CHAPTER 12

ELECTRICAL SAFETY

12-1. Human factor.

The protection of human life is paramount. Electrical equipment can be replaced; lost production can be made up; but human life can never be recovered nor human suffering ever compensated. The principal personnel dangers from electricity are that of shock, electrocution, and/or severe burn from an electrical arc or its effects, which may be similar to that of an explosion. The major contributors to work-related electrical accidents are unsafe conditions or unsafe practices. The most common unsafe conditions are damaged, defective, burned or wet insulation or other parts; improperly guarded or shielded live parts; loose connections or strands pulled loose; and equipment not grounded, or poor or inadequate grounding connection. Unsafe practices include failing to de-energize equipment being repaired or inspected; assuming an unsafe position near energized equipment; using tools or equipment too near bare energized parts; and misusing tools or equipment. Safety manuals provided by the military services are based upon the National Electrical Safety Code (NESC) which establishes general safe practices for construction, maintenance, and operation of all electric utility systems. The rules contained in these manuals are considered mandatory and must therefore be referenced at all times. Any deviations from these procedures must be agreed upon by the safety director. In general, to improve safety to personnel and avoid accidents, special attention must be directed to the following:

a. Be alert. Alertness is particularly essential on new assignments until safe habits are formed, but should never be relaxed since conditions often change.

b. Be cautious. Caution should be exercised at all times.

c. Develop safe habits. Safe habits result from repeated alertness and caution, and continuous adherence to the rules.

d. Know your job. Have complete and thorough information before proceeding.

e. Observe the rules. The rules and instructions applying to a variety of cases, both electrical and mechanical in nature, cover most of the common causes of accidents.

12-2. Equipment isolation.

As a general rule, no electrical apparatus should be worked on while it is energized. If it is not known whether a circuit is de-energized or not, it must be assumed that the circuit is energized and dangerous until such time it is proven otherwise. It is also important to regard exposed copper as energized and treat it accordingly since copper is rarely used except to carry current. When working near electricity, do not use metal rules or flashlights, or metallic pencils, and do not wear watch chains, finger rings or other objects having exposed conducting material.

a. De-energization. Personnel, who must work on de-energized equipment, should be protected against shock hazard and flash burns that could occur if the circuit were inadvertently re-energized. To provide this protection, the circuit must first be de-energized. Check applicable up-to-date drawings, diagrams and identification tags to determine all possible sources of supply to the specific equipment. Open the proper switches and/or circuit breakers for each source in order to isolate the equipment to be worked on. In cases where visible blade disconnecting devices are used, verify that all blades are fully open. Drawout-type circuit breakers should be withdrawn to the fully disconnected position. Do not consider automatic switches *or* control devices to be a disconnecting means for personnel safety.

b. Tagging and lock-out. All employees should plan for safety by following all lockout procedure rules before beginning work on any equipment. Four steps vital to any good lockout procedure are:

(1) Lock the equipment to prevent its use. Any energized equipment should be shut down by turning off power or closing valves to eliminate the possibility of electrocution, the inadvertent operation of machinery, or the release of hazardous materials.

(2) Identify the equipment to let other employees know it is not in service, when the lockout was initiated, and the purpose of the lockout.

(3) Clear the area to assure that other employees are a safe distance from the equipment before the lockout is tested.

(4) Test the equipment to verify that the equipment cannot be energized and that the lockout renders it inoperable. Before the test, check to be sure that all interlocks are engaged.

(5) Once the equipment is isolated, precautions must be taken to guard against accidental re-energization. Attach to the operating handles of the open disconnecting devices padlocks (fig 12-1) and/or approved red safety tags (fig 12-2). Red tags

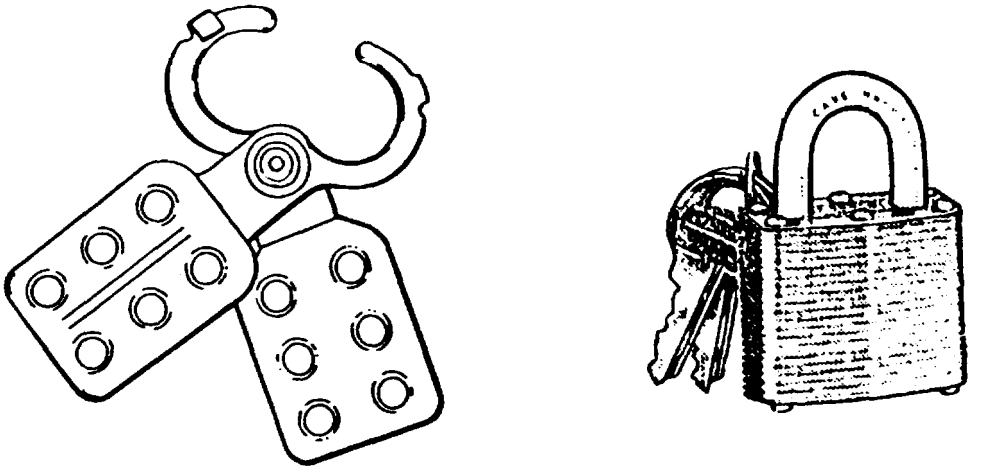


Figure 12-1. Padlock and multiple lock adapter.

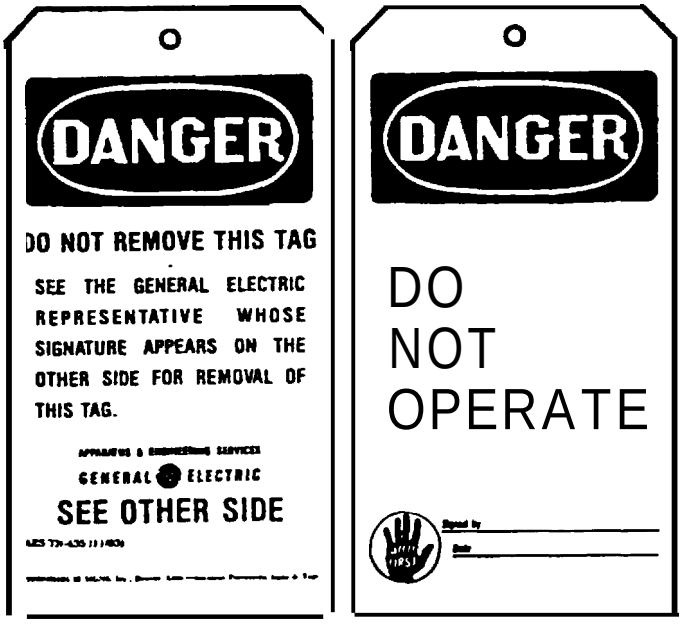


Figure 12-2. Typical safety tag.

are applied to devices to ensure that their positions will not be changed by unauthorized persons as long as equipment is blinked out and red tagged. These tags must identify the person having the key to the lock and the reason why the circuit is open. They must also show the time and date of its application. If fuses have been removed to de-energize the equipment, special precautions should be taken to prevent their unauthorized reinsertion. The following general rules should be observed in every lockout situation:

(a) An employee should never give a lock to another employee.

(b) Maintenance personnel should learn proper lockout procedures.

(c) All employees must follow correct lockout procedures.

c. Testing for voltage. After the equipment has been de-energized, tagged and locked out, the circuit must be tested to confirm that all conductors to the equipment are de-energized. This test is especially important on circuits which involve switches and freed-type breakers in which the blades cannot be visually checked. Use a volt meter or a volt-ohm-milliammeter (VOM) as described in paragraph 13-2 to test the de-energized circuit for zero volts. Before and after testing the affected conductors, determine that the VOM is operating satisfactorily by testing the voltage of a source which is known to be energized. Once these steps are completed, the equipment is safe to work on.

d. Maintenance grounding. In spite of all precautions, de-energized circuits can be re-energized inadvertently. When this occurs, adequate maintenance or safety grounding is the only protection for personnel. For this reason, it is especially important that adequate grounding procedures be established and rigidlv enforced. The tools used to apply a maintenance ground are primarily special heavy-duty clamps which are connected to cables of adequate capacity. These clamps and cable should not be larger than necessary because bulkiness and weight hinder personnel while connecting them to the conductors, Chains, small diameter wire or battery clamps should not be used to apply a maintenance ground because they can easily be vaporized in the event of a fault. Prior to application, ground cables should be inspected for broken strands in the conductors and loose connections to the clamp terminals, and clamp mechanisms should be checked for defects. Defective equipment should be replaced. Maintenance grounds should be applied on each side of a work point, or at each end of a de-energized circuit.

(1) *Ground cables.* Ground cables must be sized for the maximum available fault current. Due to the wide range of system voltages and fault currents, no published standards have been developed for specific applications or locations of grounding cables. A general survey of commercially available grounding and related safety devices shows use of 1/0 American Wire Gauge (AWG) copper cables. This size appears to be a good compromise between a reasonable range of fault currents, the cable's ability to safely conduct those currents given the thermal capacity, and the ease of physically handling the particular size wire. Ground cables (fig 12-3) should be no longer than necessary in order to keep cable resistance as low as possible and to minimize cable slack thereby preventing their violent movement under fault conditions. Ground cables should be connected first to the metal structure or switchgear ground bus and then to a phase conductor of the de-energized equipment. Then the ground cables should be connected between phases and to the system neutral (when available) to minimize the voltage drop across the work area should re-energization occur. When removing maintenance grounds, the above procedure should be reversed. Care must be taken to remove all ground cables before the equipment is m-energized. It is recommended that all conductors be tested with a megohmmeter to ascertain if any are still grounded.

(2) *Ground clamps.* Solid metal-to-metal connections are essential between ground clamps (fig 12-4) and the de-energized equipment. Ground clamps should have serrated jaws because it is impractical to clean conductors from paint or corrosion. The clamps should be tightened slightly in place, given a rotation on the conductors to provide a cleaning action by the serrated jaws, and then be securely tightened. Ground clamps which attach to switchgear ground bus are equipped with pointed or cupped set screws which should be tightened to ensure penetration through corrosion and paint, to provide adequate connections.

12-3. Switchgear.

The following precautions should be taken when working on switchgear.

a. Before you work on the switchgear enclosure, remove all drawout devices, such as circuit breakers, instrument transformers, fuses and control power transformers.

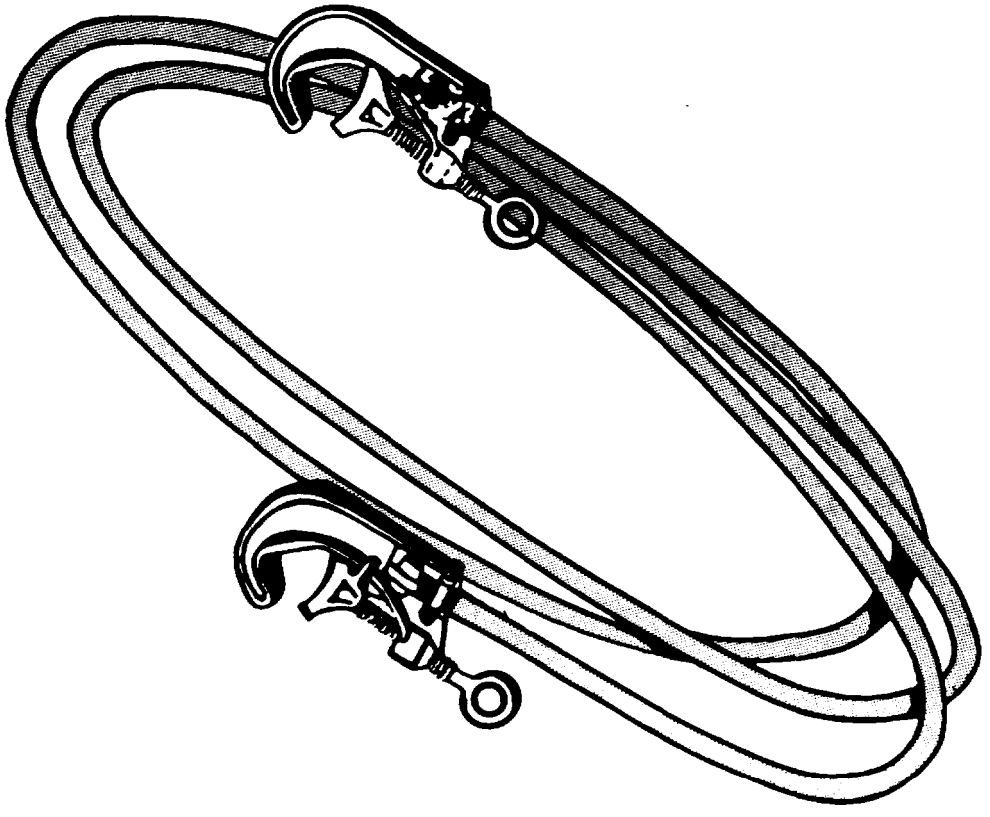


Figure 12-3. Ground cable.

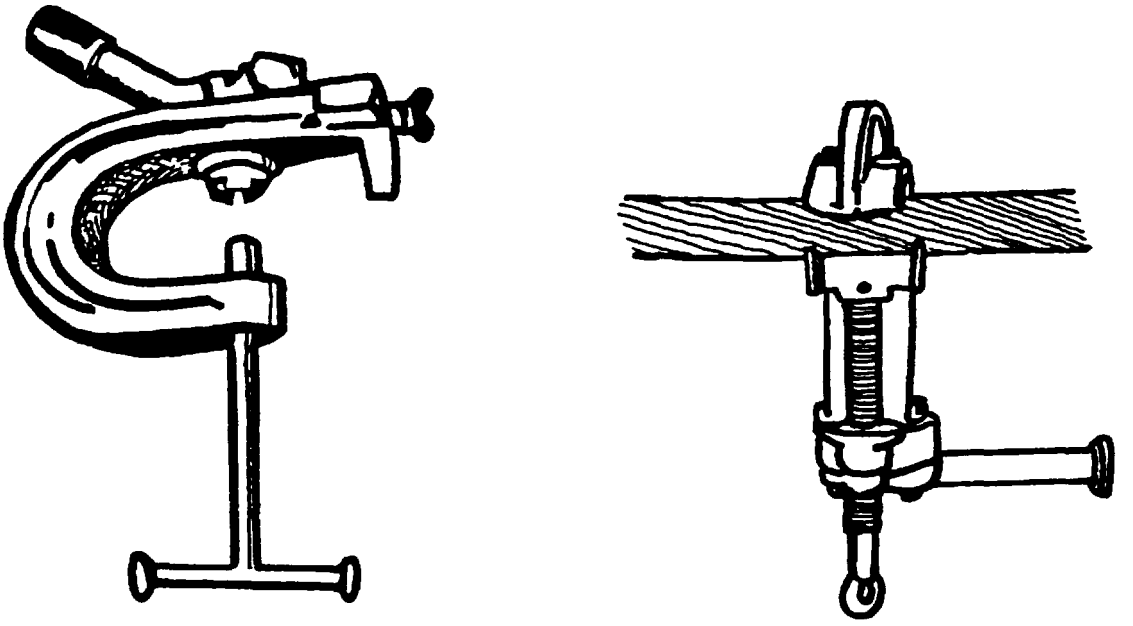


Figure 12-4. Grounding clamps.

b. Do not lay tools on the equipment while you are working. It is too easy to forget a tool when closing an enclosure.

c. Circuit breakers and switches are rated at maximum capacity and must not be used beyond this limit for fear of exploding an under-rated device.

d. If the enclosure is to be opened for any work at all, make sure power is off the bus. The insulating coating on the buswork is not sufficient to protect personnel working around it.

e. Knife switches must not be used to open power circuits, except for certain approved types of enclosed switches designed for that purpose. Before closing a disconnecting switch, make sure that conditions are safe for such an operation. Then throw the switch with a swift action without hesitation. Keep the body away from the front of these enclosures when operating them. Turn your head to prevent being burned from a possible flash.

f. Maintenance closing devices for switchgear are not suitable for closing in on an energized system.

12-4. Capacitors.

Before changing capacitor connections or doing work of any kind on them, discharge the capacitors with a properly insulated medium from terminal to terminal, terminals to case, and case to ground. Remember to keep capacitors short-circuited when not in use.

12-5. Rotating equipment.

The safety tips below must be followed when working on rotating equipment:

a. All rotating machinery must be carefully and thoroughly inspected for foreign objects before being started. This inspection must cover the machine both inside and outside. Loose articles lying on the base, pedestals, frame or blocking may fall or be drawn into the rotating parts; articles inside the machine may be thrown out.

b. Do not wear neckties or any other loose clothing, or carry loose tools that may get caught in rotating machinery.

c. At all times, the frames of all machinery, including portable hand tools, must be securely grounded.

d. While a machine is in motion or has voltage applied, brushes shall not be shifted. Even when inspecting brushes, the voltage should not be removed and extreme caution must be observed.

e. The commutators of DC machines must not be cleaned while voltage is applied. If cleaning is necessary, disconnect the source of power and allow the machine to coast while the operation is being performed.

f. Never open a field circuit unless some means is available to limit the induced voltage. Cutting in a discharge resistance is effective and protects an operator from injury and the machine from damage.

g. Rotating machinery must not be loaded or speeded beyond their ratings.

12-6. Transformers.

Never open-circuit the secondary of a current transformer having current flowing through its primary winding because of the resulting high induced voltages. If a current transformer has no secondary connected load, then the secondary terminals should be shorted. The secondary windings of both current and potential transformers must be grounded.

12-7. Wiring and testing.

Observe the safety rules below when wiring or testing:

a. Never start work or allow anyone else to start work on any circuit until you have made certain that the circuit has been properly de-energized, tagged, locked-out and grounded (see para 12-2). Inspect terminal connections and make sure that the bolted, soldered, crimped or welded lugs are secure.

b. Complete and inspect all wiring before making connection to the power circuit.

c. Before a plugging operation is attempted, the apparatus and circuit must be de-energized by opening a breaker or a switch.

d. When plugging power, first plug one end of the cable into the "load circuit" so that no power is on the cable. Then plug the other end firmly into an energized receptacle. When disconnecting a plug, reverse the sequence above.

e. When plugging to a grounded power supply the first conductor shall be connected in the grounded side of the circuit.

f. Whenever using a test table to operate electric equipment on which test set controls may be "hot-to-ground", stand on an insulated floor mat.

g. At least two persons should be present in the general area of all testing work of a hazardous nature, so that emergency assistance will be available.

h. Use only one hand whenever practical when working on circuits or operating control devices.

i. Instruments are likely to be "hot-to-ground", and power shall be removed from them before any reconnecting is attempted.

j. Carefully insulate exposed connections.

k. Under no circumstances shall cables with damaged insulation or without terminals be used.

l. Keep wiring off an iron floor. Do not roll trucks or other objects over any exposed cable.

m. The frames of all equipment under test or used in test must be grounded before power is applied.

n. Whenever connection is made to power circuits, proper protection must be afforded to both personnel and equipment by suitable opening devices.

o. Where connection is made to a DC circuit one side of which is grounded, one circuit breaker in the high side is sufficient. Where neither side is grounded, a circuit breaker must be placed on both sides of the circuit.

p. Note identification of all circuit outlets at test tables and switchboards, and be sure you make the correct connection.

q. Use only portable droplights with insulated lamp guards and handles.

r. Always test a circuit that you are to work on for zero volts. Before and after this test, check a circuit that is known to be energized so that the functionability of the tester maybe verified.

s. Do not rely on the solid insulation surrounding an energized conductor to protect personnel.

12-8. Mechanical.

Many power circuit breakers are both opened and closed with springs. These springs may remain charged even when a breaker has been withdrawn from its enclosure, and are capable of operating the breaker. If the breaker is closed, make sure the opening spring is discharged before you approach it with your tools or fingers. If the breaker is open, block it and wire the trip latch. Above all, read the manufacturer's instructions so that you can predict the condition of the breaker.

12-9. Danger warning and fire.

Approved danger warnings shall be used to indicate any temporary hazard, either electrical or mechanical, and the hazard area shall be sealed off. Under no circumstances shall this area be entered by unauthorized personnel until the warning is completely removed. Approved warning tags should be used, and military safety standards should be referenced for marking hazardous areas. Before attempting to extinguish an electrical fire, remove the voltage. Use fire extinguisher recommended for electrical fires but if none are available, attempt to contain the fire with water. Do not use carbon tetrachloride in confined areas, because of the poisonous fumes that may be emitted.

12-10. Personal protective equipment

For low voltage systems, the following personal protective equipment is recommended as a minimum:

a. Hard hats—

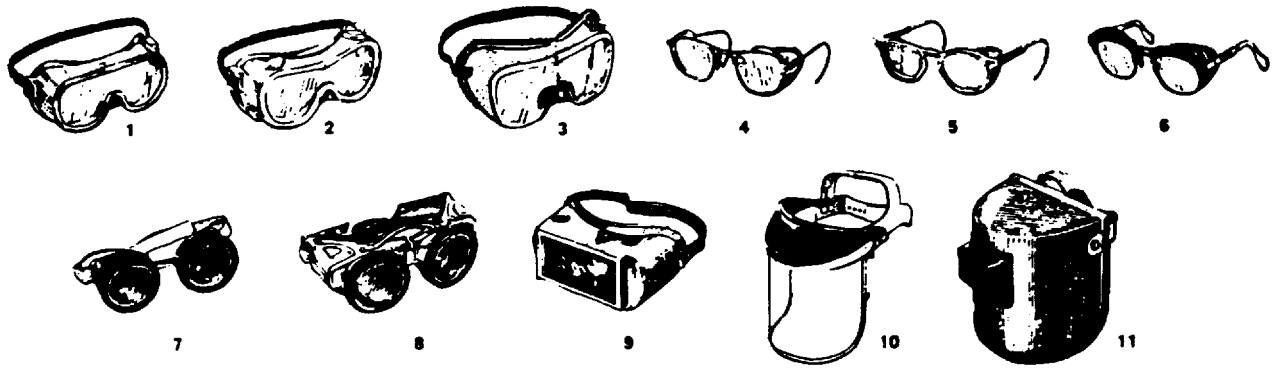
(1) ANSI Class A—limited voltage protection.
(2) ANSI Class C-no voltage protection.

b. Safety glasses (fig 12-5).

c. Safety shoes, steel toe.

d. Rubber gloves.

e. Breathing apparatus.



1. **GOGGLES,** Flexible Fitting, Regular Ventilation
2. **GOGGLES,** Flexible Fitting, Hooded Ventilation
3. **GOGGLES,** Cushioned Fitting, Rigid Body
*4. **SPECTACLES,** Metal Frame, with Sideshields
*5. **SPECTACLES,** Plastic Frame, with Sideshields
*6. **SPECTACLES,** Metal-Plastic Frame, with Sideshields
7. **WELDING GOGGLES,** Eyecup Type, Tinted Lenses (Illustrated)
7A. **CHIPPING GOGGLES,** Eyecup Type, Clear Safety Lenses (Not Illustrated)
8. **WELDING GOGGLES,** Coverspec Type Tinted Lenses (Illustrated)
8A. **CHIPPING GOGGLES,** Coverspec Type, Clear Safety Lenses (Not Illustrated)
9. **WELDING GOGGLES,** Coverspec Type, Tinted Plate Lens
10. **FACE SHIELD** (Available with Plastic or Mesh Window)
11. **WELDING HELMETS**

APPLICATIONS

OPERATION	HAZARDS	RECOMMENDED PROTECTORS: Bold Type Numbers Signify Preferred Protection
ACETYLENE–BURNING ACETYLENE–CUTTING ACETYLENE–WELDING	SPARKS, HARMFUL RAYS, MOLTEN METAL, FLYING PARTICLES	**7, 8, 9**
CHEMICAL HANDLING	SPLASH, ACID BURNS, FUMES	**2, 10** (For severe exposure add 10 over 2)
CHIPPING	FLYING PARTICLES	**1, 3, 4, 5, 6, 7A, 8A**
ELECTRIC (ARC) WELDING	SPARKS, INTENSE RAYS, MOLTEN METAL	**9, 11** (11 in combination with 4, 5, 6, in tinted lenses, advisable)
FURNACE OPERATIONS	GLARE, HEAT, MOLTEN METAL	**7, 8, 9** (For severe exposure add 10)
GRINDING–LIGHT	FLYING PARTICLES	**1, 3, 4, 5, 6, 10**
GRINDING–HEAVY	FLYING PARTICLES	**1, 3, 7A, 8A** (For severe exposure add 10)
LABORATORY	CHEMICAL SPLASH, GLASS BREAKAGE	**2** (10 when in combination with 4, 5, 6)
MACHINING	FLYING PARTICLES	**1, 3, 4, 5, 6, 10**
MOLTEN METALS	HEAT, GLARE, SPARKS, SPLASH	**7, 8** (10 in combination with 4, 5, 6, in tinted lenses)
SPOT WELDING	FLYING PARTICLES, SPARKS	**1, 3, 4, 5, 6, 10**

Figure 12-5. Eye and eye protection selection guide.