Hz use maximum phase-to-ground values. The maximum use phase-to-phase values relate to guarded-phase-to-guarded-phase. The units are not rated for bare-phase-to-guarded-phase potentials.

8-4. Prework Procedures. Do not start work until the requirements of *Table 8-5* have been completed.

Table 8-5. Prework procedures

1. Obtain energized work approval.
2. Determine existing conditions and complete a job hazard analysis (see *Chapter 2)*.
3. Determine the voltage rating of circuits to be worked on, distances to other energized lines, and location of work. Evaluate the following:
If aerial lift equipment can be used.
What personnel qualifications are needed for the work.
If special equipment, tools, or hazard protection are needed.
4. Prepare a work procedure, preferably written (see *Chapter 2)*.
5. Review work and safety precautions with the crew before work begins (including tailgate briefing).
6. Inspect tools/equipment before starting work.

8-5. General Job-in-Progress Procedures. Observe the precautions given in *Table 8-6* before proceeding with the procedures given in *Table 8-7*.

Table 8-6. Energized work precautions

1.	Check that circuit automatic reclosing devices have been made inoperative while work is being performed.
2.	All items of a voltage class lower than required for the work should not be available to the workers at the work site.
3.	Exercise special care when working in the proximity of equipment such as fuses, surge arresters, and similar equipment, or where conductor checks indicate burns or other defects in conductors, tie wires, and insulators. Procedures may require that some equipment be bypassed for the duration of the work.
4.	Comply with adverse weather and number of qualified worker requirements.

Table 8-7. Voltage level work procedures

Voltage levels, 600 volts and below
1. Ground vehicles and aerial lifts in the vicinity of the work site.
2. Cover with approved protective equipment, or isolate with suitable barriers, energized phase and neutral wires, ground wires, messengers, and guy wires in the vicinity of the work. Apply covering to the nearest and lowest conductor first and remove in reverse order. See *Tables 7-5, 7-6*, and *7-7*.
3. See *Table 8-2* for work methods. Rubber gloves with leather protectors must be worn when entering a glove-required area and removed only after leaving that area.
4. Observe the working distance requirements of *Table 3-2*.
5. Protective equipment and vehicle grounds should be removed at the end of each workday.
6. Perform work on only one conductor at a time.
7. Tape or otherwise protect splices. Secure loose ends of conductors

Table 8-7. Voltage level work procedures (cont.)

Voltage levels, 601 to 15,000 volts
8. Ground vehicles and aerial lifts in the vicinity of the work site.
9. Cover with approved protective equipment, or isolate with suitable barriers, energized phase and neutral wires, ground wires, messengers, and guy wires in the vicinity of the work. Apply covering to the nearest and lowest conductor first and remove in reverse order. See *Tables 7-5, 7-6*, and *7-7*.
10. Use approved live-line tools where required by *Table 8-2*. Rubber must be worn when entering a glove-required area and removed only after leaving that area.
11. Observe the working distance requirements of *Table 3-2*.
12. Protective equipment and vehicle grounds must be removed at the end of each workday.
13. Work performed must be under the direct supervision of a qualified work leader devoting full time and attention to the workers and the safety of their work.
14. Perform work on only one conductor at a time, although it is recognized that three-phase lifting tools may be used.
15. When moving an energized conductor with live-line tools, stay below the conductor until it is firmly secured in a safe working position
16. Do not raise, move, or lower conductors more than 1.5 feet (0.45 meters) when energized at 7,500 to 15,000 volts. Do not move conductors energized at more than 15,000 volts.

Table 8-7. Voltage level work procedures (cont.)

Voltage levels, above 15,000 volts
17. Except for the replacement of fuses and switching, work on energized lines or apparatus at this voltage range should be performed by qualified contract personnel. Follow the requirements of *Table 8-2*.
18. Do not move conductors energized at more than 15,000 volts.
19. Live-line work above 36,000 volts must be done by qualified contract personnel.

CHAPTER 9. SUBSTATIONS AND SWITCHGEAR

9-1. Safety Precautions. Review the applicable safety rules given in *AFMAN 32-1185* for outdoor substations and interior medium-voltage systems for the specific safety rules applying to the work which you will be doing. Ensure that everyone is alerted to possible job hazards and is aware of their responsibilities. Discuss any question you have at your tailgate briefing before the job is started. (See *Table 2-4*.)

9-2. Major Equipment Hazards and Safety Precautions. Each type of equipment has its own safety rules. *Table 9-1* summarizes safety reminders. Essential to all safe operations is the use of proper protective equipment, knowledge of the manufacturer's safety instructions, and correct identification of the devices worked on.

9-3. Examples of Safety Checks. Examples of some of the working methods or checks to assure safety are shown on *Pictures 9-1* through *9-8*.

Table 9-1. Major device important safety reminders

Testing
1. Provide a written switching order sequence.
2. Determine interrupting capability for opening loads.
3. Lock out switches.
4. Check procedures for opening/closing oil switches.
5. Check fuses for partial melting and do not bypass, except with plainly visible jumpers.
Energy storing devices
6. Positively disconnect surge arresters and choke coils. Discharge and ground them.
7. Provide the correct discharge period for disconnected capacitors. Wait at least 5 minutes after de-energizing a capacitor bank before grounding its terminals. Use hot-line tools and install grounding equipment to dissipate residual charges.
Instrument transformers
8. Ground case and one secondary winding of voltage (potential) transformers (PT). Remove secondary fuses before replacing primary fuses.
9. Short secondary leads and ground them if the primary of a current transformer (CT) is energized. Use a CT short-circuiting type terminal block, if provided.

Table 9-1. Major device important safety reminders (cont.)

Power transformers and regulators
10. Disconnect all primary wires and disconnect or ground all secondary wires on power transformers.
11. After de-energizing the transformer, verify there is a good transformer tank ground.
12. Set regulators in the neutral position before opening or closing their bypass switch.
Metalclad switchgear and network protectors
13. Prior to racking out a metalclad switchgear circuit breaker, trip the circuit breaker, and then de-energize and ground the switchgear. De-energize heater circuits if necessary for the work. Caution: Stand-alone circuit breakers may use a capacitive trip device that retains a charge (up to 500 volts). The device does not contain a built-in discharge resistor. If available use the manufacturer's procedure to discharge the trip device. Otherwise, discharge the trip device using a minimum 10-kilohm, 1-watt resistor. Do not use a jumper.
14. Shutters in medium-voltage metal clad switchgear are not intended to prevent electric shock. When working near the rear of the switchgear, use lockout/tagout procedures and temporary grounding.
15. Do not use circuit breaker grounding and test devices unless specifically qualified on this specialty item.
16. Do not work on network protectors unless specifically qualified on this specialty item. Always wear flash-resistant clothing when operating network protectors and keep unnecessary personnel clear.

Table 9-1. Major device important safety reminders (cont.)

Batteries
17. Wear protective clothing *(Picture 9-4).* 18. Check ventilation for adequacy. 19. Do not smoke or use an open flame. 20. Do not use brushes or devices which can short out a battery cell. 21. Check that all safety equipment is provided.
Phasing
22. Check correct phase relationship. For two buses (1 and 2) correctly in-phase, expect to measure: a. Rated line-to-line voltage: 1A-1B, 1A-1C, 1B-1C, 2A-2B, 2A-2C, 2B-2C. b. Rated line-to-line voltage: 1A-2B, 1A-2C, 1B-2A, 1B-2C, 1C-2A, 1C-2B. c. Zero (or near zero) voltage: 1A-2A, 1B-2B, 1C-2C.
Rotating equipment
23. Rotating equipment (such as engine- and motor-generators and many motors) is often automatically started or remotely started. Ensure all means of manual and automatic operation are locked out and tagged, both locally and remotely. 24. Ensure approvals are obtained before shutdown of critical, emergency, or standby equipment.

Picture 9-1
Working around overhead hazards

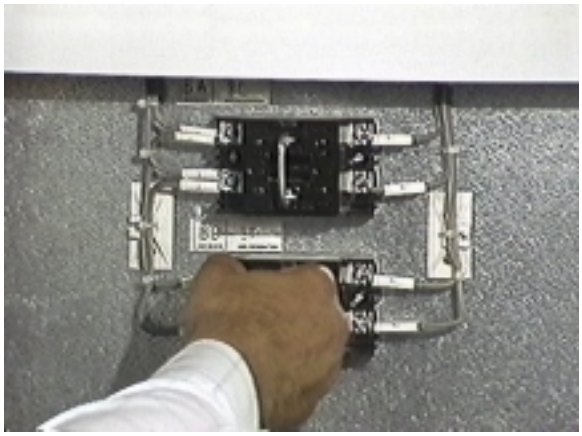
Picture 9-2
Dry cleaning substation insulators

Picture 9-3
Testing a circuit breaker for no potential

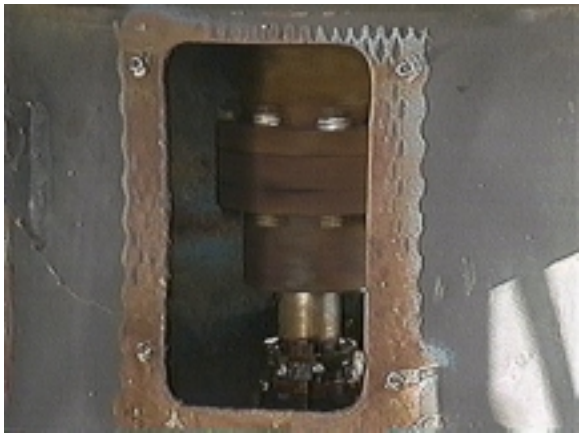
Picture 9-4
Protective clothing for maintaining a battery

Picture 9-5
Opening a disconnect switch

Picture 9-6
Insulating mat for protection against step ground potential at switchgear



Picture 9-7
Remove control fuses



Picture 9-8
Residual energy of a rotating object

CHAPTER 10. AERIAL LINES

10-1. Safety Precautions. Review the applicable safety rules given in *AFMAN 32-1185* for overhead lines and associated electrical components. Ensure presite job requirements *(Table 2-4)* are completed. Discuss any question at the tailgate briefing before the job is started.

a. On-Ground Work. On-ground work is not covered in this handbook. See *AFMAN 32-1185* for information on pole handling and installation, and conductor stringing and removal.

b. Above-Ground Work. Above-ground work may be accomplished from an aerial lift truck or by climbing the pole. Consider street lighting circuits as possibly energized to the highest voltage of conductors occupying the same poles. See *Subparagraph 5-1d* for equipment for positioning a worker. See *Subparagraph 4-2a* for climbing protection and training. *Figure 4-2* covers fall protection.

10-2. Climbing and Working on Poles. Precautions for equipment such as surge arresters, switches, fuses, capacitors and power transformers are discussed in *Table 9-1*.

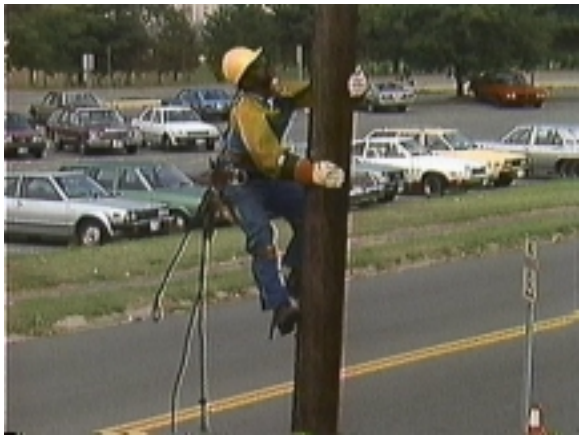
Table 10-1. Pole climbing and working precautions

1.	Determine that the pole is safe to climb and the best climbing space.
	The safety strap should not be attached to the pole while climbing or descending the pole except in conditions of high winds or severely inclement weather.
3.	Never depend on crossarm assemblies for support nor attach your safety strap close enough to the top of the pole where it could slip off. Always carry a safety handline.
4.	Where there are two workers on the same pole, one must be in a working position or on the ground before the other ascends or descends. Never work directly under another worker on the pole or on the ground, except in an emergency.
5.	Take special care when crossing pole-mounted structures from one side the other.

10-3. Aerial Rope Use. Select and treat the aerial rope you use in accordance with the requirements of *AFMAN 32-1185*. Always use polypropylene synthetic rope in good condition and of the proper strength. Rope must be dry, and of the necessary length. Do not allow the rope to be damaged by contamination or abraded by pulling methods.

10-4. Examples of Safety Checks. Examples of some of the working methods or checks to assure safety are given in *Pictures 10-1, 10-2, 10-3,* and *10-4*.

Picture 10-1
Sounding a pole for adequate strength



Picture 10-2
Proper body position for pole climbing

Picture 10-3
Proper foot positioning

Picture 10-4
Installing hot-line wire tongs

CHAPTER 11. UNDERGROUND LINES

11-1. Safety Precautions. Review the applicable safety rules given in *AFMAN 32-1185* for underground cables, structures, and associated electrical components. Ensure presite job requirements *(Table 2-4)* are completed. Discuss any questions at the tailgate briefing before the job is started.

a. Worker Protection. Treat underground structures such as manholes and unvented vaults as confined spaces and conform to the requirements of *AFOSH Standard 91-25 (Confined Spaces)*. Treat these structures as permit-required confined spaces and conform to the requirements for testing/monitoring, ventilation, attendants, respiratory protection, personal protective equipment, and training. Provide the number of workers required by *Tables 3-4 and 3-5* as a minimum. Illumination should be at least the minimums given in *Table 3-1*.

b. Public Safety. Protect the public around the work area in accordance with *Subparagraph 3-1b*.

c. Existing Utility Protection. Locate and mark existing utilities in work areas where excavations are to be made. Digging restrictions may apply. Coordinate with the appropriate maintenance group or the fire department for unexpected hazards.

11-2. Underground Structure Precautions. Work in underground structures must conform to the confined space entry permit requirements. *Table 11-1* summarizes the major steps in determining that structures can be safely entered.

Table 11-1. Precautions before entering underground structures

1. Secure the work area *(Picture 11-1).*
2. Use the probes of an atmospheric tester to check air. First check for moisture on the end of the probe. If none found, test for air.
3. If air is acceptable, remove manhole cover *(Picture 11-2).*
4. Inspect the structure interior for the presence of water, oil, gasoline, or other contaminants which must be removed before work can proceed *(Picture 11-3).* Then check the structure by lowering the probe as far as possible
5. If air is acceptable, set up the lifting A-frame on the manhole *(Picture 11-4).*
6. Enter (and leave) the structure by means of a ladder or climbing device for structures more than 4 feet (1.2 meters) deep. Never climb in or out by stepping on cables or their supports.
7. Test the air at each corner of the structure and at each of the duct entrances *(Picture 11-5).*
8. Provide additional ventilation as necessary *(Picture 11-6).* Continuous monitoring of air quality should be performed for work taking longer than 15 minutes. Whenever the cover has been replaced, repeat air testing.
9. Lower tools using a handline (*Picture 11-7*). Use the A-frame for heavy tools and parts, or when a manhole rescue must be made (*Picture 12-3*).

Picture 11-1
Securing the work area

Picture 11-2
Lifting a manhole cover

Picture 11-3
Checking a manhole for contaminants

Picture 11-4
Setting up the A-frame

Picture 11-5
Testing the atmosphere at conduit openings

Picture 11-6
Ventilating the manhole with a blower

Picture 11-7
Lowering tools into the manhole

Picture 11-8
Looking at elbow separable connectors

11-3. Work in Underground Structures. All work on separable connector or other equipment parts of energized cables shall be handled with live-line tools and/or rubber gloves as appropriate to the voltage level. See *Picture 11-8*. Work on equipment must be done in the same manner as given in *Table 9-1* with particular consideration given to the dangers of working in locations with limited access. Comply with the precautions given in *Table 11-2* for work in underground structures. Observe the safety precautions of *Table 11-3* when working on cables in structures underground.

Table 11-2. Precautions when working on underground structures

1. Use only flashlights or facility approved lighting units for illumination. In hazardous locations, use a light certified for NEMA Class 1, Division 1, Groups C and D locations (heat, spark, and impact resistant).
2. Never have open flames inside the structure and avoid spark producing connections/ disconnections.
3. Move energized cables only when specifically approved. Never change energized cable bends.
4. Splicing and terminating of cable must be done by qualified cable splicers/terminators.
5. Equipment for heating cable splicing materials must be operated only by workers trained in such use.

Table 11-3. Underground structure cable work precautions

1. Identify cables to be worked on and examine them for any damage.
2. Protect the work space by covering all live parts and cables with temporary insulation.
3. De-energize a cable and test for no voltage after waiting long enough for the dissipation of any static or capacitive charges. This period should be at least 5 minutes for capacitors with internal discharge resistors and at least twice the duration of an applied voltage test (“Hi-Pot”).
4. Ground the de-energized cable downstream from all sources of electric power and on both sides of the work location as hazardous potential differences may occur on de-energized (but not grounded) cables (see *Table 7-1)*.
5. Proceed with cable work (such as cutting, resplicing, other reconnections, and fireproofing) in accordance with standard work procedures.

CHAPTER 12. ELECTRICAL WORKER RESCUE

12-1. Rescue Needs. Electrical workers on poles and in underground structures require training in rescue methods in addition to the required standard first aid training. See *paragraph 1-3* for mishap handling and locating treatment for electrical shock victims. They must be certified to administer cardio-pulmonary resuscitation.

12-2. Pole-Top Rescue. Apply first aid on the pole as necessary to prevent loss of life or minimize further injuries. Lower the victim from the pole as soon as practical and obtain medical assistance.

a. Pole-Top First Aid. Artificial respiration can be applied to a victim on a pole with victim in an unusual position like the one shown in *Figure 12-1.* If no aerial lift device is available for rescue, then a qualified climber (rescuer) should climb the pole. Free the victim from the energized line if the victim is still in contact with the line. Use great care to ensure you are not electrocuted. Use rubber gloves, rubber sleeves, hot-line tools, and other personnel protective devices as necessary for your safety. Mouth-to-mouth resuscitation can be applied to a victim on a pole and the best position will be slightly above the victim. See *Figure 12-2.* When the victim begins breathing naturally, keep the victim in position and under control until the victim can be lowered to the ground. If CPR is required, lower the victim as quickly as possible and then administer CPR.

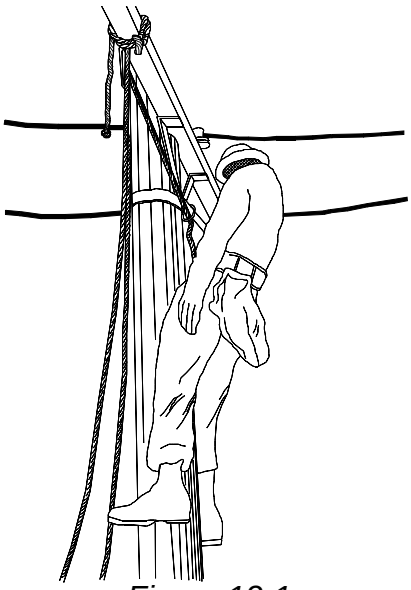


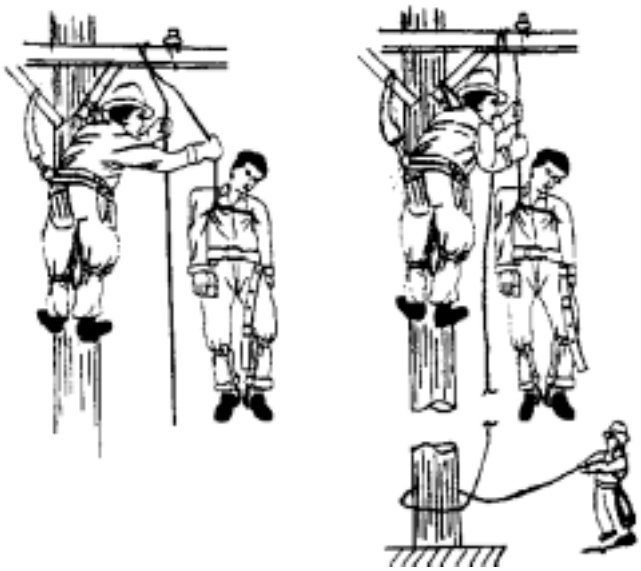
Figure 12-1
Unconscious victim on a pole

Figure 12-2
Mouth-to-mouth resuscitation on a pole

b. Lowering the Victim from the Pole. Use the handline method given in *Table 12-1* and as shown in *Figure 12-3.* After reaching the ground, summon help by whatever means available without delaying CPR (if required).

Table 12-1. Method for lowering a victim

1. Place a handline on the crossarm, preferably 2 or 3 feet (0.6 to 0.9 meters) from the pole.
2. With only one rescuer, it is necessary to add friction to the handline to control the rate of descent of the victim. This may be done by making two full wraps of the handline around the crossarm or other solid support before tying the handline to the victim. See *Pictures 12-1* and *12-2* and *Figure 12-3*.
3. Pass the handline under the victim's armpits.
4. Tie three half-hitches in the handline.
5. Cinch the handline tightly around the victim.
6. Remove the slack in the handline.
7. Cut the victim's safety strap.
8. With one rescuer, lower the victim by guiding the load line with one hand and controlling the rate of descent with the other hand. See *Figure 12-3.*
9. With two rescuers, the worker on the ground should make one full wrap of the handline around the base of the pole to add sufficient friction to control the rate of descent of the victim. See *Figure 12-3*.



1. One person 2. Two people

Figure 12-3
Control of a Handline

Picture 12-1
Handline wrap around victim

Picture 12-2
Handline wrap around crossarm

Picture 12-3
Effective manhole rescue

Picture 12-4
Rescue from an aerial lift

12-3. Rescue from a Manhole. Even though normal precautions are observed, there is always a possibility that personnel will be overcome by gas or injured, and rescue from a manhole is necessary.

a. Protect Yourself. Immediate rescue is important, but workers engaged in rescue attempts must protect themselves. In cases of asphyxiation or gas poisoning, it is advisable to ventilate with a blower *(Picture 11-6)* or other methods while preparing the rescue.

b. Safety Observance. All measures of safety must be observed. If at all possible, there should be another worker present to help with the rescue before you go into a manhole. If no other worker is available, you may proceed with the rescue if you are absolutely certain you will not become a second victim. Otherwise, obtain assistance from the fire department or other personnel trained in confined space rescue. There are many ways in which a rescue can be done. An effective method is shown in *Picture 12-3.*

12-4. Aerial Lift Rescue. Aerial lifts must be equipped to lower victims (see *Picture 12-4).*

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DCS/Installation & Logistics

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