Test Prep Training for NABCEP® PV Installer Test

Structure of Test

- Working Safely with Photovoltaic Systems 15%
- Conducting a Site Assessment 5%
- Selecting a System Design 5%
- Adapting the Mechanical Design 15%
- Adapting the Electrical Design 20%
- Installing Subsystems and Components at the Site 20%
- Performing a System Checkout and Inspection 10%
- Maintaining and Troubleshooting a System 10%

Safety

Electricity - The Dangers

- About 5 workers are electrocuted every week
- Causes 12% of young worker workplace deaths
- Takes very little electricity to cause harm
- Significant risk of causing fires

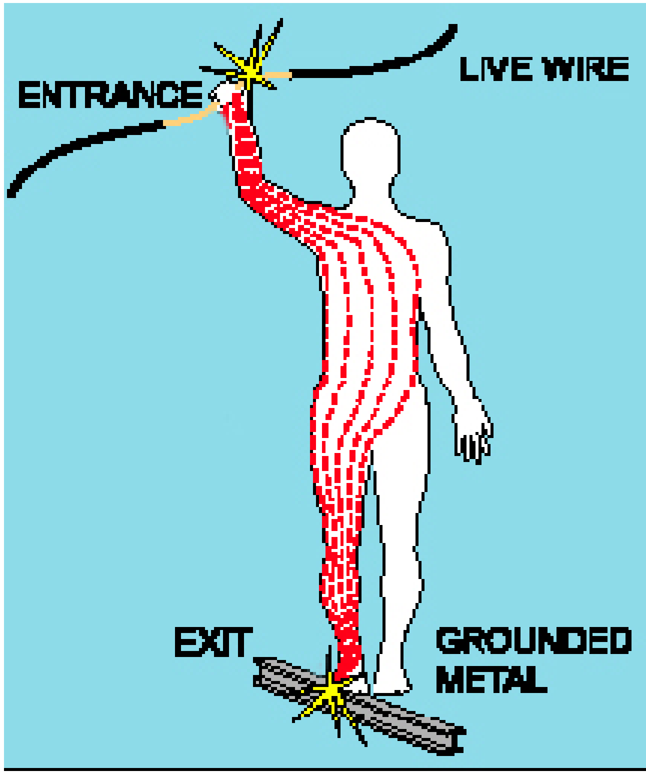
Electrical Injuries

There are four main types of electrical injuries:

- Direct:
  - Electrocution or death due to electrical shock
  - Electrical shock
  - Burns
- Indirect - Falls

Shock Severity

- Severity of the shock depends on:
  - Path of current through the body
  - Amount of current flowing through the body (amps)
  - Duration of the shocking current through the body,
- LOW VOLTAGE DOES NOT MEAN LOW HAZARD



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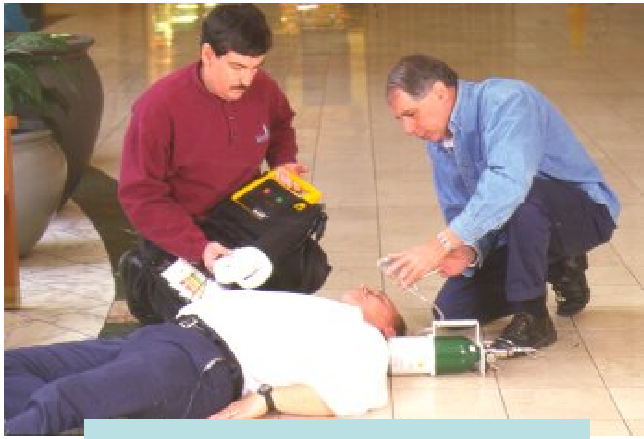
Dangers of Electrical Shock

- **Currents above 10 mA* can paralyze or "freeze" muscles.**
- **Currents more than 75 mA can cause a rapid, ineffective heartbeat -- death will occur in a few minutes unless a defibrillator is used**
- **75 mA is not much current – a small power drill uses 30 times as much**



Defibrillator in use

Burns

- Most common shock-related injury
- Occurs when you touch electrical wiring or equipment that is improperly used or maintained
- Typically occurs on hands
- Very serious injury that needs immediate attention

Falls

- **Electric shock can also cause indirect injuries**
- **Workers in elevated locations who experience a shock may fall, resulting in serious injury or death**

Electrical Hazards and How to Control Them

Electrical accidents are caused by a combination of three factors:

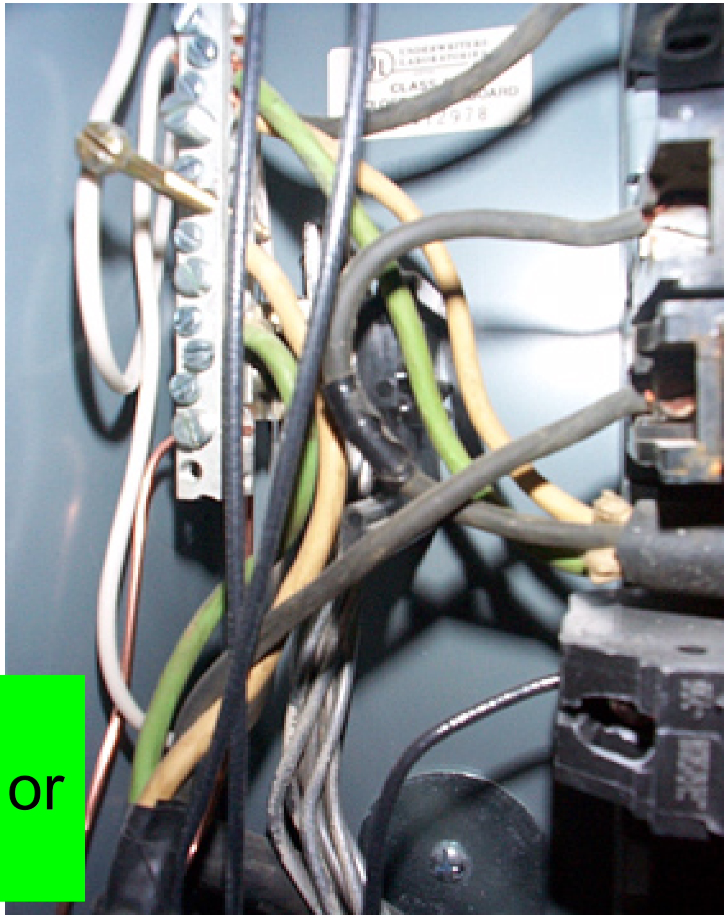
- Unsafe equipment and/or installation,
- Workplaces made unsafe by the environment, and
- Unsafe work practices.

Hazard – Exposed Electrical Parts

Cover removed from wiring or breaker box

Control – Isolate Electrical Parts

- **Use guards or barriers**
- **Replace covers**



Guard live parts of electric equipment operating at 50 volts or more against accidental contact

Isolate Electrical Parts - Cabinets, Boxes & Fittings

Conductors going into them must be protected, and unused openings must be closed

Control – Close Openings

- Junction boxes, pull boxes and fittings must have approved covers
- Unused openings in cabinets, boxes and fittings must be closed (no missing knockouts)

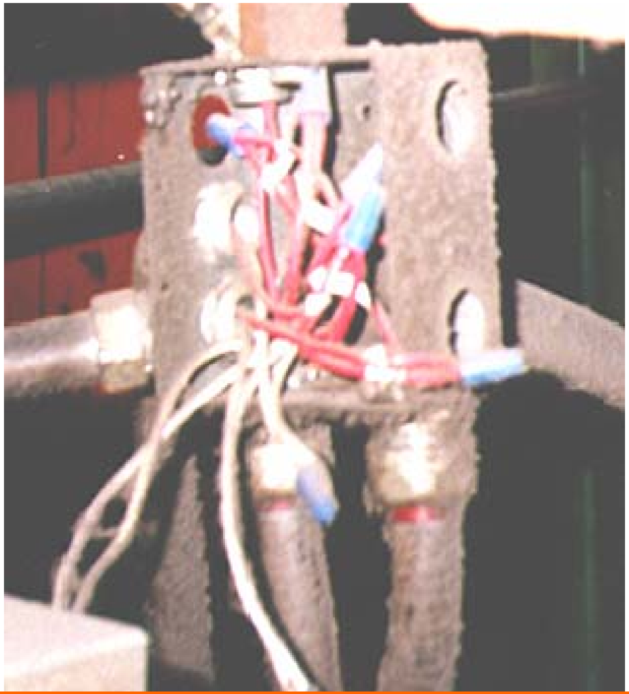


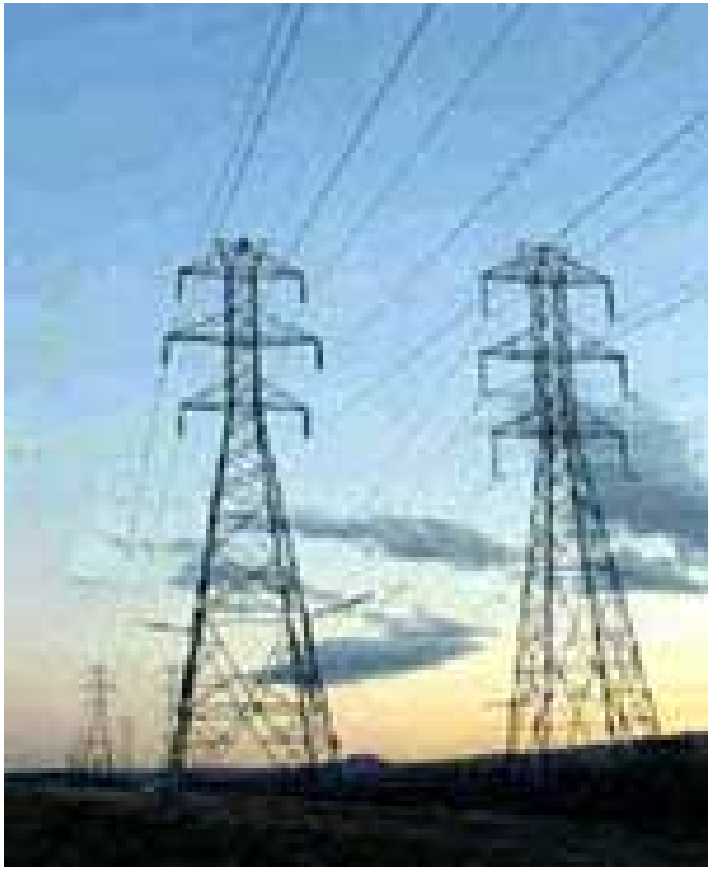
Photo shows violations of these two requirements

Hazard - Overhead Power Lines

- **Usually not insulated**
- **Examples of equipment that can contact power lines:**
  - **Crane**
  - **Ladder**
  - **Scaffold**
  - **Backhoe**
  - **Scissors lift**
  - **Raised dump truck bed**
  - **Aluminum paint roller**

Control - Overhead Power Lines

- Stay at least 10 feet away
- Post warning signs
- Assume that lines are energized
- Use wood or fiberglass ladders, not metal
- Power line workers need special training & PPE



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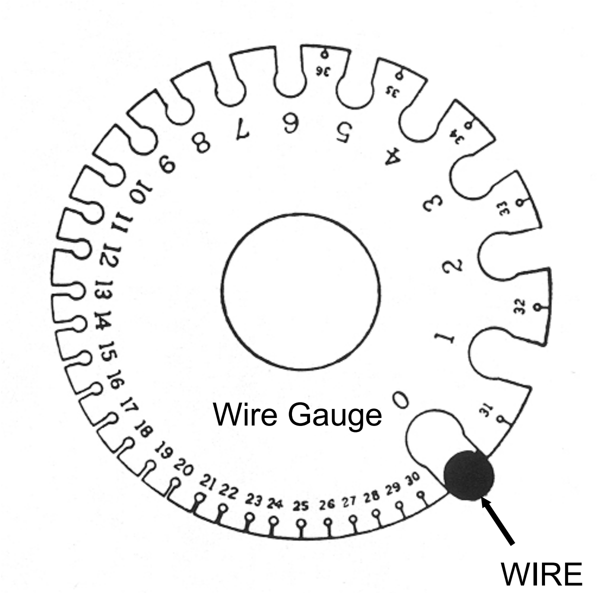
Hazard - Inadequate Wiring

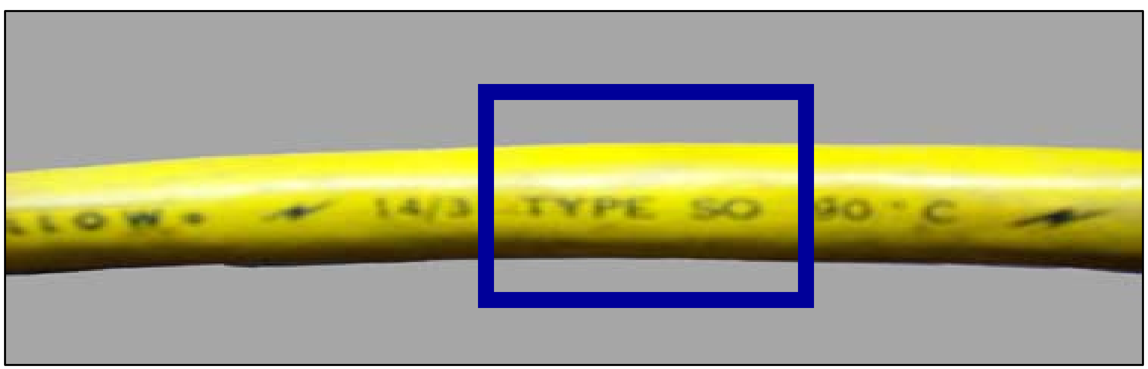
- **Hazard** - wire too small for the current
- **Example** - portable tool with an extension cord that has a wire too small for the tool
  - The tool will draw more current than the cord can handle, causing overheating and a possible fire without tripping the circuit breaker
  - The circuit breaker could be the right size for the circuit but not for the smaller-wire extension cord



Wire gauge measures wires ranging in size from number 36 to 0 American wire gauge (AWG)

Control – Use the Correct Wire

- **Wire used depends on operation, building materials, electrical load, and environmental factors**
- **Use fixed cords rather than flexible cords**
- **Use the correct extension cord**



Hazard – Defective Cords & Wires

- **Plastic or rubber covering is missing**

- **Damaged extension cords & tools**

Hazard – Damaged Cords

- **Cords can be damaged by:**
  - **Aging**
  - **Door or window edges**
  - **Staples or fastenings**
  - **Abrasion from adjacent materials**
  - **Activity in the area**
- **Improper use can cause shocks, burns or fire**

Control – Cords & Wires

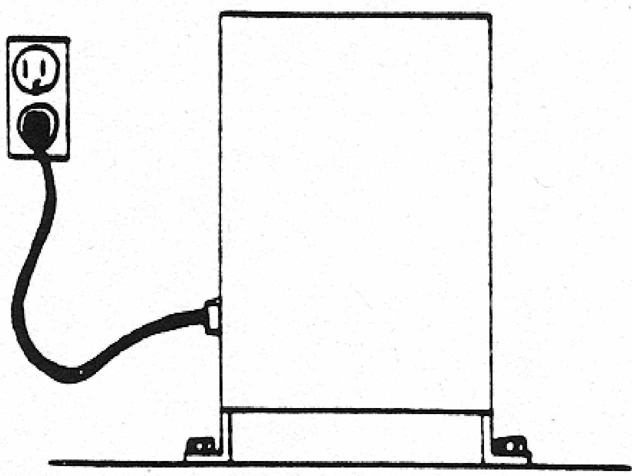
- Insulate live wires
- Check before use
- Use only cords that are 3-wire type
- Use only cords marked for hard or extra-hard usage
- Use only cords, connection devices, and fittings equipped with strain relief
- Remove cords by pulling on the plugs, not the cords
- Cords not marked for hard or extra-hard use, or which have been modified, must be taken out of service immediately

Permissible Use of Flexible Cords

DO NOT use flexible wiring where frequent inspection would be difficult or where damage would be likely.

Flexible cords must not be . . .

- **run through holes in walls, ceilings, or floors;**
- **run through doorways, windows, or similar openings (unless physically protected);**
- **hidden in walls, ceilings, floors, conduit or other raceways.**



Stationary equipment-to facilitate inspection or interchange

DC Power Systems

Grounding

Grounding creates a low-resistance path from a tool to the earth to disperse unwanted current.

When a short or lightning occurs, energy flows to the ground, protecting you from electrical shock, injury and death.

Hazard – Improper Grounding

- **Tools plugged into improperly grounded circuits may become energized**
- **Broken wire or plug on extension cord**
- **Some of the most frequently violated OSHA standards**

Control – Ground Tools & Equipment

- Ground power supply systems, electrical circuits, and electrical equipment
- Frequently inspect electrical systems to insure path to ground is continuous
- Inspect electrical equipment before use
- Don’t remove ground prongs from tools or extension cords
- Ground exposed metal parts of equipment

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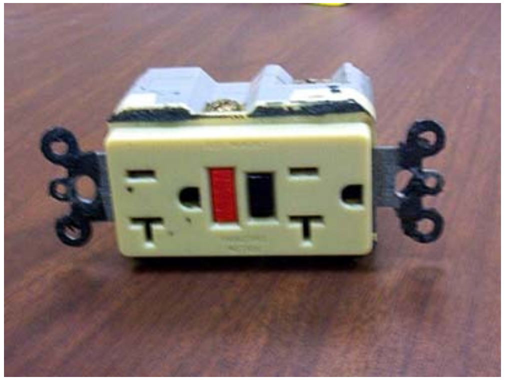
Control – Use GFCI (ground-fault circuit interrupter)

- **Protects you from shock**
- **Detects difference in current between the black and white wires**
- **If ground fault detected, GFCI shuts off electricity in $1/40^{th}$ of a second**
- **Use GFCI's on all 120-volt, single-phase, 15- and 20-ampere receptacles, or have an assured equipment grounding conductor program.**



Hazard – Overloaded Circuits

Hazards may result from:

- **Too many devices plugged into a circuit, causing heated wires and possibly a fire**
- **Damaged tools overheating**
- **Lack of overcurrent protection**
- **Wire insulation melting, which may cause arcing and a fire in the area where the overload exists, even inside a wall**

Control - Electrical Protective Devices

- **Automatically opens circuit if excess current from overload or ground-fault is detected – shutting off electricity**
- **Includes GFCI's, fuses, and circuit breakers**
- **Fuses and circuit breakers are <u>overcurrent</u> devices. When too much current:**
  - **Fuses melt**
  - **Circuit breakers trip open**

Power Tool Requirements

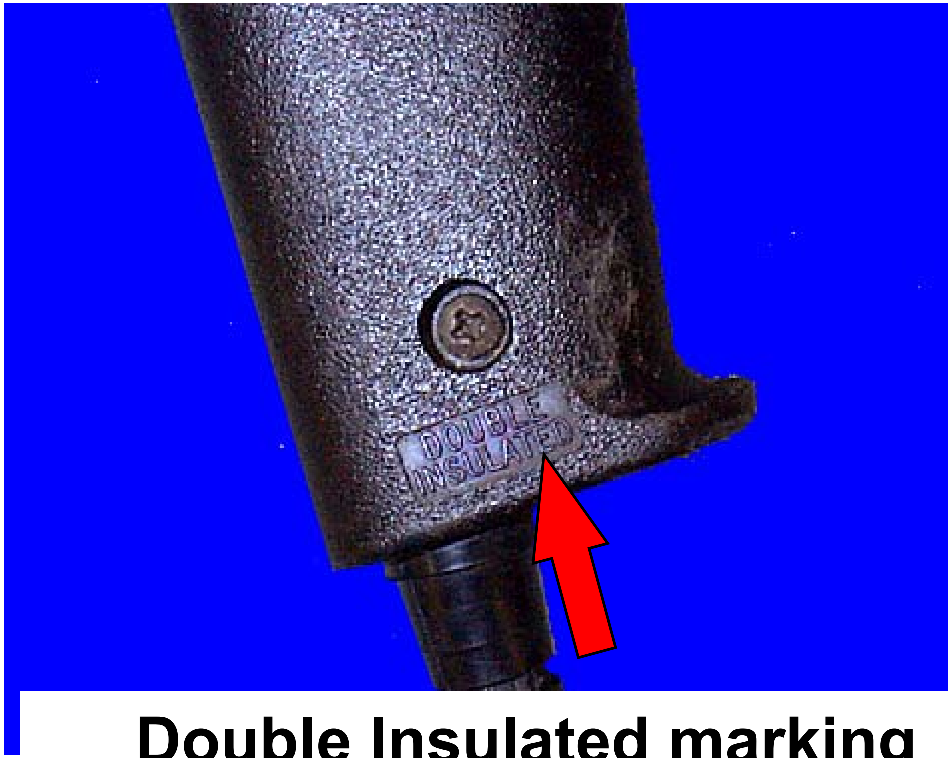
- Have a three-wire cord with ground plugged into a grounded receptacle, or
- Be double insulated, or
- Be powered by a low-voltage isolation transformer

Tool Safety Tips

- Use gloves and appropriate footwear
- Store in dry place when not using
- Don’t use in wet/damp conditions
- Keep working areas well lit
- Ensure not a tripping hazard
- Don’t carry a tool by the cord
- Don’t yank the cord to disconnect it
- Keep cords away from heat, oil, & sharp edges
- Disconnect when not in use and when changing accessories such as blades & bits
- Remove damaged tools from use

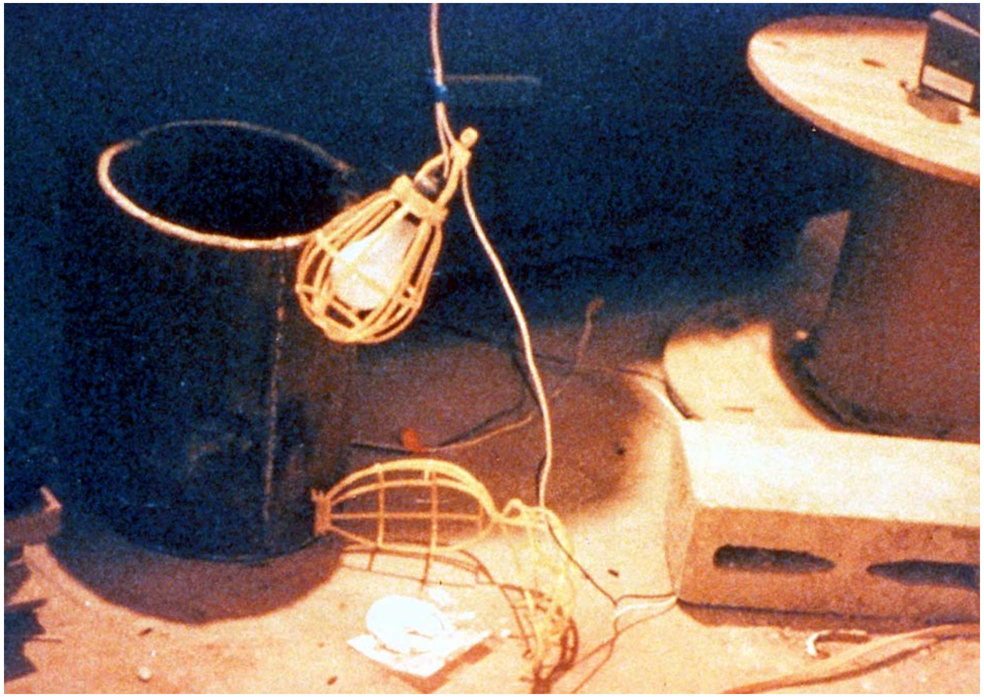
Preventing Electrical Hazards - Tools

- Inspect tools before use
- Use the right tool correctly
- Protect your tools
- Use double insulated tools



Double Insulated marking

Temporary Lights



Protect from contact and damage, and don't suspend by cords unless designed to do so.

Clues that Electrical Hazards Exist

- **Tripped circuit breakers or blown fuses**
- **Warm tools, wires, cords, connections, or junction boxes**
- **GFCI that shuts off a circuit**
- **Worn or frayed insulation around wire or connection**

Lockout and Tagging of Circuits

- Apply locks to power source after de-energizing
- Tag deactivated controls
- Tag de-energized equipment and circuits at all points where they can be energized
- Tags must identify equipment or circuits being worked on

Safety-Related Work Practices

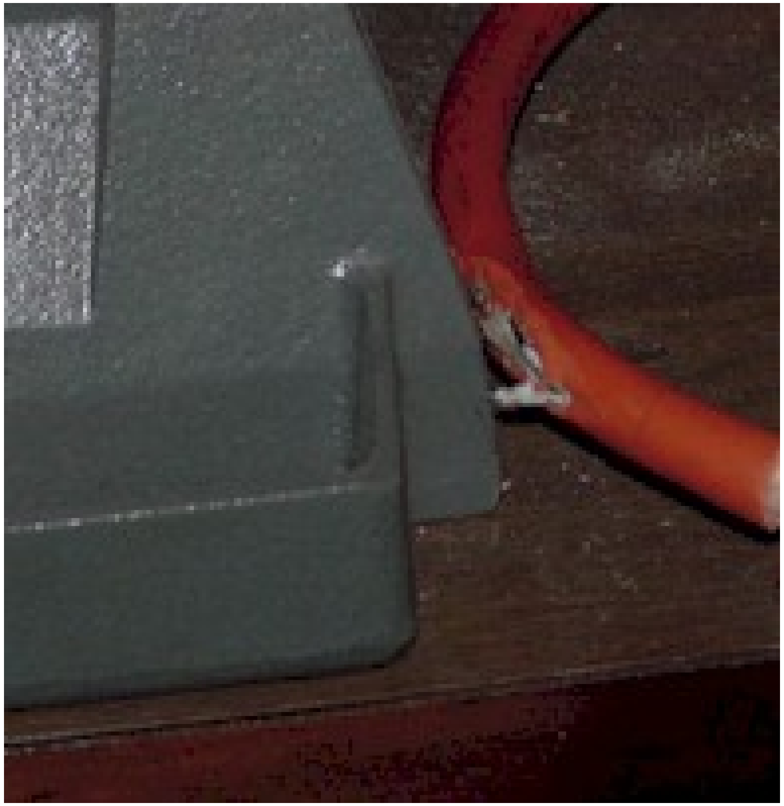
To protect workers from electrical shock:

- **Use barriers and guards to prevent passage through areas of exposed energized equipment**
- **Pre-plan work, post hazard warnings and use protective measures**
- **Keep working spaces and walkways clear of cords**

DC Power Systems

Safety-Related Work Practices

- **Use special insulated tools when working on fuses with energized terminals**
- **Don’t use worn or frayed cords and cables**
- **Don’t fasten extension cords with staples, hang from nails, or suspend by wire.**



Preventing Electrical Hazards - Planning

- Plan your work with others
- Plan to avoid falls
- Plan to lock-out and tag-out equipment
- Remove jewelry
- Avoid wet conditions and overhead power lines

Avoid Wet Conditions

Wet conditions are hazardous because you can become an easy path for electrical current.

Circumstances that create wet conditions:

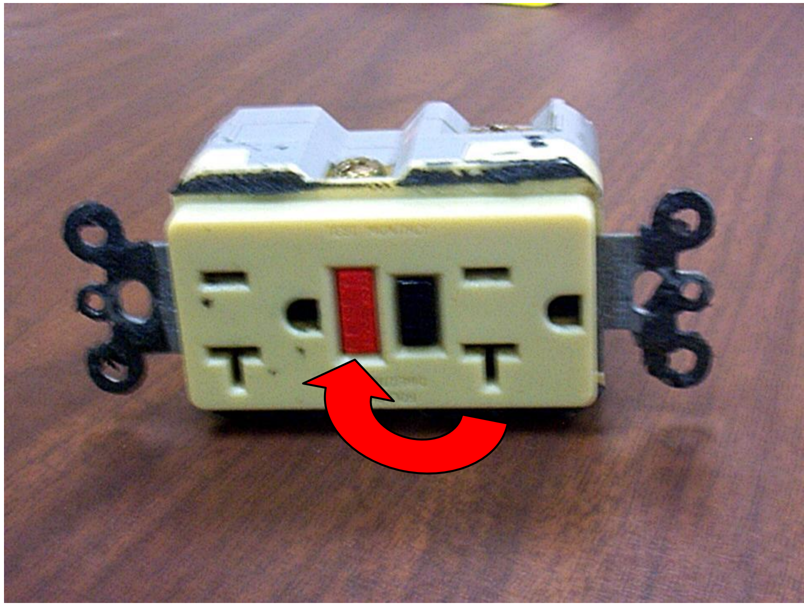
- Standing in water
- Wet clothing
- High humidity
- Perspiration

Preventing Electrical Hazards - PPE

- Proper foot protection (not tennis shoes)
- Rubber insulating gloves, hoods, sleeves, matting, and blankets
- Hard hat (insulated - nonconductive)

Preventing Electrical Hazards – Proper Wiring and Connectors

- Use and test GFCI's
- Check switches and insulation
- Use three prong plugs
- Use extension cords only when necessary & assure in proper condition and right type for job
- Use correct connectors



Safe Work Practices: Training

Training must include how to:

- De-energize the equipment
- Use lockout and tag procedures
- Use insulating protective equipment
- Use appropriate PPE
- Maintain a safe distance from energized parts

Test circuits to make sure they are de-energized.

Summary

- Deenergize electric equipment before inspecting or repairing
- Using cords, cables, and electric tools that are in good repair
- Lockout / Tagout recognition and procedures
- Use appropriate protective equipment

Summary – Hazards & Protections

Hazards

- Inadequate wiring
- Exposed electrical parts
- Wires with bad insulation
- Ungrounded electrical systems and tools
- Overloaded circuits
- Damaged power tools and equipment
- Using the wrong PPE and tools
- Overhead powerlines
- All hazards are made worse in wet conditions

Protective Measures

- Proper grounding
- Use GFCI's
- Use fuses and circuit breakers
- Guard live parts
- Lockout/Tagout
- Proper use of flexible cords
- Close electric panels
- Training

Summary

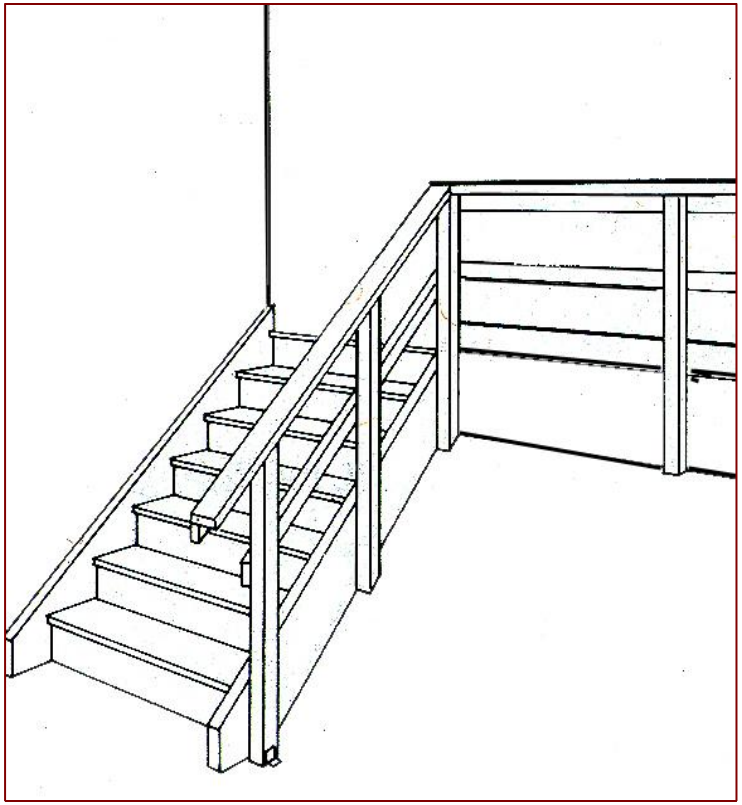
Electrical equipment must be:

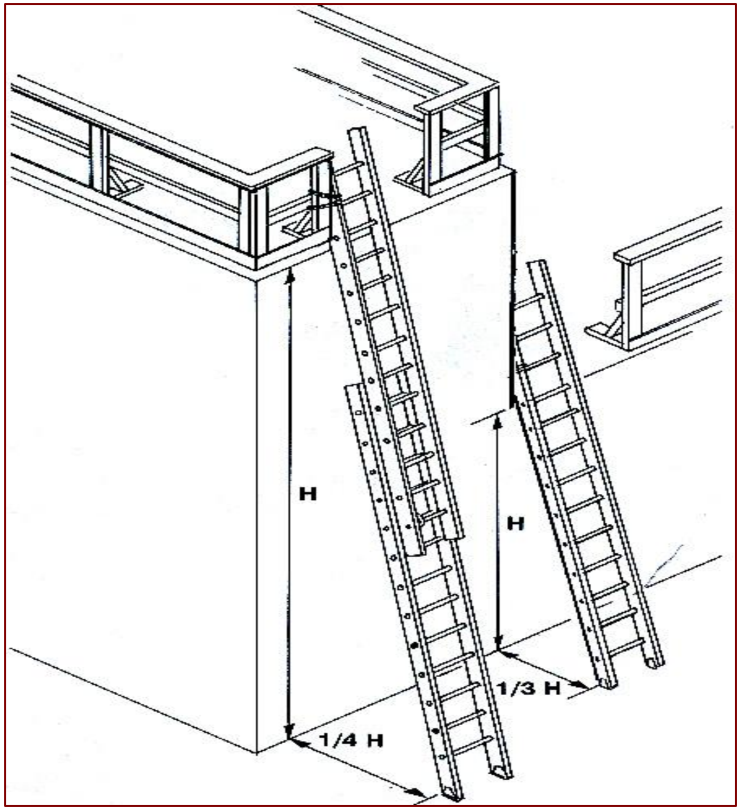
- Listed and labeled
- Free from hazards
- Used in the proper manner

If you use electrical tools you must be:

- Protected from electrical shock
- Provided necessary safety equipment

Stairways and Ladders





Hazards

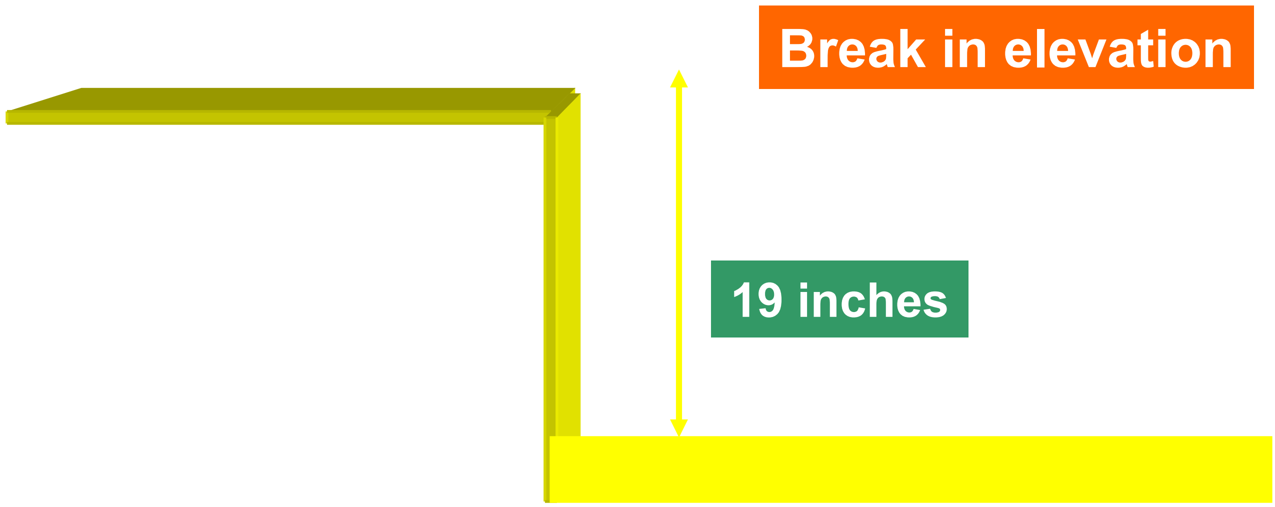
- Stairways and ladders cause many injuries and fatalities among construction workers
- About half the injuries caused by slips, trips and falls from ladders and stairways require time off the job

Improper use of the top rung of a step ladder

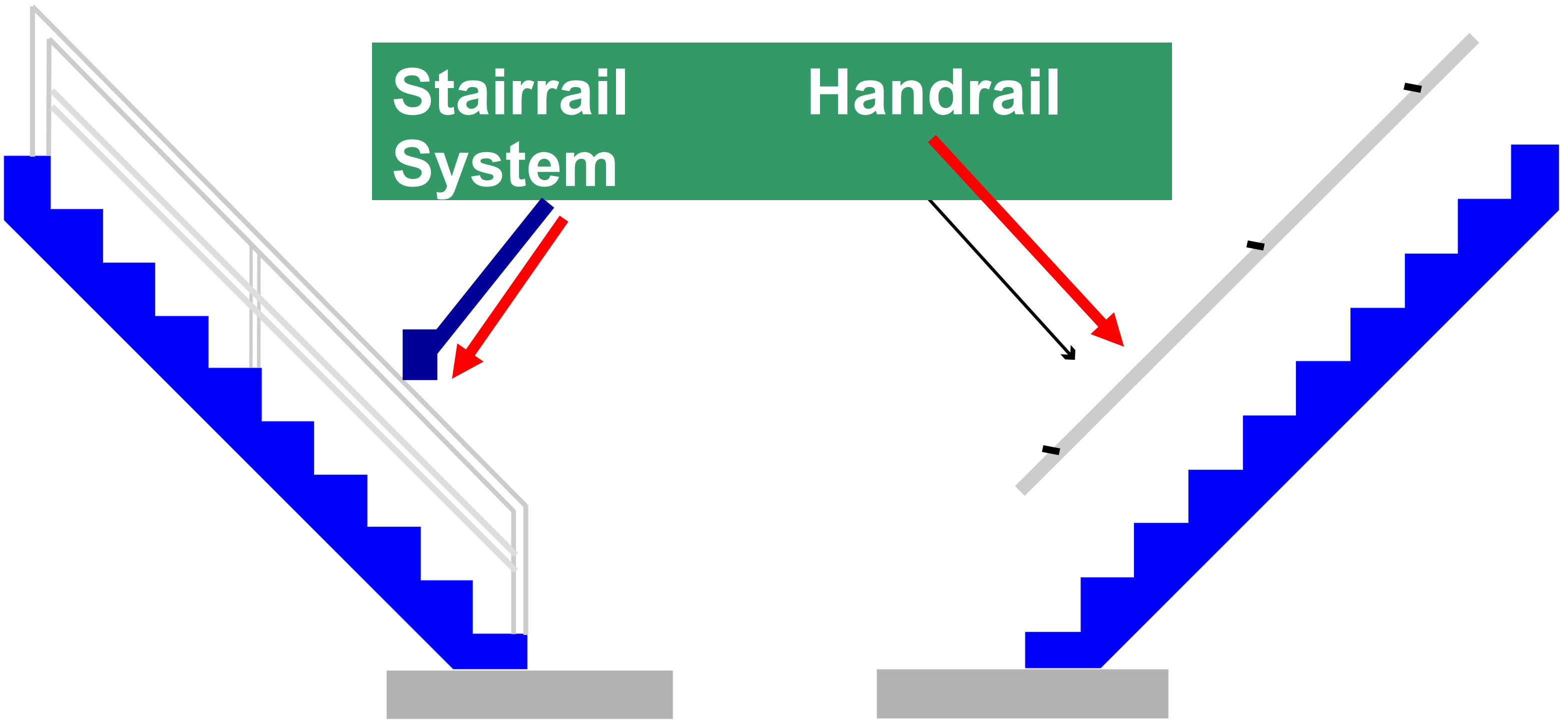
Stairway or Ladder

There must be a stairway or ladder at points of access where there is an elevation break of *19 inches* or more.

At least one point of access must be kept clear.



Handrail vs. Stairrail



Handrail and Top Rail Strength

Rails must be able to withstand a force of 200 pounds

DC Power Systems

Handrails

Stairways with four or more risers, or higher than 30 inches, must be equipped with at least one handrail.

The stairway to this platform has more than 4 risers and is not guarded. The platform requires guarding.

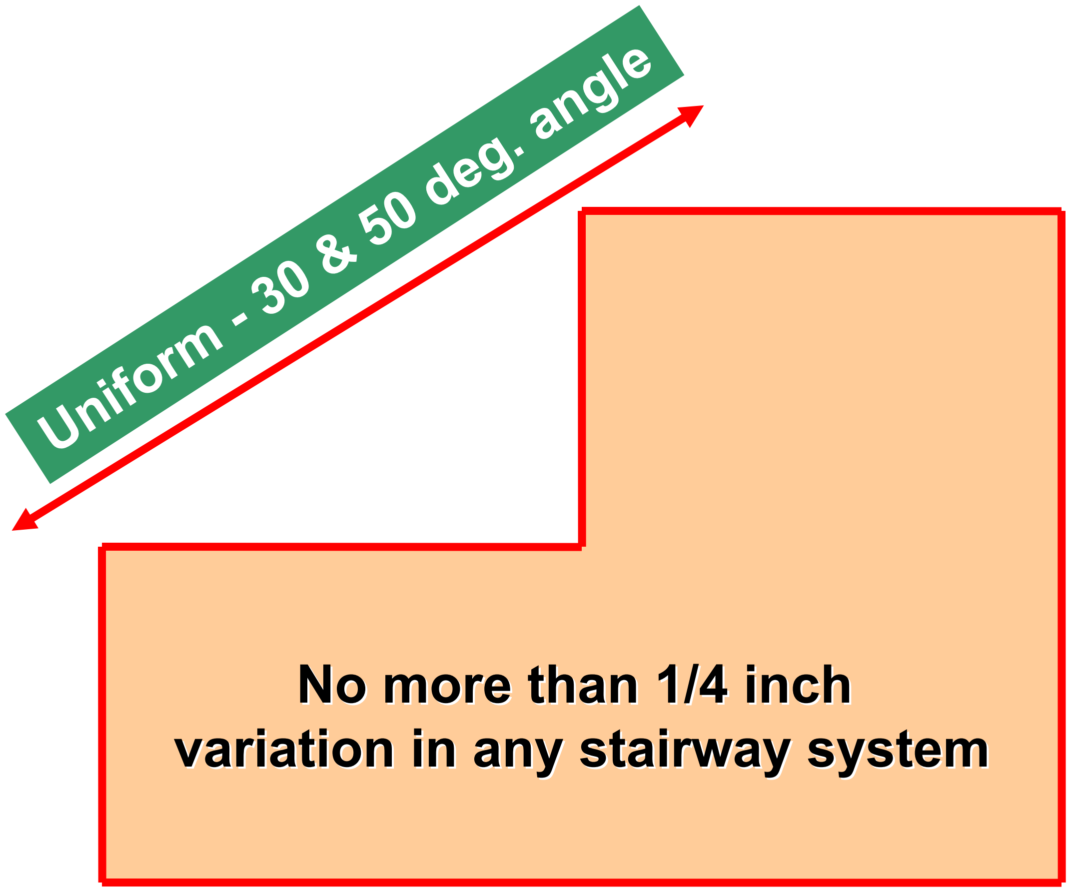
Stairrails

Stairways with four or more risers or more than 30 inches high must have a stairrail along each unprotected side or edge.

Stairs

Install between 30 and 50 degrees.

Must have uniform riser height and tread depth, with less than a 1/4-inch variation.



Temporary Stairways

Only use pan stairs if filled with filler material at least to the top edge of each pan.

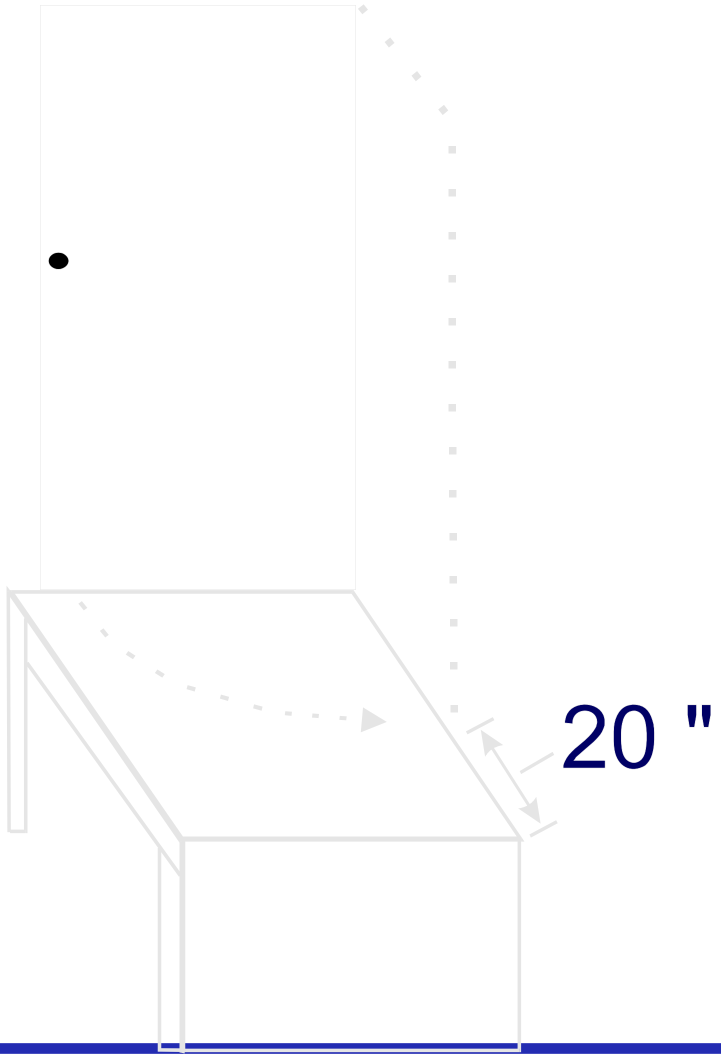
Stairway Landings

Stairways landings must be at least 30 inches deep and 22 inches wide at every 12 feet or less of vertical rise

Unprotected sides of landings must have standard 42 inch guardrail systems

Platforms and Swing Doors

Where doors or gates open directly on a stairway, provide a platform that extends at least 20 inches beyond the swing of the door.



Dangerous Conditions

Fix slippery conditions before using.

Stairway parts must be free of projections which may cause injuries or snag clothing.

Ladders

General Ladder Requirements

-- DO –

Keep the area around the top and bottom of a ladder clear

Ensure rungs, cleats, and steps are level and uniformly spaced

Ensure rungs are spaced 10 to 14 inches apart

Keep ladders free from slipping hazards

General Ladder Requirements

-- DON'T –

Tie ladders together to make longer sections, unless designed for such use

Use single rail ladders

Load ladders beyond the maximum load for which they were built, nor beyond the manufacturer's rated capacity

Securing Ladders

- Secure ladders to prevent accidental movement due to workplace activity
- Only use ladders on stable and level surfaces, unless secured
- Do not use ladders on slippery surfaces unless secured or provided with slip-resistant feet

Portable Ladders

Inspect before use for cracks, dents, and missing rungs

Design or treat rungs to minimize slipping

Side rails -- at least 11 1/2 inches apart

Must support 4 times the maximum load

Double - Cleated Ladder

Use a double-cleated ladder (with center rail) or 2 or more ladders:

- when ladders are the only way to enter or exit a working area with 25 or more employees
- when a ladder will serve simultaneous two-way traffic

Painting Wood Ladders

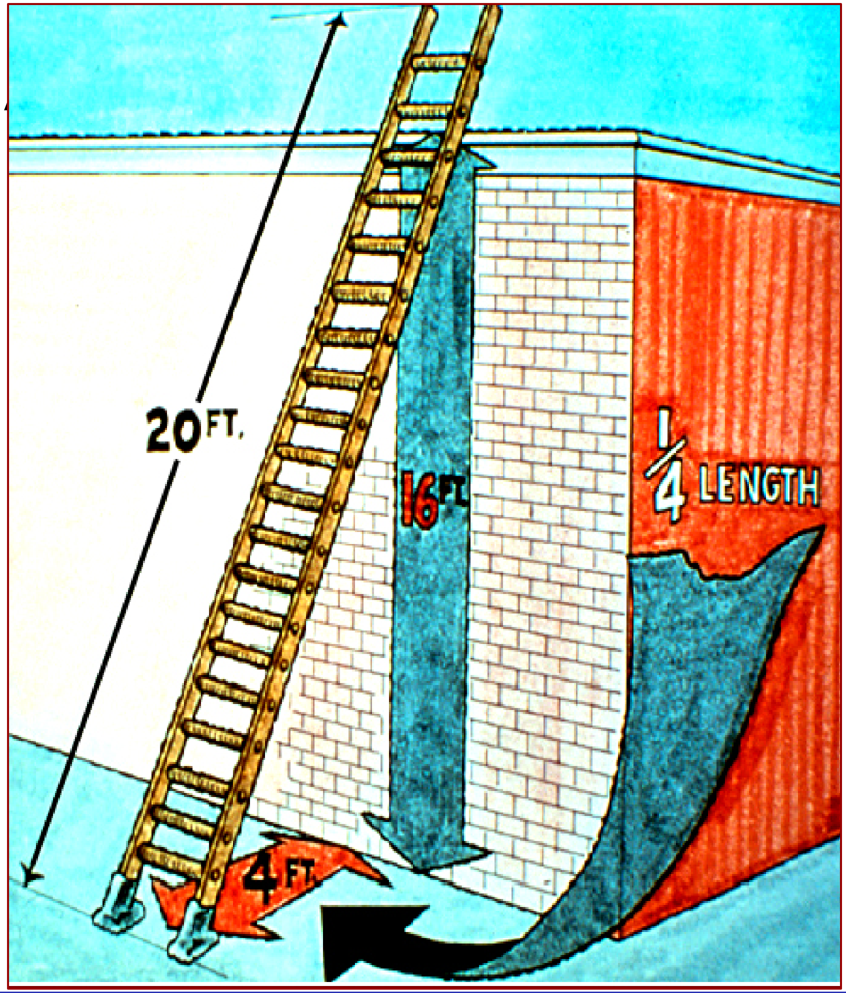
Don’t paint ladders

Don’t use an opaque covering (like varnish) on a wood ladder

Non-self-supporting ladders: Ladder

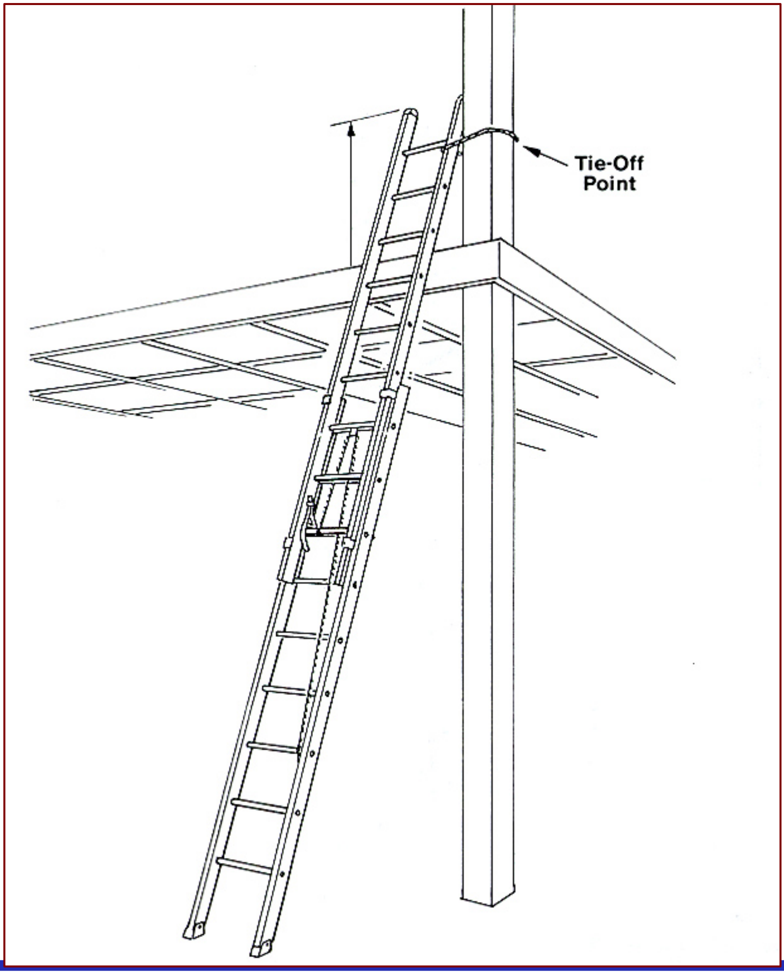
(which lean against a wall or other support)

- Position at an angle where the horizontal distance from the top support to the foot of the ladder is 1/4 the working length of the ladder



Ladder Rail Extension

When using a portable ladder for access to an upper landing surface, the side rails must extend at least 3 feet above the upper landing surface



Tall Fixed Ladder Requirements

Equip a fixed ladder 24 feet or longer with either a:

- Ladder safety device
- Self-retracting lifelines with rest platforms every 150 feet or less
- Cage or well, and multiple ladder sections, each section not exceeding 50 feet

Near Energized Electrical Equipment

If using ladders where the employee or the ladder could contact exposed energized electrical equipment, they must have nonconductive siderails such as wood or fiberglass.

This is an unsafe condition

Summary

Key Components for Ladder Safety

- A competent person must inspect
- Use the correct ladder for the job
- Use the correct angle, supports, treads, cross braces and rails
- Don't overload
- Your employer must train you in proper use of a ladder

4.1 Working Safely with Photovoltaic Systems

1. A fall protection system must be in place for all work done at heights in excess of:

a. 4 feet
b. 6 feet
c. 8 feet
d. 10 feet

2. OSHA rules for personal protection and life-saving equipment are found in OSHA Part 1926:

a. Subpart A
b. Subpart E
c. Subpart M
d. Subpart Q

3. The severity of electrical shock depends on:

a. the duration, path, and amount of current
b. the voltage and power of the electrical source
c. the temperature and humidity in the workplace
d. the current available from the electrical source

4. Electrical currents as low as __?__ mA can paralyze muscles and cause a worker to fall when working at heights.

a. 10
b. 30
c. 50
d. 75

5. Electrical currents as low as __?__ mA ac can cause a rapid, irregular heartbeat and lead to death in a few minutes.

a. 10
b. 30
c. 50
d. 75

6. Lockout and tagging is used to __?__.

a. prevent unknowing individuals from energizing electrical circuits while they are being serviced or maintained
b. disable a PV system from being interconnected to the utility grid until inspections have been passed
c. identify and isolate defective components in an electrical system until service can be performed
d. identify hazards that must be removed prior energizing equipment

4.1 Working Safely with Photovoltaic Systems

7. OSHA requires that fall protection be used for walkways and ramps, holes and excavations, roofs, and wall openings where an employee or worker can fall __?__ feet or more.

a. 4

b. 6

c. 8

d. 10

8. Guardrails used to protect open-sided floors and platforms must have top rails __?__ tall, a mid rail, and toe boards.

a. between 36 and 42 inches

b. between 36 and 45 inches

c. between 39 and 45 inches

d. exactly 42 inches

9. Toe boards on guardrail systems must be __?__ high.

a. 3 inches

b. 3-1/2 inches

c. 4 inches

d. 4-1/2 inches

10. Where used for fall protection, safety nets must be deployed no further than __?__ feet below where work is performed.

a. 12
b. 16
c. 24
d. 30

11. OSHA requires that a stairway or ladder be used at points of access where there is an elevation break of __?__ inches or more on a jobsite.

a. 13
b. 16
c. 19
d. 21

12. Stairways with four or more risers, or higher than __?__ 30 inches, must be equipped with at least one handrail.

a. 30
b. 36
c. 42
d. 48

13. Handrails must be capable of withstanding a force of __?__ pounds.

a. 150
b. 200
c. 250
d. 300

14. Stairs must be installed at an angle no greater than __?__ degrees.

a. 30
b. 40
c. 50
d. 60

15. Stairways landings must be at every __?__ feet or less of vertical rise.

a. 10
b. 12
c. 14
d. 16

4.1 Working Safely with Photovoltaic Systems

16. A 24-foot extension ladder is used to access an upper landing 20 feet off the ground. How far should the base of the ladder be positioned back from the point the ladder makes contact with the upper landing?

a. 4 feet

b. 5 feet

c. 6 feet

d. 8 feet

17. What is the minimum length of a ladder required to access a roof surface 12 feet off the ground?

a. 12.3 feet

b. 15.4 feet

c. 17.2 feet

d. 20 feet

18. Ladders used where the employee or ladder could contact exposed energized electrical equipment must have __?__.

a. electrical rating

b. grounding means

c. insulated rungs

d. nonconductive side rails

4.1 Working Safely with Photovoltaic Systems

19. What class of hardhat offers the maximum head protection from impacts and electrical shock?

a. Class A
b. Class III
c. Class B
d. Class C

20. Employee responsibilities for PPE include which of the following?

a. Assessing the workplace for hazards
b. Determining when to use PPE
c. Providing PPE gear
d. Using PPE in accordance with training and instructions

21. What PPE would be most important when operating a power drill?

a. Ear plugs
b. Gloves
c. Goggles
d. Shoes

22. If no specific fall protection system is in place, according to OSHA, it is acceptable to provide fall protection by using a person competent in recognition of fall hazards who

a. monitors the operation on closed circuit TV and is in contact with the crew by walkie-talkie

b. is a part of the work crew who is capable of warning other workers

c. is not a part of the work crew, but who is stationed at the level of the work crew within sight of and speaking distance of the crew, who is capable of warning other workers

d. provides safety instructions to the crew before the crew begins work

23. Temporarily shorting the output terminals of a PV module will

a. destroy the module if the short is not immediately cleared

b. have no effect on the module

c. destroy the insulation on the module wiring if the short is not immediately cleared

d. cause damage only if the module is connected in series with other modules

24. If the open circuit voltage of a crystalline silicon PV array is 315 V at 25°C, then, according to the NEC, if the array is operated at −20°C, maximum system voltage must be corrected to

a. 269 V

b. 315 V

c. 369 V

d. 394 V

4.1 Working Safely with Photovoltaic Systems

25. The purpose of the ground-fault protection device in a PV system is to

a. reduce the probability of electrical shock to service personnel

b. reduce the possibility of fire from an arcing fault to ground

c. reduce losses of the PV output energy to ground

d. reduce degradation of structural supports from rapid electrolysis

26. If the maximum power voltage of a crystalline silicon PV module is 17.1 V at STC, then at 60°C (module temperature) and 1000 W/m2 incident on the module, the maximum power voltage of the module will be closest to

a. 20.1 V

b. 17.1 V

c. 14.1 V

d. 12.0 V

4.1 Working Safely with Photovoltaic Systems

27. According to the National Electrical Code, if flooded lead-acid batteries are chosen for energy storage for a PV system, the battery enclosure must

a. have provisions for sufficient diffusion and ventilation of the gases from the battery to prevent the accumulation of an explosive mixture, and if a tray is used it shall be resistant to deteriorating action by the electrolyte

b. have adequate ventilation at the top only, with vent holes screened to keep out bugs and small animals as well as a plastic tray under the batteries to contain spills of electrolyte

c. have adequate ventilation at bottom and top, with screened vents and a plastic tray under the batteries to contain spills of electrolyte

d. be sealed and insulated so the battery temperature will not drop below 40°F, and have a plastic tray under the batteries to contain spills of electrolyte

28. If electronic equipment is to be housed in a container above the battery container with battery cables passing between the two containers, then the batteries should be of what type?

a. Flooded lead-acid

b. Nickel-iron acid

c. Valve-regulated lead-acid

d. Any type of nickel-cadmium

4.1 Working Safely with Photovoltaic Systems

29. If the electrolyte freezes,

a. the battery should be slowly charged

b. the battery should not be charged

c. the battery should be slowly discharged

d. the battery should be heated with a hair dryer

30. Using the sun path chart of Figure 5 in the this Guide, assuming that if the altitude is less than 30° when the azimuth is 45° that the array will be shaded, the months of the year when the array will be shaded at any time between 9 a.m. and 3 p.m. include

a. None

b. November, December and January

c. September through March

d. April through August

4.1 Working Safely with Photovoltaic Systems

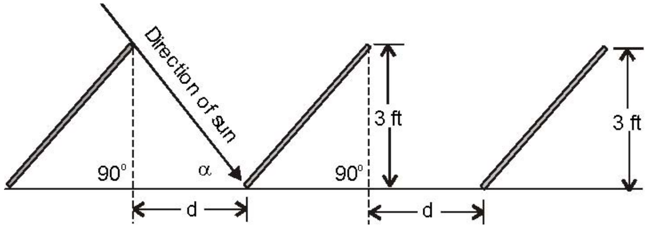
31. **Suppose a PV array consists of three rows of rack-mounted modules facing south, as shown in the Figure. Suppose also that all rows are on a level surface and that the tops of the modules are spaced three feet higher than the bottoms. Suppose also that the array is to be used at latitude 30°N. In order to avoid any shading of modules from other modules at 12 p.m. on December 21, the spacing between rows, d, must be no less than**

a. 0.24 feet

b. 4.13 feet

c. 6 feet

d. 9 feet



32. **Using the sun path chart of Figure 5 in this Guide, the minimum annual sun altitude between the hours of 9 a.m. and 3 p.m. sun time is closest to**

a. 10°

b. 20°

c. 30°

d. 45°

4.2 Conducting a Site Assessment

33. With the PV array rack mounted at ground level, which would normally be of greatest concern?

a. Overheating of the modules

b. Electrical hazards from exposed (conductors) open circuit voltages

c. Earthquake stresses on the modules

d. Physical damage to the array and wiring

34. A concern associated with 12-V PV systems that use large wire sizes to minimize voltage drop is

a. the difficulty in obtaining dc-rated disconnects with adequate current ratings.

b. the possibility of using junction boxes (terminal blocks) or switch boxes that are too small to house the large wire.

c. the difficulty in obtaining wire with dc-rated insulation

d. the possibility of animals chewing on the wires

4.3 Selecting a System Design

35. If a proposed PV installation site has an unobstructed south-facing roof area of 60 m2, and if thin-film modules with six watts-per-square-foot power output at STC are to be installed on 50% of the roof, then the maximum available PV array output power (based on the sum of module ratings) at STC will be closest to

a. 4500 watts

b. 3600 watts

c. 2250 watts

d. 1900 watts

36. Which of the following devices does the NEC require to be a part of PV systems mounted on residential dwellings?

a. A stand-off mount for the PV modules

b. A utility interconnection

c. A ground-fault protection device

d. An accessible source circuit combiner box

4.3 Selecting a System Design

37. A crystalline silicon PV array that has bipolar outputs of +252 V and −252 V with a common grounded conductor under Standard Test Conditions is selected for a large single-family residence. The lowest expected temperature at the installation site is −25°C. For this system, the maximum system voltage is closest to

a. 252 V.

b. 315 V.

c. 504 V.

d. 630 V.

38. A crystalline silicon PV array that has bipolar outputs of +252 V and −252 V with a common grounded conductor under Standard Test Conditions (STC) is selected for a large single-family dwelling. The lowest allowable ambient temperature in which the system can be installed at a single-family dwelling is

a. 0°C

b. -10°C

c. -20°C

d. -40°C

4.3 Selecting a System Design

39. **A PV system is to be selected for operating a PV water pumping system. The pump will require 300 W of PV modules for proper operation. A 12 -Vdc model and a 48-Vdc model are available. If both pumps operate at the same power level, the resistance of the wire to the 48-V pump, compared to the resistance of the wire to the 12-V pump, assuming the same percentage voltage drop in the wiring, may be**

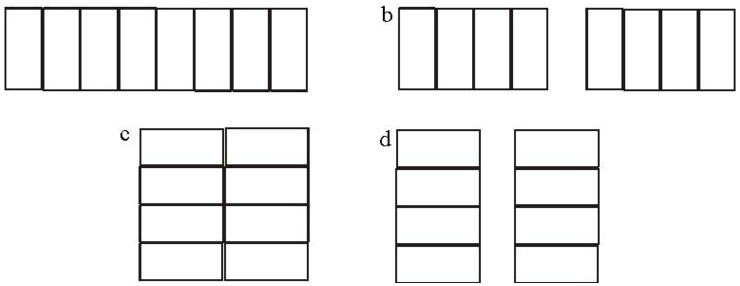
a. 1/16th as much

b. 1/4th as much

c. 4 times as much

d. 16 times as much

40. **Assume a roof-mounted PV array is to consist of two source circuits of four modules each. Assume the drawings are to scale and that the roof is large enough for any of the configurations shown. Which of the following configurations can be expected to result in the coolest operation of the modules?** **(b)**



4.4 Adapting the Mechanical Design

41. **A ¼″x3½″ lag screw that has a 3″ thread is used to attach an L-bracket to an asphalt-shingle roof. If the combined thickness of the L-bracket, shingles, and roof membrane is ¾ inch, and if the screw penetrates directly into a roof truss made of Southern Yellow Pine, into a properly sized pilot hole, then the withdrawal resistance will be closest to**

a. 632 pounds
b. 773 pounds
c. 843 pounds
d. 984 pounds

42. **Four PV modules, each with an area of 10 ft2, are to be mounted with a stand-off mount that is secured to a metal seam roof with six L-Brackets. If the modules can withstand a load of 75 pounds per square foot, and if it is desired to support the full load with one lag screw in each bracket, and each screw has a withdrawal resistance of 300 pounds per inch including a safety factor of four, the minimum screw thread length that will need to penetrate wood will be closest to**

a. 1.1”
b. 1.67”
c. 2.25”
d. 6.67”

43. **Stainless-steel hardware is most important in which of the following areas?**

a. Coastal areas where the air contains salt spray.
b. Desert areas where the air contains a mixture of dust.
c. Mountainous areas where the solar spectrum contains more ultraviolet rays.
d. Inland regions that are subject to freezing temperatures.

4.4 Adapting the Mechanical Design

44. For the situations described, which would result in the most cost-effective use of a two-axis tracking mount?

a. In areas of low wind, latitude less than 30°, and moderate daytime summer cloud cover

b. In areas of low wind, latitude greater than 30°, and minimal daytime summer cloud cover

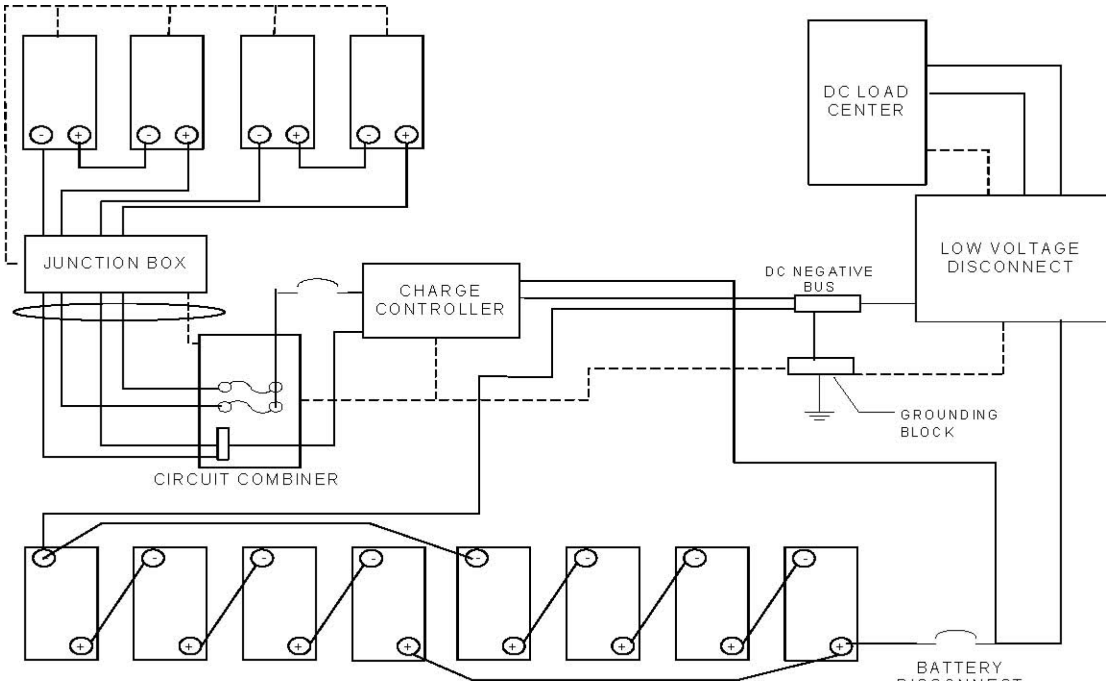
c. In areas of moderate wind, latitude greater than 30°, and moderate year-around cloud cover

d. In areas of moderate wind, latitude less than 30°, and minimal year-around cloud cover

4.5 Adapting the Electrical Design

45. **Referring to Figure 4, if 4 AWG THWN-2 copper wire in a single run of 1.5-inch conduit is used between the array junction box and the source-circuit combiner box, and the wiring from the modules to the junction box is exposed 10 AWG copper wire that enters through a one-inch cord connector at right angles to the 4 AWG conductors, and if the volume of the terminal strip in the junction box is six cubic inches, the junction box must be sized from**

a. NEC Article 314.16
b. NEC Article 314.17
c. NEC Article 314.27
d. **NEC Article 314.28**



DC Power Systems

4.5 Adapting the Electrical Design

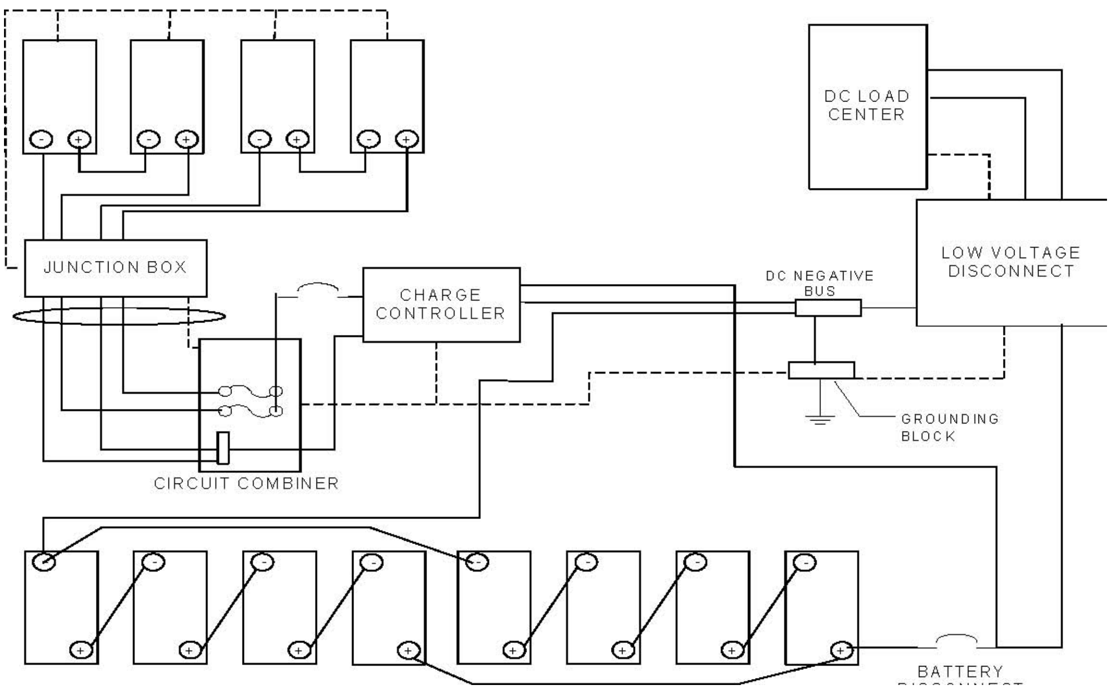
46. **For the PV modules used in Figure 4, if the maximum wire temperature (ambient temperature that the wire sees) is estimated to be 45°C between the array junction box and the source-circuit combiner box, then the ampacity of the conductors at 30°C, assuming THWN-2 insulation, must be at least**

a. 16.1 A

b. 12.9 A

c. 11.2 A

d. 7.8 A



4.5 Adapting the Electrical Design

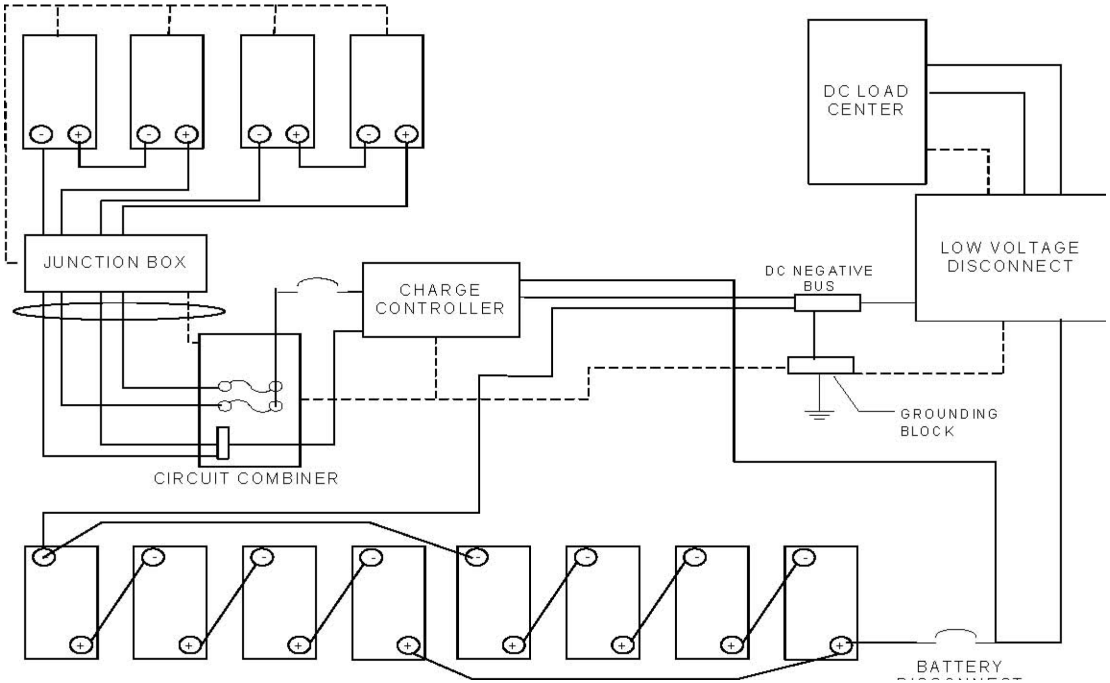
47. **If the distance from the junction box to the combiner box of Figure 4 is 60 feet, then the smallest wire size between junction box and combiner box that will limit the voltage drop to less than 2% when Im is flowing is**

a. 10 AWG copper

b. 8 AWG copper

c. 6 AWG copper

d. 4 AWG copper



4.5 Adapting the Electrical Design

48. **If the lowest temperature of the PV modules is expected to be 10°F, then the maximum system voltage for the PV system of Figure 4 will be closest to**

a. 24.6 V
b. 34.2 V
c. 40.0 V
d. 49.1 V

49. **Referring to Figure 4, if the length from the junction box to the circuit combiner is five feet, the smallest wire size needed to keep the voltage drop in this circuit less than 1% when the current in the circuit is the maximum power current, is**

a. 14 AWG copper
b. 12 AWG copper
c. 10 AWG copper
d. 8 AWG copper

50. **If the distance from the junction box to the combiner box is 60 feet, to keep the voltage drop between the module junction box and the source circuit combiner box less than 2% under maximum power conditions at STC, the smallest wire size that can be used for each source circuit in the system in Figure 4 is**

a. 10 AWG copper
b. 8 AWG copper
c. 6 AWG copper
d. 4 AWG copper

4.5 Adapting the Electrical Design

51. The charge controller battery temperature sensor should be connected to

a. the side of the battery compartment
b. the top of a battery that is at the end of the row of batteries
c. the bottom of any battery
d. on the side of a battery between two batteries

52. The charge controller connected to the PV output circuit of Figure 4 normally requires adjustment for

a. voltage drop
b. battery type
c. maximum input power
d. maximum input current

53. Suppose an alternate series three-stage charge controller is available as a backup to a parallel three-stage PV charging source such as a utility-interactive battery-based inverter. Suppose, also, that the PV source is intended to be the dominant charging source. To ensure that the PV source is the dominant charging source, one should

a. set the float voltage of the PV charging source higher than the bulk voltage of the alternate controller
b. set the float voltage of the PV charging source lower than the bulk voltage of the alternate controller
c. set the bulk voltage of the PV charging source lower than the float voltage of the alternate controller
d. set the absorption mode time of the PV charging source lower than the absorption time of the alternate controller

4.5 Adapting the Electrical Design

54. Four 6-volt, 240-Ah batteries manufactured by manufacturer A, and four 6-volt 120-Ah batteries manufactured by manufacturer B are available. It is acceptable to incorporate all of these batteries into a 12-volt PV battery storage bank under the following circumstances:

a. If the 240-Ah batteries are connected in 2 series groups and the 120-Ah batteries are connected in 2 series groups, and then the four series groups are connected in parallel
b. If the 240-Ah batteries are all connected in parallel, the 120-Ah batteries are all connected in parallel, and then the two parallel sets of batteries are connected in series
c. If each 240-Ah battery is connected in series with a 120-Ah battery, and then the four sets are connected in parallel
d. There is no acceptable connection of the batteries into a single battery bank

55. A good reason for large wire sizes in battery interconnections, even if they are oversized for ampacity, is to

a. keep all battery currents as equal as possible
b. provide a lower resistance path for battery short circuit currents
c. allow for increases in load size or array size
d. better secure the batteries in case of high winds

56. The purpose of a linear current booster is to

a. keep its output voltage the same as its input voltage and boost the output current to a value larger than the input current
b. convert a high input voltage and low input current to a lower output voltage and a higher output current
c. convert a low input voltage and high input current to a higher input voltage and a lower input current
d. keep its output current the same as its input current and boost the output voltage to a value larger than the input voltage

4.5 Adapting the Electrical Design

57. The purpose of an inverter is to

a. convert dc at one voltage to ac at the same or another voltage
b. convert ac at one voltage to dc at the same or another voltage
c. convert dc at one voltage to dc at another voltage
d. convert ac at one voltage to dc at another voltage

58. Sine wave inverters are required for connection to utility lines, because

a. they are more efficient than other types of inverters
b. they are the only inverters that have low enough harmonic distortion
c. only sine wave inverters can be designed to disconnect from the utility when utility power is lost
d. non-sine wave inverters cannot develop adequate power for utility interconnection

59. A 2500-W inverter is used to supply a 120-V ac load of 1500 watts. This means that the ampacity of the wire at the inverter output must be at least

a. 12.5 A
b. 15.6 A
c. 20.8 A
d. 26.0 A

4.5 Adapting the Electrical Design

60. **A 2500-W inverter with an input-voltage range of 22 V to 32 V has an efficiency of 88% at full output. This means the maximum inverter input current at full rating will be closest to**

a. 129 A
b. 100A
c. 89 A
d. 69 A

61. **If the maximum ac output rating of an inverter with 120-V ac output is 1500 W, the rating of the circuit breaker at the point-of-utility connection should be**

a. 15 A
b. 20 A
c. 25 A
d. 30 A

62. **If the inverter in a utility-interactive PV system begins to hum quietly about five (5) minutes after closing the connection to the utility, then, it is most likely**

a. working
b. overloaded
c. connected to a motor load on the utility side
d. not working

4.5 Adapting the Electrical Design

63. If the PV array in Figure 9 of this Guide is operated at a minimum temperature of −20°C, then the inverter maximum input voltage rating must be at least

a. 29.2 V

b. 34.3 V

c. 42.0 V

d. 49.1 V

64. Assume a 225-A, 42-position, single-phase, three-wire main distribution panel fed by a 200-A main breaker is used in a dwelling unit. The maximum inverter output current that can be fed to this panel is

a. 20 A

b. 25 A

c. 56 A

d. 70 A

65. For the system of Figure 9, assuming that the grounding electrode is a ground rod, the size of the grounding electrode conductor is NOT required to be larger than

a. 10 AWG copper

b. 8 AWG copper

c. 6 AWG copper

d. 4 AWG copper

4.5 Adapting the Electrical Design

66. **The size of the equipment-grounding conductor for each of the PV source circuits in the system shown in Figure 9 should be no smaller than**

a. 14 AWG copper
b. 12 AWG copper
c. 10 AWG copper
d. 8 AWG copper

67. **The size of the equipment-grounding conductor (type THWN-2) for the PV output circuit should be no smaller than**

a. 14 AWG copper
b. 12 AWG copper
c. 10 AWG copper
d. 8 AWG copper

68. **If the output of the inverter is connected to the optional standby system panel through a 30-A circuit breaker, the appropriate size of the equipment-grounding conductor between the inverter and the emergency panel is**

a. 14 AWG copper
b. 12 AWG copper
c. 10 AWG copper
d. 8 AWG copper

4.5 Adapting the Electrical Design

69. **A 5-kVA, 120-V generator has a rated output current of 42 A. It does not have a mechanism to limit its output current to the rated value. Assuming they are run in conduit, the output conductors should have an ampacity of no less than**

a. 8 AWG THWN
b. 8 AWG THHN
c. 6 AWG THWN
d. 6 AWG THHN

70. **A 5-kVA, 120-V generator is used as a backup generator for a system designed with two days of battery storage to 80% depth of discharge. If the generator is sized for charging rate of C/10, and if the generator burns 1 gallon of fuel per hour of run time, the average daily fuel consumption when the generator is the only power source will be closest to**

a. 4 gallons
b. 5 gallons
c. 8 gallons
d. 10 gallons

71. **If the 5-kVA, 120-V generator is protected with a 50-A circuit breaker, then the equipment-grounding conductor must be no smaller than**

a. 12 AWG copper
b. 10 AWG copper
c. 8 AWG copper
d. 6 AWG copper

4.6 Installing Systems and Subsystems at the Site

72. **In a PV system, the equipment-grounding conductors should be**

a. white
b. black
c. red
d. green

73. **The 2005 NEC allows marking conductors with colored tape, provided that they are larger than**

a. 10 AWG
b. 8 AWG
c. 6 AWG
d. 4 AWG

74. **The width of the working space in front of an inverter that is 24-inches wide must be at least**

a. 24 inches
b. 30 inches
c. 36 inches
d. 42 inches

4.6 Installing Systems and Subsystems at the Site

75. The minimum depth of the working space in front of a charge controller for which the input voltage never exceeds 60 V dc is

a. 30 inches

b. 36 inches

c. 42 inches

d. negotiable

76. Which of the following items does NOT require UL or equivalent listing?

a. the concrete anchors

b. the surge protectors

c. the battery cables

d. the charge controllers

77. In order for a PV array to directly face the sun at 2:30 p.m. sun time on June 21 at 300 N latitude (see Figure 5 of this Guide), which array orientation is correct?

a. 60° W of S with a tilt of 40° with respect to the horizontal

b. directly west with a tilt of 60° with respect to the horizontal

c. directly west with a tilt of 30° with respect to the horizontal

d. 45° W of S with a tilt of 60° with respect to the horizontal

4.6 Installing Systems and Subsystems at the Site

78. If 5/16-inch lag screws are used to fasten a charge controller to wooden studs, an appropriate pilot hole size would be closest to

a. 1/8 inch
b. 19/64 inch
c. 7/32 inch
d. 1/4 inch

79. When mounting a heavy inverter or other piece of equipment to a "dry-wall" type of wall, to provide a solid attachment to the wall it may be necessary to use

a. thumb tacks
b. plastic anchors
c. plywood
d. moly bolts

80. The first step in system checkout after completing the installation is

a. test open-circuit voltage
b. visually check the entire system
c. install the source-circuit fuses
d. close all disconnects

81. Before applying PV power to either an inverter, a charge controller, batteries or a load, one should first

a. check the polarity of the PV output
b. install the source circuit fuses
c. call the electrical inspector
d. close all disconnects

82. Assume the STC maximum-power voltage of a crystalline silicon PV array is 68.4 V. If the irradiance is 800 W/m2 and the module temperature is 50°C, assuming the inverter is tracking maximum power with a 1.6% voltage drop between modules and inverter input, the inverter input voltage should be closest to

a. 68.4 V
b. 58.9 V
c. 54.7 V
d. 47.1 V

83. A 4-kWSTC crystalline silicon PV array is operated in a utility-interactive mode with no battery backup. The inverter tracks maximum power, and the array is operating at 50°C with 900 W/m2 incident on the array. There is a 2% power loss in the wiring and the inverter is 94% efficient. On a typical PV system, the inverter output power will be closest to

a. 3316 watts
b. 2985 watts
c. 2612 watts
d. 1492 watts

4.7 Performing a System Checkout and Inspection

84. **A typical 4-kW crystalline silicon array is operating at STC in a utility-interactive system with battery backup. The STC maximum-power voltage rating of the PV array is 68.4 volts. The system uses a conventional charge controller that does not track maximum power. Wiring losses are 3% and inverter losses are 5%. If the batteries are at full charge at a voltage of 52 V, and if all PV output is delivered to the grid (assume that no power is being used to hold the batteries at 52 volts), the inverter output power will be closest to**

a. 1261 watts

b. 2207 watts

c. 2522 watts

d. 3152 watts

85. **A typical 4-kW crystalline silicon array is operating at STC in a utility-interactive system with battery backup. The STC maximum power voltage rating of the PV array is 68.4 volts. The system uses a MPT charge controller that has 5% losses. Wiring losses are 3% and inverter losses are 5%. If the batteries are at full charge at a voltage of 52 V, and if all PV output is delivered to the grid (assume that no power is being used to hold the batteries at 52 volts), the inverter output power will be closest to**

a. 1261 watts

b. 2207 watts

c. 2522 watts

d. 3152 watts

86. **In the event that the utility voltage is lost in a utility-interactive system that has battery backup and an optional standby system ac distribution panel, and if the inverter is programmed in the sell mode,**

a. the inverter should not supply power to the terminals connected to utility point-of-connection

b. the inverter should not supply power to the terminals connected to the optional standby ac distribution panel

c. the inverter should not supply power to either set of ac terminals

d. the inverter should no longer take dc power from the batteries

4.8 Maintaining and Troubleshooting a System

87. **When connecting and disconnecting wires while troubleshooting a PV system, the best way to avoid electrical shock is to**

a. inspect all questionable terminals, wear rubber gloves and turn off all switches

b. keep one hand behind your back, with all switches turned off and only touch grounded surfaces

c. turn off switches, measure voltages and currents, and wear protective equipment

d. wear shoes with soft rubber soles, turn off all switches, and don't touch metal surfaces

88. **If the current in one source circuit is significantly lower than the currents in the remaining source circuits of a PV array, and all modules are in full sun, then without disconnecting any conductors, an appropriate follow-up test is**

a. measure the individual module currents in this source circuit

b. measure the voltage at the inverter input

c. measure the short circuit current of this source circuit

d. measure the individual module voltages in this source circuit

89. **Different length battery cables can lead to what effect?**

a. Excessive voltage drop

b. Uneven charge and discharge current

c. Induction heating

d. Eddy currents

4.8 Maintaining and Troubleshooting a System

90. A utility-interactive PV system with no batteries consists of 15 100-W modules in series that feed a 1500-W inverter. The inverter output power is found to be 780 W when the modules are operating at 50°C with an irradiance level of 800 W/m2. If three modules are observed to be shaded, which conclusion is most likely?

a. The inverter input current is probably too low

b. The system is probably functioning properly

c. The inverter is probably not tracking maximum power

d. The modules probably do not have bypass diodes

4.8 Maintaining and Troubleshooting a System

- **Modules (Crystalline Silicon) VOC (STC) ISC (STC) Vmp (STC) Imp (STC) Max Power (STC) dimensions weight** 21.0 V 4.58 A 17.1 V 4.39 A 75 W 41 cm x 157 cm 7.3 kg
- **Distances/Dimensions Modules to Junction Box Junction Box to Combiner Combiner to Charge Controller All other wiring lengths to dist panel** 3 m (max one way) 25 m (one way) Negligible Wire Sizes 10 AWG Cu 6 AWG Cu 10 AWG Cu 8 AWG Cu
- **Module Mounting Mount Type Mount Tilt Module facing Site Latitude Max module temp Min module temp Max total load Details** Rack/ground 39° South 39°N 55°C −15°C 30 psf

91. Suppose the irradiance on the array is measured with a handheld solar meter at 955 W/m2 and the input current to the inverter is measured to be 8.35 A. The voltage across the top fuse is 0.01 V, and the voltage across the bottom fuse is 10

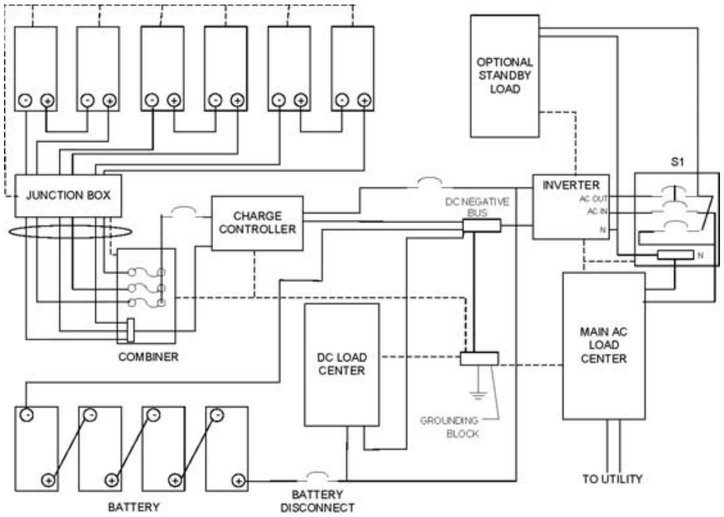
a. V. From this information, it can be concluded that

b. the charge controller is in the float phase

c. the top fuse is blown

d. the bottom fuse is blown

e. the battery disconnect is open



4.8 Maintaining and Troubleshooting a System

- **Modules (Crystalline Silicon) VOC (STC) ISC (STC) Vmp (STC) Imp (STC) Max Power (STC) dimensions weight** 21.0 V 4.58 A 17.1 V 4.39 A 75 W 41 cm x 157 cm 7.3 kg
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- **Module Mounting Mount Type Mount Tilt Module facing Site Latitude Max module temp Min module temp Max total load Details** Rack/ground 39° South 39°N 55°C −15°C 30 psf

92. Suppose the irradiance on the array is measured with a handheld solar meter at 955 W/m2 and the dc current from the charge controller is measured to be 0 A, and the inverter is supplying 0.5 A to the battery. The fuses have been confirmed to be good, and the charge controller is fully operational and indicating a full battery. From this information it can be concluded that

a. the standby loads are interfering with the inverter operation

b. the charge controller is set above the inverter set point

c. the utility disconnect is open

d. the charge controller is set below the inverter set point