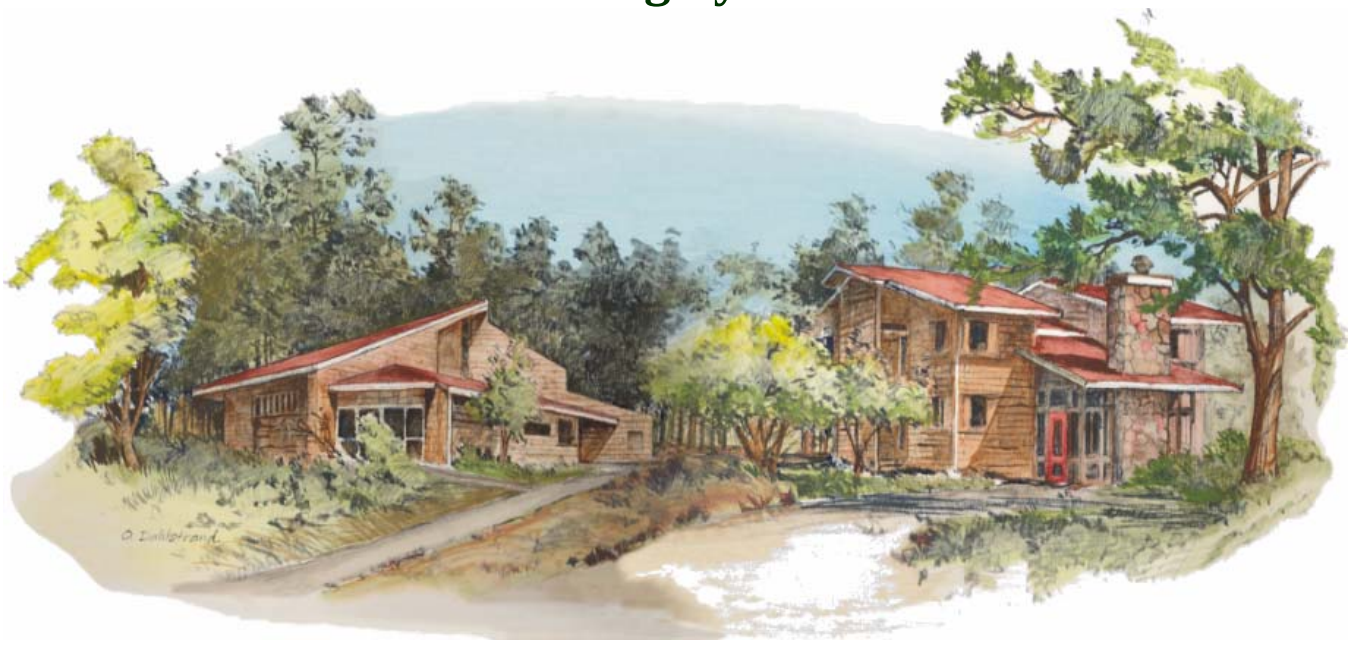
State of California . The Resources Agency . Department of Parks and Recreation

INTERMEDIATE ELECTRICAL SKILLS

January 21-26, 2007

Training Syllabus



William Penn Mott Jr. Training Center

State of California

M e m o r a n d u m

Date: January 2, 2007

To: Supervisor

From: **Department of Parks and Recreation**
William Penn Mott Jr. Training Center

Subject: Employee Attendance at Formal Training
Intermediate Electrical Skills Group 33

An employee from your office will soon be attending the formal training program described in the attached. Please insure that the employee is fully prepared to attend the session and that the groundwork is laid for the employee's implementation of the training upon returning to work.

You can assist with capturing the full value of the training by taking the following steps:

Prior to Training

1. Make sure that **specific** employee needs are identified and, if necessary, called immediately to the attention of the Training Coordinator.
2. Review with the employee the reason for the employee's attendance.
3. Review objectives and agenda with the employee.
4. Discuss objectives and performance expected after the training.

Immediately Following Attendance

1. Discuss what was learned and intended uses of the training.
2. Review the employee's assessment of the training program for its impact at the workplace and review the due date of the Post-Training Evaluation form.
3. Support the employee's use of the training at the work place.

Prior to Three Months Following Training

1. Employee, after discussion with supervisor, must login to the Employee Training Management System (ETMS) to complete the Post-Training Evaluation form.
2. Supervisor evaluates the effectiveness of the training on the employee's job performance and logs in to the ETMS to complete the Training Effectiveness Assessment form.

Thank you for your assistance in seeing that the full benefit of training is realized.

Michael D. Green
Acting Department Training Officer

Attachment

cc: Participant

TABLE OF CONTENTS

Mission Statement
Training Office

The mission of the Training Office is to improve organizational and individual performance through consulting, collaboration, training and development.

MOTT TRAINING CENTER STAFF

Michael Green ..... Acting Department Training Officer
Joanne Danielson ..... Training Specialist
Chuck Combs ..... Training Specialist
Dave Galanti ..... Training Specialist
Sara Skinner ..... Training Specialist
Michelle Gardner ..... Cadet Training Officer
Connie Breakfield ..... Cadet Training Officer
Pat Bost ..... Assistant Program Coordinator
Pamela Yaeger ..... Assistant Program Coordinator
Bill Spencer ..... Assistant Program Coordinator
Edith Alhambra ..... Assistant Program Coordinator
Summer Kincaid ..... Assistant Program Coordinator
Brian Petersen ..... Program Assistant

THE MISSION

of the California Department of Parks and Recreation is to provide for the health, inspiration and education of the people of California by helping to preserve the state's extraordinary biological diversity, protecting its most valued natural and cultural resources, and creating opportunities for high quality outdoor recreation.

FORMAL TRAINING GUIDELINES

Welcome to formal training, an essential component in your career development.

Since 1969, our Department has been providing a continuously changing number of diverse training programs at its Training Center. The Department strives to enhance your learning and job performance with formal training of the highest quality. This fact demonstrates the commitment your Department has made to you in your service to the public. This commitment is costly and represents an important investment in you and your career. You and the Department realize a return on that investment by your positive participation and post training follow-through.

The program you will be participating in is described in this training syllabus, which outlines what you can expect from this training and what is expected of you. This syllabus details what you should do before you leave for training; what to do when you arrive; what you will be doing while in training; and, importantly, what you should be able to do when you return to your work site. Specifically:

1. SYLLABUS: The syllabus is now accessible on the Employee Training Management System (ETMS). You should print a copy of the syllabus to bring with you to class. Your copy of this syllabus is an important part of your training experience and should be brought with you to training. Read it before you arrive and review it following the program along with material you received at training.

2. PRE-TRAINING ASSIGNMENTS: Your completion of pre-training assignments is essential to the success of your training. You are responsible for all reading assignments in preparation for classroom sessions. Time will be provided during working hours to accomplish any assignments which involve either individual or group efforts and resources. (Pre-training assignments are listed in the "Training Attendance Requirements" section.)

3. TRAVEL: Arrange your travel to and from the training through your District or Office. (No reimbursement for travel expense - including per diem costs - will be approved for travel not specifically authorized in advance by the District Superintendent.) Individuals may claim reimbursement for incidental expenses

incurred as outlined in DAM 0410.6. The Training Center does not have the capability to provide transportation to/from Monterey Airport.

4. HOUSING: Housing will be assigned to you on a shared-room basis and will be available from 3 p.m. on the date of arrival to 12 noon on the date of departure. The Department provides your room and board expenses at the Training Center only. No per diem allowance will be authorized for living off-grounds. This does not preclude living off-grounds at your own expense. Please advise the Department Training Officer no later than one week before your scheduled arrival if you plan to live off-grounds. No animals are permitted in Asilomar housing. In the event of an emergency, staff must know your room assignment, therefore, you may not switch rooms without staff approval. Overnight guests are not allowed in the buildings unless registered beforehand at the front desk in Asilomar's Administration Building. Quiet hour for lodge living areas is 10 p.m.

HOUSING CANCELLATION POLICY: If you do not need lodging or must change or cancel your reservation, you must contact the Training Center at least 72 hours prior to your date of arrival. The Training Center is committed to ensuring that the reservation that has been made for you is accurate and needed.

5. MEALS: Meals will be provided, semi-cafeteria style, from dinner on the date of arrival through lunch on the date of departure. Meals will be served at 7:15 a.m. for breakfast, 12 noon for lunch, and 6 p.m. for dinner. Hot or box lunches may be provided on some days. If you require a special diet, notify the Asilomar Chef at 831-372-8016 no later than one week before your scheduled arrival.

   In order to assist participants with limited mobility, Asilomar provides a shuttle to and from the dining hall. Please contact either Asilomar staff upon check in, or Training Center staff upon your arrival, for instructions on arranging a transport.

6. OFF-GROUNDS ACCOMMODATIONS: When authorized to stay off-grounds by the Department Training Officer, the Training Center will pickup the cost of your room and meals at the current DPR Asilomar rate. If you stay off grounds and have meals on grounds, the Training Center will authorize only what the Department pays Asilomar for lodging.

7. CLOTHING: Field uniforms as found in “Description of Required Field Uniforms”, DOM Chapter 2300, Uniform Handbooks, not including optional items, will be worn daily by all uniformed employees during formal training sessions unless specified in the Program Attendance Checklist. Non-uniformed employees shall wear professional business attire.

Because we are on the conference grounds with many other groups, and the image we project as State Park employees is important not only during working hours but off duty hours as well, your informal sportswear should be appropriate.

8. ROOM SAFES: Two safes have been installed in each of the lodge rooms used by the Training Center (Live Oak, Tree Tops, and Deer Lodge). These safes are a type that allows the user to input their own combination of numbers to facilitate opening and closing. The Training Center has a master key for emergency entry. Safes are to be left in the open position when checking out of your room.

9. WEAPONS: Weapons are permitted in rooms under the following conditions. Authorized firearms and magazines stored while at the Training Center shall be in a safe condition and stored in one of the following locations: your room safe in Live Oak, Tree Tops, or Deer Lodge, one of the Training Center's safes in the Whitehead Room or secured in your vehicle.

10 ALCOHOLIC BEVERAGES: Participants shall not possess or consume alcoholic beverages in common areas (living room) while on the Asilomar Conference Grounds unless provided and hosted by Concessionaire Delaware North.

11. SMOKING: Smoking is not permitted in the Training Center or in any lodge or guest room on the Asilomar Conference Grounds.

12. TRAINING CENTER: The Training Center is located on Asilomar Conference Grounds, part of Asilomar State Beach. The Conference Grounds are operated for our Department by a concessionaire, and all lodging and food services are provided to us by employees of the concessionaire. Constant efforts are made to maintain a sound, harmonious working relationship between the Department and concessionaire. None of us can expect preferential treatment for any reason and, as a departmental employee, you will be expected to join in our continuing effort toward an effective relationship with each Asilomar concession staff member. On occasion, non-departmental groups may be staying in the same lodges. It is imperative that you represent the Department well on and off duty.

13. REGISTRATION: When you arrive at Asilomar Conference Grounds, go directly to the front desk at the Asilomar Administration Building for your room key and dining room ticket. If you require vegetarian meals, notify the front desk representative and your meal ticket will be marked accordingly.

14. COURSE LEADERS: The formal training you will attend is developed and, for the most part, conducted by experienced State Park employees in field and staff positions. Some courses will be conducted by qualified instructors from other agencies and educational institutions. Your course leaders have proven their ability and knowledge in their profession, and provide a level of expertise difficult to match.

15. TRAINING CENTER STAFF: A Training Center staff member has been assigned responsibility for your training group as well as for your training program. That staff member usually serves as a Course Leader as well as a Coordinator. During the program, you may be asked to assist Training Center staff in the logistics of your training program (organizing field trip transportation, supervising classroom breaks, etc.). Center staff will do all within their power to make your training experience pleasant and meaningful.

16. TRAINING MATERIALS: May be made available to you at both your unit and the Training Center. Handout materials issued at your unit should be brought to training for possible use. A conference binder or notebook will be issued to you at the training session for note taking and convenience in handling materials. Copies of DAM and DOM will be available to you for self-study. Bring your own pens and pencils.

17. ATTENDANCE: Regular attendance is a critical course requirement and your participation is important to the success of this training. All absences, except those of an emergency nature, must be approved in advance by the Training Specialist.

18. COLLEGE CREDIT: Most training programs are accredited by Monterey Peninsula College for lower division credit. If you successfully complete an accredited program, you will receive either a letter grade or a credit/no-credit designation.

19. VEHICLES: All vehicles should be parked in the lots adjacent to the Training Center. Any questions regarding use of a State vehicle while at the Training Center should be discussed with your supervisor prior to your departure for training, or with your Program Coordinator while at the Training Center.

20. BICYCLES: If you bring your bicycle, store it in the bicycle shed next to the Training Center. Bicycles may not be brought into any building nor chained to lamp posts, trees, etc. The Training Center has a limited number of bicycles available for your use. Prior to your use, you are required to complete a safety inspection and sign a waiver which is posted in the bicycle shed.

21. MAIL: Mail forwarded to you during your time at the Center should be addressed to you in care of:

    Department of Parks and Recreation
    WILLIAM PENN MOTT JR. TRAINING CENTER
    P. O. Box 699, Pacific Grove, CA 93950

22. CELL PHONES: As a courtesy to your fellow participants and course leaders ensure that your cell phone is turned off during classes. Participants should not be receiving or making cell phone calls during class time. Please limit those calls to your breaks.

23. FAX: The Training Center's FAX number is (831) 649-2824.

24. TELEPHONE: Limit phone calls during classroom hours to urgent business or emergencies. Anyone wishing to contact you by telephone during working hours should call the Center at (831) 649-2954. Calls after 5 p.m. or during weekends should be made to (831) 372-8016, Asilomar Conference Grounds, and the caller should tell the switchboard operator you are with a Department of Parks and Recreations training group.

25. LAUNDRY AND DRY CLEANING: May be taken care of by you at one of several local establishments. An iron is available for 24-hour checkout from the Training Center front desk.

26. RECREATION: Facilities available on grounds include a heated swimming pool, ping-pong and pool tables, and a volleyball court. The Monterey area offers horseback riding, golf, tennis, racquetball, deep sea fishing, and many historical landmarks and scenic sights to explore.

27. POST-TRAINING ASSIGNMENTS: In connection with formal training are to be completed under the direction of your supervisor. See "Program Attendance Requirements" in this syllabus.

28. COFFEE BREAK REFRESHMENTS: Will be available throughout each session at the Center. You will be asked to contribute to the "Hospitality Fund" to defray expenses. Please bring your own coffee cup.

PROGRAM ATTENDANCE CHECKLIST

To assist you in your preparation for formal training session at the William Penn Mott Jr. Training Center the following list is provided:

_____1. Read and understand the Intermediate Electrical Skills Program Syllabus prior to your arrival at the Training Center.

_____2. Complete the following pre-training assignment.

- ❑ Complete the Intermediate Electrical Skills Pre-Training Assignment at the end of this syllabus and record your answers in BOTH the Pre-Training Assignment and answer sheet.
- ❑ Discuss the Electrical Skills program with your supervisor. What specific changes in your abilities and performance are expected to result from you attending this training? List these expectations along with your own under "Expectations" on the back of the "Equipment Check Sheet".
- ❑ Review the Post-Training Assignment form at the end of the syllabus with your supervisor. Discuss the projects you will be assigned in the next twelve months, which will utilize the skills developed during the training program.
- ❑ Make arrangements with your supervisor to demonstrate your ability to safely use the items listed on the Equipment Check Sheet. All items must be initialed by your supervisor, or your supervisor's representative, and signed by your District Maintenance Chief for you to participate in the practical portion of the training program.

NOTE: The Pre-Training Assignment (Workbook Answer Sheet, Equipment Check Sheet and Expectations) will be collected during the program orientation. Completion of the Pre-Training assignment and bringing the proper personal protective equipment is mandatory; it will count for 20% of your program grade. If you have questions or need help, call the Program Coordinator, Chuck Combs, at (831) 649-7124 or e-mail chuck@parks.ca.gov

_____3. Remember to bring the following with you to training:

- ❑ Program syllabus and workbook.
- ❑ Personal safety equipment (eye, ear, head and hand protection). *Note: Gloves must be rated for electrical use!*
- ❑ Proper field uniform, rain gear, coveralls and/or appropriate work clothing.
- ❑ Coffee cup, alarm clock, pens, pencils.

POST-TRAINING ASSIGNMENT

Prior to ninety days after the completion of this program, the employee and his/her supervisor should sit down and discuss the impact and assess the effectiveness this program has had on the employee. Then both the supervisor and employee should login to the Employee Training Management System (ETMS) and complete the Post-Training Evaluation form (an email will be sent to both employee and supervisor notifying them that the evaluation needs to be completed). Once you login to the ETMS, you will need to fill out the evaluation form before you will be able to do anything else.

The post-training evaluation process is intended to provide a bridge between classroom instruction and the on-the-job application of training. The information obtained through this process will assist the training participant, supervisor, and Training Center in providing a return on the investment the Department has on training.

INTERMEDIATE ELECTRICAL SKILLS GROUP 33-AGENDA-January 21-26, 2007

Lead Instructor: Lawrence "Sparky" Ross

> ***Special Notice:*** This program will be conducted at the Mott Training Center Shop Annex, 2211 Garden Road, Building C, Monterey, California. Vans are available to transport you to and from the Shop Annex and will leave the Mott Training Center promptly at 0800 daily and return by 1700.

Sunday
January 21

1500-	Registration: *Check in at the Asilomar Administration* Building.	All

Monday
January 22

0800-0830	Vanpool to Annex	
0830-0900	Orientation/MPC Registration/Expectations	Combs
0900-1100	Electrical System Review	Ross
1100-1200	Blueprints and Schematics	Ross/Moon
1200-1300	Lunch	
1300-1500	Introduction to Codes	Ross
1500-1630	Electrical Distribution Systems	Ross
1630-1700	Vanpool to Mott Training Center	All

Tuesday
January 23

0800-0830	Vanpool to Annex	
0830-0930	Transformers	Ross
0930-1000	Personal Safety Requirements-THA	Ross
1000-1200	Shop Applications-Wiring	All
1200-1300	Lunch	
1300-1330	Field Applications-Theater Assessment	All
1330-1530	Estimating Practices	Ross
1530-1630	Project Assessment Submittals	Ross
1630-1700	Vanpool to Mott Training Center	All

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Wednesday
January 24

0800-0830	Vanpool to Annex	
0830-1000	Motors and Controls	Ross
1000-1200	Shop Applications	All
1200-1300	Lunch	
1300-1630	Shop Applications	All
1630-1700	Vanpool to Mott Training Center	All

Thursday
January 25

0800-0830	Vanpool to Annex	
0830-0930	Quiz	Ross
0930-1200	Power Quality/Troubleshooting	All
1200-1300	Lunch	
1300-1500	Testing and Practical Performance Evaluations	All
1500-1630	Tear Down/Clean Up	All
1630-1700	Vanpool to Mott Training Center	All

Friday
January 26

0800-0830	Travel to Annex	All
0830-1000	Communication/Network Systems	Ross
1000-1130	Exam and Exam Review	Ross
1130-1230	Program Summary and Evaluation	Combs
1230-	*Lunch and Departure*	

INTERMEDIATE ELECTRICAL SKILLS TRAINING PROGRAM (36 HOURS)

PROGRAM OUTLINE	HOURS
Program Orientation and Overview	0.5
Electrical System Review	2.0
Blueprints and Schematics	1.5
Electrical Codes	2.0
Electrical Distribution	2.0
Electrical Safety Considerations	0.5
Hardware and Demonstrations (Wire, Conduit, Transformers)	6.0
Troubleshooting	3.0
Telephone/Network Wiring	1.5
Shop Applications	11.5
Tests and Practical Performance Evaluations	4.5
Program Summary and Evaluation	1.0
Total Hours	36.0

INTERMEDIATE ELECTRICAL SKILLS

PROGRAM ORIENTATION

Purpose: Participants will meet one another and the program coordinator and instructor. The group will share expectations for the training program. In addition, program content will be reviewed and registration for Monterey Peninsula College completed.

Performance Objectives: By the close of the session the participant will

1. Review program content, procedure and evaluation processes.
2. Share and record expectations with group members.
3. Complete Monterey Peninsula College registration materials.
4. Adhere to all Training Center guidelines.

ELECTRICAL SYSTEM REVIEW

Purpose: To review the Electrical Skills Pre-Training Assignment.

Performance Objectives: By the close of the session the participant will

1. Review answers to questions from the pre-training study quiz.
2. Review general safety items to be considered when working with electricity.
3. Review the basic wiring techniques commonly used in constructing residential electrical circuits.

BLUEPRINTS AND SCHEMATICS

Purpose: To introduce the participant to electrical symbols, lines and scale.

Performance Objectives: By the close of the session the participant will

1. Recognize common electric symbols.
2. Identify basic residential electric system design.

3. Develop the ability to use construction drawings for troubleshooting and repair of residential electrical circuits.

INTRODUCTION TO CODES

Purpose: To introduce the participant to the codes, laws and policies which apply to electrical wiring of State owned facilities.

Performance Objectives: By the close of the session the participant will

1. Identify how to use the National Electrical Codebook.

2. Review selected sections of the National Electric Code.

3. Recognize that wiring State facilities to meet code is mandatory.

ELECTRICAL DISTRIBUTION SYSTEMS

Purpose: To introduce the participant to the function and configuration of meter/main panels and loadcenters

Performance Objectives: By the close of the session the participant will

1. Demonstrate an understanding of the function of main panels, load centers, grounding and their component parts.

2. Distinguish between single phase and three phase load centers.

3. Demonstrate the ability to safely replace circuit breakers.

4. Demonstrate the ability to safely install and maintain components and connections in a single phase load center.

PERSONAL SAFETY

Purpose: To provide information on special safety considerations and special personal safety equipment.

Performance Objectives: By the close of the session the participant will

1. Recognize the precautionary steps that must be taken before attempting to work on electrical systems.

2. Acquire the knowledge and ability to select the proper safety procedure used in each electrical system failure repair.

3. Develop the necessary skills for properly using electrical safety and testing equipment.

4. Discuss the specific safety considerations, which must be observed while participating in the Electrical Skills training program.

ELECTRICAL SKILLS - SHOP APPLICATIONS

Purpose: To provide the Maintenance Worker with an opportunity to observe, practice and demonstrate practical application of electrical skills.

Performance Objectives: By the close of the session the participant will

1. Observe instructor demonstrations of installing a load center, running wire, wiring devices and loads.

2. Practice laying out and testing electrical circuits, using tools and test equipment, running wire, and wiring electrical devices and loads.

3. Demonstrate knowledge and ability to accurately assess, plan and construct the electrical circuits commonly found in commercial and residential construction.

ELECTRICAL HARDWARE DEMONSTRATIONS

Purpose: To provide information on how to select the proper materials for making repairs and upgrading existing park facility electrical systems and when planning new installations for new facilities.

Performance Objectives: By the close of the session the participant will

1. Recognize the proper size and type of wire when making repairs to electrical systems.

2. Identify the various types and application of electrical conduit.

3. Review the application of transformer systems used in park facilities.

TROUBLESHOOTING

Purpose: To develop the ability in the Maintenance Worker to inspect, test and correct deficiencies in electrical systems.

Performance Objectives: By the close of the session the participant will

1. Perform a routine inspection of an electrical system.

2. Use test equipment to identify system failures and recommend corrective action.

TELEPHONE/NETWORK WIRING

Purpose: To develop the ability in the Maintenance Worker to inspect, test and repair common communication circuits.

Performance Objectives: By the close of the session the participant will

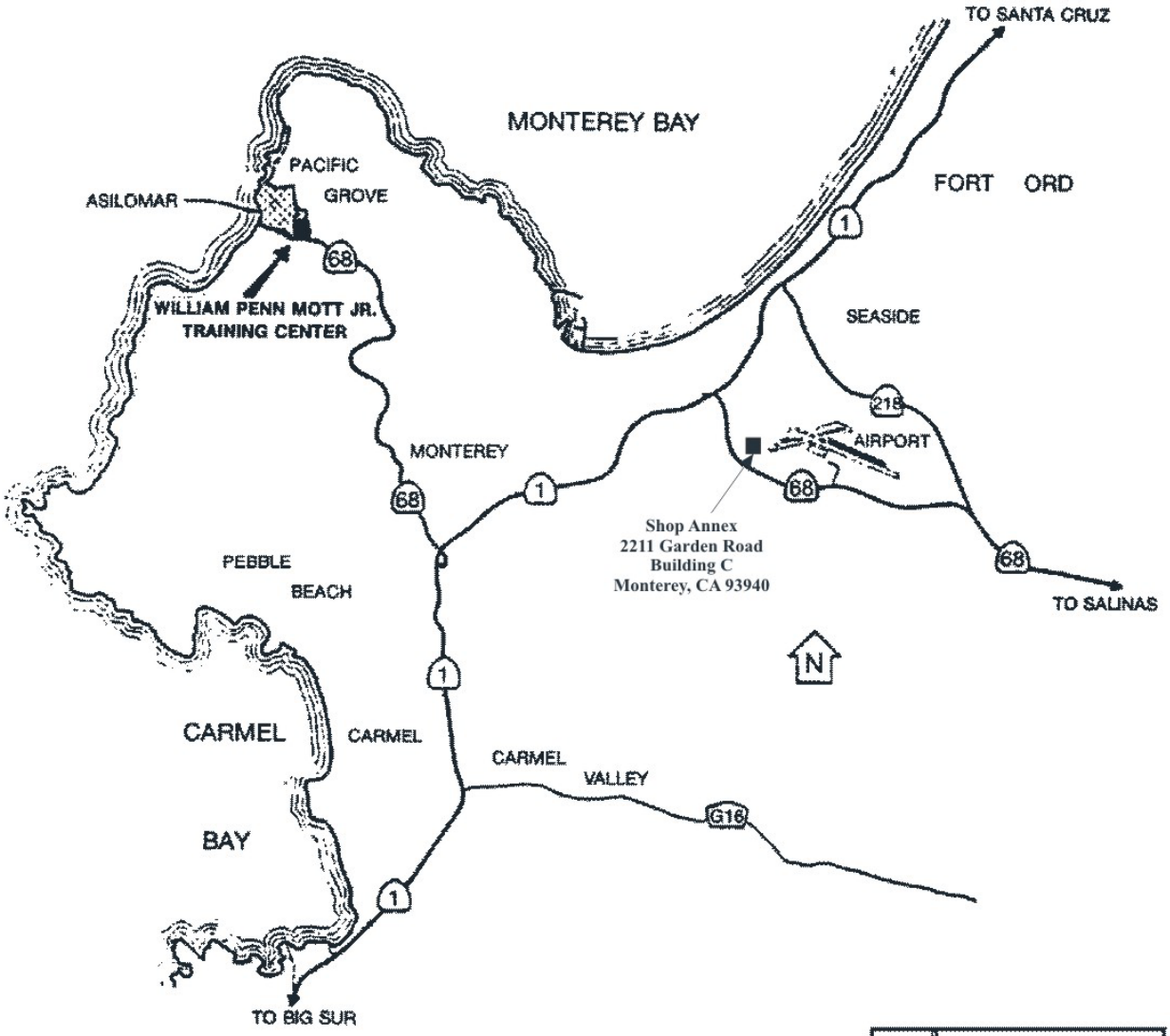
1. Recognize common telephone and networking circuits.

2. Demonstrate the ability to inspect and replace the defective elements.

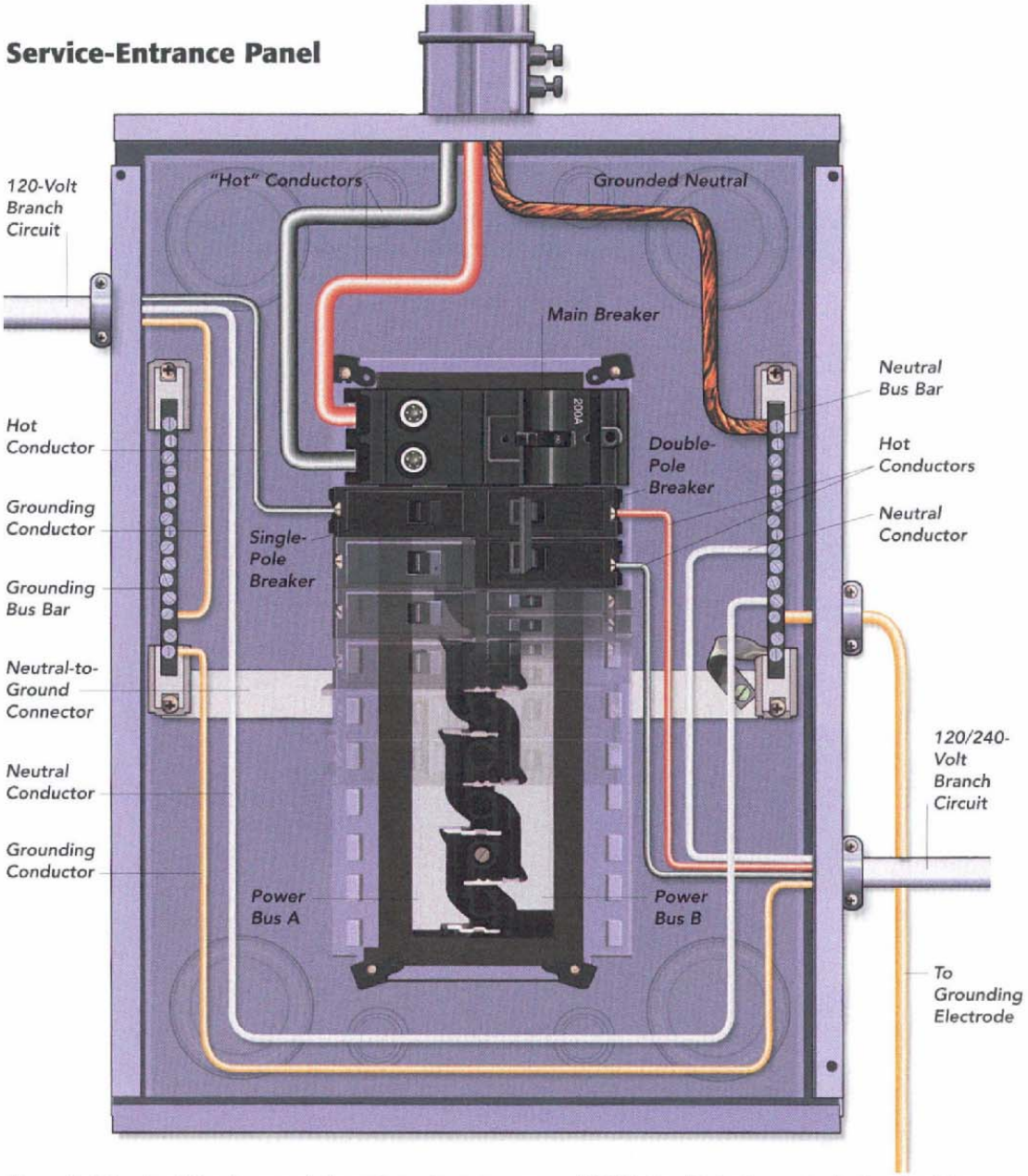
3. Recognize the basic differences in each system.

location map for

WILLIAM PENN MOTT JR. TRAINING CENTER
837 ASILOMAR BLVD.
PACIFIC GROVE, CALIFORNIA 93950



Service-Entrance Panel



Also called the circuit-breaker panel, *the main service-entrance panel (SEP) is the distribution center for the electricity you use in your home. Incoming red and black hot wires connect to the main breaker and energize the other circuit breakers that are snapped into place. Hot (black or red) wires connected to the various circuit breakers carry electricity to appliances, fixtures, and receptacles throughout the house. White and bare-copper wires connect to the neutral and grounding bus bars, respectively. (Representative 120-volt and 120/240-volt circuits are shown.)*

How Electricity Works

Electric Current Flow

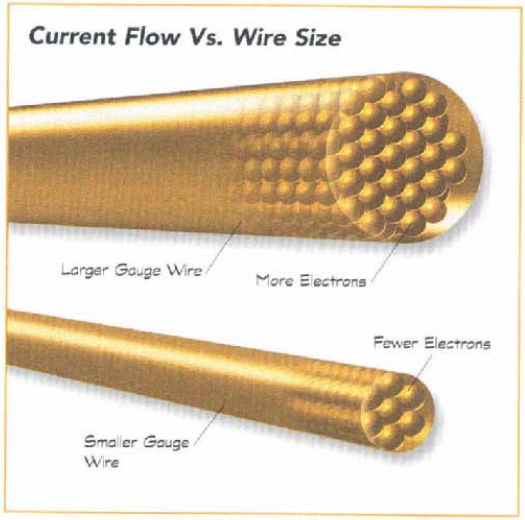
Electric current flow can be defined as the flow of electrons through a conductor (wire) or circuit. This passage of electrons is often described as being analogous to the flow of water in a pipe or hose. For example, water flows through a pipe or hose because it is under pressure. Similarly, electric current surges through a wire because it is under pressure. Earlier, voltage was defined as the pressure, or moving (electromotive) force, that causes current (electrons) to flow in an electrical circuit. (See "Terminology of Electricity," pages 9–11.) Furthermore, just as the size of a hose or pipe can affect the degree of water pressure, the size of an electrical wire can affect the flow of current passing through it. The maximum current-carrying capacity of a particular-size wire is called its ampacity. (See page 9.)

As electric current passes through your electrical system, it reaches your receptacles and switches where, again like water, it becomes available for use—provided that you flip the switch on your wall or appliance just as you would turn the faucet on at your sink. And, like the water, once the electric current is used, it exits the system. Instead of exiting through a drainpipe, the current exits (or returns to the utility) by means of a grounded conductor.

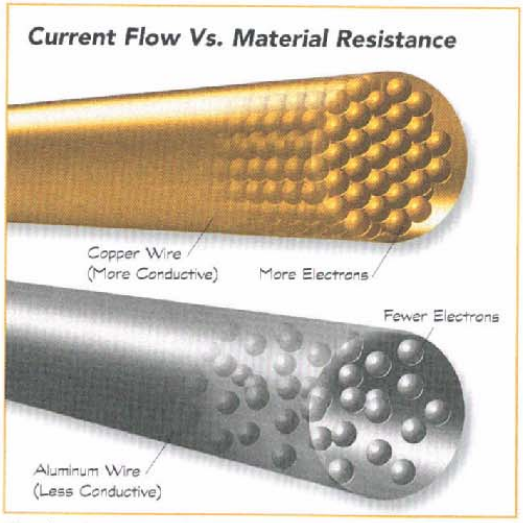
Flow Resistance

The passage of electric current through a wire is not only restricted by the size of the wire and the amount of voltage pressure but also by the material of which it is made. Some materials resist the flow of electricity more than others because of their chemical composition. Imagine water trying to flow along an incline; if the incline is downward, the flow will be unrestricted; if the incline is upward, the flow will be resisted. Whether the incline is sharp or shallow will affect the speed of the water flow, and if the pressure is not sufficient or the upward incline is too great, then the flow may be stopped altogether. Further, if the incline is strewn with obstacles, like the bed of a stream is strewn with boulders and stones, then the flow will be slowed in comparison with that on a smooth incline. It is the chemical composition of a given material that determines whether it is "rock strewn" or "smooth."

Materials that allow electric current to pass through them fairly easily are electrical conductors, while materials that prevent the passage of electric current are insulators. Common conductors include copper and aluminum, which are used in the manufacture of electrical wiring. Most metals are good electrical conductors, yet even these offer some resistance to the flow of electric current. This property can be measured in units of resistance called ohms. (See "Terminology of Electricity," pages 9–11.) Materials commonly used as insulators include glass, various plastics, and rubber.



***A larger wire gauge** permits more electricity to flow through it than a smaller gauge wire.*



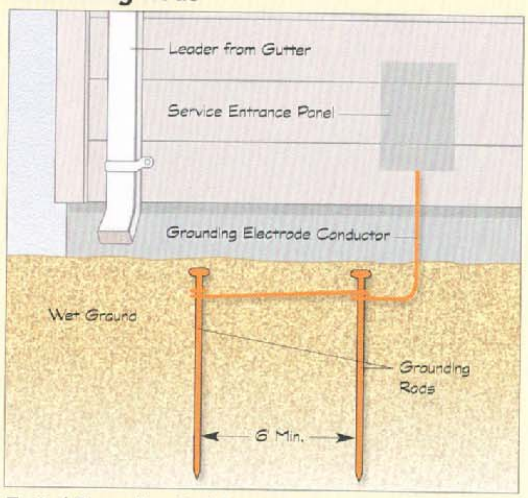
***Conductive materials** allow more current to pass through them than less conductive materials of the same size.*

Grounding Rods

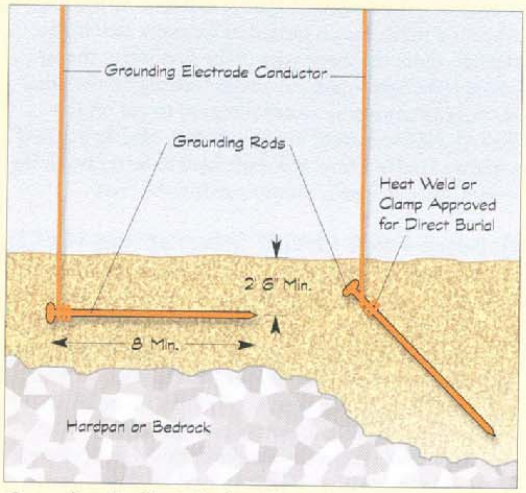
Grounding rods are usually composed of galvanized or copper-clad metal ⅝ inch in diameter and typically 8 feet long or longer. A good grounding system may include several grounding rods. A single grounding electrode composed of a rod or pipe must have a resistance to ground not to exceed 25 ohms (NEC Section 250.56), otherwise one or more additional grounding rods must be used. Multiple rods or pipes must be placed at least 6 feet apart and be connected to the neutral bus bar with a continuous copper conductor. Never overlook these code requirements. Note, for example, that effective grounding is essential for the proper functioning of a surge arrester. Unless low ground resistance is available, a surge arrester will not be able to draw the spikes, or massive intermittent increases in voltage or amperage, coming into a circuit during a power surge.

▸ ***Because of their length and awkwardness,*** *it is best to drive grounding rods using a borrowed or rented rotary hammer. This tool enables the rods to vibrate through soil and past small rocks with little or no difficulty.*

Grounding Rods



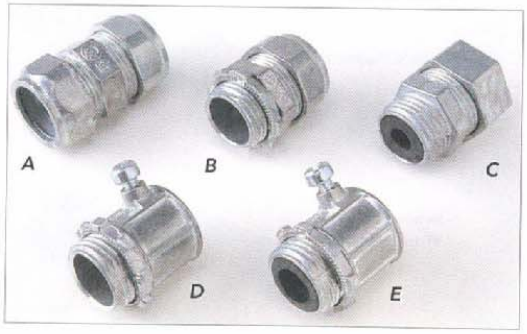
Typical Grounding-Rod System. *Grounding rods conduct electricity from the grounding electrode conductors directly into the earth, where it is harmlessly dissipated. Some grounding systems may require more than one rod, in which case they must be spaced at least 6 feet apart. Rainwater directed near grounding rods helps to lower the ground resistance.*



Grounding-Rod Installation. *If a grounding rod cannot be driven directly into the earth because of boulders or bedrock, the NEC requires (Section 250.52) that it still must have at least 8 feet of length in contact with the soil. To accomplish this, a rod may either be driven at an angle not less than 45 deg. or placed horizontally in a trench at least 2½ feet deep.*

Conduit Connectors. Special types of connectors are needed to secure conduit at junctions and connection points.

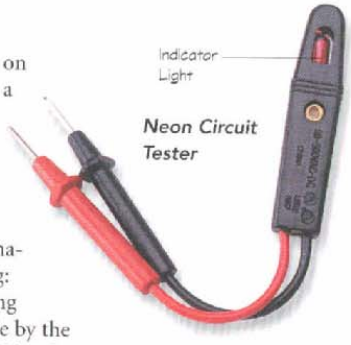
*Below are examples of straight conduit connectors for rigid and intermediate metallic conduit. **A** straight compression coupling; **B** concrete-tight straight compression; **C** straight compression with insulated throat; **D** concrete-tight setscrew; and **E** setscrew with insulated throat.*



Wrenches and Pliers. Many conduit connections, as with conventional plumbing pipes, consist of compression fittings. You will need pliers and sized or adjustable wrenches to properly secure these connections.

Testing Circuits

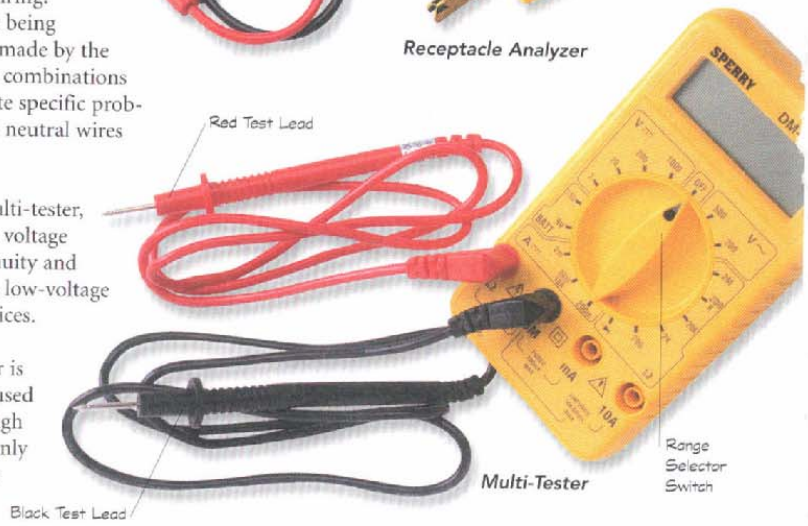
Neon Circuit Tester. Use the two probes on a circuit tester to check for live voltage in a circuit. The neon bulb will light if the circuit is live. You can also use the tester to verify that the power to a circuit has been turned off before you work on it.



Receptacle Analyzer. Use a receptacle analyzer to identify faults in receptacle wiring: simply plug the device into the outlet being tested; then read the lighting pattern made by the three bulbs on the analyzer. Different combinations of lighted and unlighted bulbs indicate specific problems with the wiring, such as hot and neutral wires connected in reverse.

Multi-tester. An analog or digital multi-tester, or multimeter, is required to measure voltage and current, as well as to make continuity and resistance checks in switches, fixtures, low-voltage transformers, and other electrical devices.

Continuity Tester. A continuity tester is powered by its own battery, which is used to generate an electrical current through an attached wire and clamp. It must only be used when the power to a circuit is



turned off. The tester is especially useful for determining whether or not a cartridge fuse has blown. You can test this type of fuse by touching the tester clamp and probe to the opposite end caps of the fuse. A lighted bulb indicates a working fuse, an unlighted bulb means that the fuse has blown and is in need of replacement. The tester can also be used to detect faults and current interruptions in switches and other types of electrical equipment.

Low-Voltage Circuit Tester. A low-voltage circuit tester looks similar to a neon circuit tester, but it is strictly limited to testing circuits less than 50 volts such as doorbells, transformers, low-voltage lamps, and outlets, etc.

Telephone Line Tester. Use a telephone line tester to resolve problems with standard telephone wiring. A telephone line tester has a phone-jack plug on one end and an LED on the other. Some testers come with a splitter that enables you to strip as well as test telephone wires. Plugging the tester into a modular jack allows you to test whether any of the circuit wires have been reversed or are loose or disconnected. You can also use a telephone line tester used to check the telephone itself for dial-tone and wiring function.

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SMART TIP

Using Ladders

Always use nonconductive ladders—wood or fiberglass. Aluminum ladders can be an electrician's nightmare. Should you accidentally cut into a hot wire, you must be insulated from ground—not connected to it. Always wear rubber-soled shoes and electrician's gloves to serve as additional insulators. If you are in doubt about the security of the ladder base, hammer stakes into the ground to brace it. It is also important to maintain good balance while working on a ladder. Never lean too far right or left or do work from an awkward angle.

Safety

Electrician's Gloves. For electrical work you should use a pair of insulated electrician's gloves, rather than using ordinary work gloves. Some high-voltage gloves can protect you up to 20,000 volts, while low-voltage gloves are sufficient for up to 1,000 volts.

Safety Glasses. When doing electrical work of any kind, you should always wear safety glasses or goggles. A sudden spark or a bit of clipped wire could shoot out and burn or scratch your eye. When drilling overhead it is important to wear safety goggles to keep debris from falling into your eyes as you work. Be sure that the glasses you buy have extendable arms to fit properly around your ears.

Extension Cords. Because you should never plug a power tool into an electrical circuit unless it is ground-fault protected, a GFCI extension cord can literally be a lifesaver. This device can save your life if a tool malfunctions and short-circuits to the housing while you are using it. You can never assume that the receptacle from which you are working has GFCI protection. A 3-foot extension cord with GFCI protection built in is ideal because of its portability. It is sold at most electrical wholesalers and retailers. Use, at minimum, a 12-gauge heavy-duty extension cord to allow your high-voltage tools to obtain maximum voltage, which prolongs their life. Under-gauged extension cords can be a fire hazard.

CHAPTER 3

Materials & Equipment

Even if you have the proper tools to do your own electrical work, you are only half-prepared for the task. You must also have the right materials and equipment. Every code requirement must be carefully considered before you purchase a single item. Plan your electrical work on paper first so that you will know exactly what to purchase—from the service panel and electrical boxes to the receptacles, switches, and fixtures. First, you must determine what you're installing and how much power it requires. Then you can decide what categories and quantities of wire to buy; how many circuit breakers and at what amperage; whether or not conduit or cable will be used, and what type; and the accessories needed to connect and fasten wires, conduit, cable, and other materials. Carefully identifying everything you need in advance saves you time and money as well as effort.

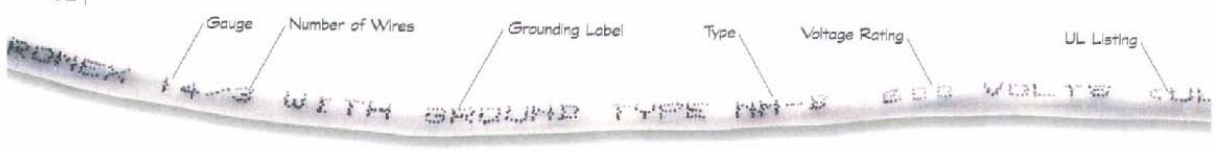
Wires and Cables

Types and Designations

Technically, the metallic material through which electric current flows is called a conductor. In practical terms, most people call it wire. Wire is designated as bare or insulated, stranded or solid, single or multiple, sheathed in cable or encased in insulated cord. In residential work, most wires made of a solid conductive material, such as copper, are encased and protected in plastic insulation. You can buy this type of wire in custom lengths cut from a roll or precut and packaged in standard lengths. Cables usually consist of two or more insulated wires wrapped together in a second protective layer of plastic sheathing. If the cable includes a grounding wire, it can be insulated, bare, or covered copper wire. Cable is commonly sold boxed in precut lengths. Stranded wires are typically enclosed in an insulating jacket, called a cord. Flexible cord is sometimes precut and packaged but is usually sold off the roll. Whether on a roll or precut, conductors are always sold by the linear foot.

Aluminum and copper-clad aluminum wires have also been used in the past, in addition to copper, as conductive materials. For any electrical work you do, you should use only the kind of wire that is already installed in your home. To find out which kind of wire you have, check the cable type at the main service panel by reading the designation printed on the plastic sheathing. For this, you need to have an accurate circuit map to identify the circuit you are planning to check. An abbreviated coding system reveals the voltage, the wire or cable type, and the American Wire Gauge (AWG) wire size. (See table "American Wire Gauges," page 10.)

Wire comes in many types: *bare or insulated; solid or stranded; single or multiple; sheathed in plastic or metal. Each type serves a different purpose.*



Markings on a cable jacket *indicate the gauge and number of wires in the cable, the UL-listing, voltage rating, and whether a grounding wire is included.*

For example, consider the following designation: 14/3 WITH GROUND, TYPE NM-B, 600 Volts (UL). The first number shows that the insulated wires inside the cable are 14 gauge (AWG). The second number indicates that the cable contains three wires. "With ground" signifies that a fourth bare copper or green insulated grounding wire is incorporated within the cable. This may simply be designated with the letter G following the number of wires in the cable. "Type NM-B" denotes that the wire is rated at 90 degrees Centigrade (194 degrees Fahrenheit) and is encased in a nonmetallic (plastic) sheathing. Next, the maximum voltage safely carried by the cable is specified as 600 volts. And, finally, the UL notation ensures that the cable is rated as safe for its designated use.

Wire Sizes. You will be concerned mostly with solid-copper wires of 14, 12, and 10 gauge because these are most commonly used for house wiring. Again, the term wire refers to a single conductor. In a cable containing two or more wires, they will all be the same gauge. The AWG system codes the wire diameter as a whole number. The smaller the number, the greater the diameter and current-carrying capacity of the wire. Because wire size recommendations are for copper wires, you must readjust the designation to the next larger size whenever you use aluminum or copper-clad aluminum wire. (12- and 10-gauge aluminum and copper-clad aluminum are no longer manufactured and are not available.)

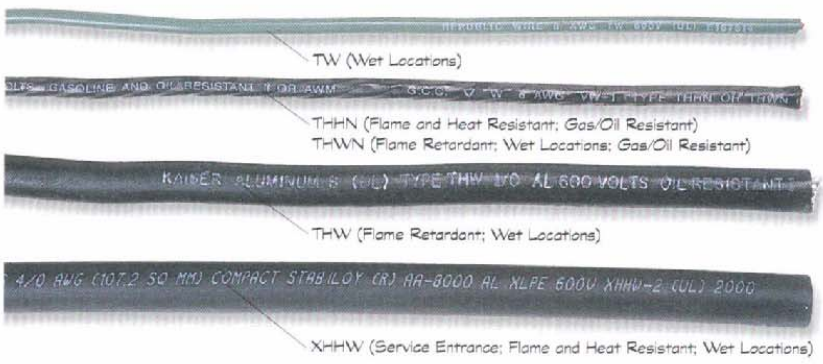
Aluminum Concerns. Be extremely cautious if you use aluminum wire. Though commonly used for heavy appliance circuits, aluminum wire requires special attention in switches and receptacles. Don't use aluminum wire where copper wire is designated. If aluminum wire is used in a device designed for copper wire, the wire will expand and contract as it heats and cools, eventually working loose from the terminal screws. This will create a dangerous situation and may result in an electrical fire. If your home contains copper-clad aluminum wiring, do not add aluminum wiring to it. Instead, use copper wires. If your home has aluminum wire, check whether the switches and receptacles are marked CO/ALR (rated to be connected to aluminum). If the switches and receptacles do not bear this marking, replace them with those that do. Be careful, too, when working with single-strand aluminum wire because it breaks easily. Also, never connect aluminum wire to a back-wired switch or receptacle that uses push-in terminals. Aluminum wire must always be connected to terminal screws (NEC Section 110.14). Note, too, that you can buy UL-listed crimp and twist-on connectors that are specifically made to connect aluminum to copper wire pigtails. These devices are recommended by the Consumer Product Safety Commission.

Aluminum cable is sometimes used for service-entrance cable and large appliances such as electric ranges and electric furnaces. If large diameter, multistranded aluminum cable is used, the ends must be coated with a noncorrosive compound. (NEC Section 110.14)

Connect aluminum wire *only to receptacles or switches approved for it and clearly marked with the letters CO/ALR.*

Color-Coding

In addition to the markings on plastic wire insulation, wires are coded by color. Black wires are always hot, as are the red, blue, and yellow wires. White or gray wires are generally (grounded) neutral, with the exception noted below. Green wires are used for grounding only. In addition to having green insulation, grounding wires may also be bare copper. An exception: when a white wire is combined with a black wire in a two-wire cable, the white wire may be used as a hot wire in a switch loop or in a single 240-volt appliance receptacle. In these cases, the white wire must be wrapped with black electrical tape at



Just as there are many types of wires, *wire insulation comes in categories, each having a maximum operating temperature and ampacity rating.*

visible points to identify it as a hot wire. Two-wire cable has a black and white wire; three-wire cable, white, black, and red; four-wire cable, black, white, red, and blue; and five-wire cable, white, black, red, blue, and yellow.

Wire terminal screws are also coded by color. Neutral wires are typically connected to silver or white; grounding or bonding (ensuring a continuously conductive path) wires to green; and hot wires to brass or copper. In a three-way switch, the common (COM) wire is usually connected to a screw with a dark finish.

Insulation Categories

Wire comes in a variety of insulation types. Be sure that you select the appropriate type for the use and location you have in mind. Always check local code before doing any work to be sure that your materials meet code requirements. The most common insulation categories used in residential wiring are THHN, THW, and THWN. The T stands for ordinary thermoplastic insulated cable. You will probably use more of this than any other type of cable in residential wiring projects. The letter H specifies wire that is heat resistant. A double H indicates wire that can operate at a higher temperature (up to 194 degrees Fahrenheit) than wire designated with a single letter H. The W denotes wire that can be used in dry, damp, or wet locations. The letter N (nylon) specifies that the wire also resists gasoline and/or oil.

Wire Types. THHN wire has flame-retardant, heat-resistant insulation specified for both dry and damp locations. The absence of a W, however, means that the wire is not approved for wet locations. Because nylon insulation is thinner than other kinds of plastic insulation, THHN wire is often used to fit more wires into a conduit. THW wire is flame retardant, and heat and moisture resistant. THWN wire also resists gasoline and oil. Both THW and THWN can be used in dry, damp, or wet locations. They are commonly used in place of THHN in conduit. Another type of wire, XHHW, is often used for service entrance (SE) cable in wet areas instead of THWN. The X indicates that the wire insulation is a flame-retardant, synthetic polymer. It is specified for use in dry, damp, and wet locations.

Cable Sheathing Insulation. Indoor house circuits are usually wired using nonmetallic (NM) cable, which is wire contained in a plastic sheathing that's labeled with its specific use. This flexible cable is sometimes known by its trade name, Romex. NM cable contains insulated neutral and power wires and a bare grounding wire. It is used in dry locations only. Each wire is individually wrapped in plastic insulation that is color-coded according to the type of wire inside. Again, hot wires are typically wrapped in black and neutral wires in white. Where the grounding wire is insulated, it is wrapped in green. If it is bare, it will be wrapped in paper.

The wires in NM cable for common receptacle, light, and small appliance circuits are usually 12/2G or 14/2G. Wire a 20-amp circuit with 12/2G cable. Larger appliance circuits require larger wire sizes. A 30-amp clothes dryer requires 10/3G cable, while a 60-amp range requires 6/3G cable. See the table, "Representative Loads and Circuits for Residential Equipment," page 44, for other common residential appliance and power needs.

If a cable is designated type UF (underground feeder and branch-circuit cable), this means that it is suitable for use in wet locations, including direct burial underground. UF cable can be used in place of wire in conduit in some areas and is permitted for interior wiring in place of Type NM cable (NEC Section 340.10). Check local code requirements. The distinguishing characteristic of this type of cable is that the individually insulated wires are embedded in solid, water-resistant plastic.

Cord Insulation. Wire designated as cord differs from cable. The type of wires sheathed in cord are stranded wires. The sheathing usually consists of some type of

Representative Loads and Circuits for Residential Electrical Equipment

Appliance	Volt/ Amperes	Volts	Gauge/ No. of Wires	Circuit Breaker or Fuse in Amps
Range	12,000	115/230	6/3	60
Built-in oven	4,500	115/230	10/3	30
Range top	6,000	115/230	10/3	30
Dishwasher	1,200	115	12/2	20
Waste-disposal unit	300	115	14 or 12/2	15 or 20
Broiler	1,500	115	12/2	20
Refrigerator	300	115	14 or 12/2	15 or 20
Freezer	350	115	14 or 12/2	15 or 20
Washing machine	1,200	115	12/2	20
Clothes dryer	5,000	115/230	10/3	30
Iron	1,650	115	14 or 12/2	15 or 20
Workbench	1,500	115	12/2	20
Portable heater	1,300	115	12/2	20
Television	300	115	14 or 12/2	15 or 20
Fixed lighting	1,200	115	14 or 12/2	15 or 20
Room air conditioner	1,200	115	14 or 12/2	15 or20
Central air conditioner	5,000	115/230	10/3	30
Sump pump	300	115	14 or 12/2	15 or 20
Forced-air furnace	600	115	14 or 12/2	15 or 20
Attic fan	300	115	12/2	20

Wherever the information is available, *use actual equipment ratings. A heavy-duty, fixed-location appliance should generally be on its own circuit. Check the manufacturer's literature to determine circuit and direct connections for any appliance before installing and connecting it to your electrical system.*

plastic, rubber, or cloth insulation. Zip cord, for example, contains two wires, usually 18 gauge, encased in a neoprene, synthetic, or other rubberlike insulation. A thin strip of this insulation between the wires is all that holds them together. You can easily separate the wires by pulling, or zipping, them apart. Cord is used primarily for lamps, small appliances, and other wires that have plugs or receptacles attached to one or both ends of the cord. Because flexible cords contain smaller gauge wires, never use them for fixed appliances.

Wire Ampacity

When selecting wire, you must also consider its ampacity. This is the amount of current in amperes that a wire can carry safely and continuously under normal conditions of use, without exceeding its temperature rating. For example, 10-gauge copper wire is rated to carry up to 30 amps;

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Estimating Wire

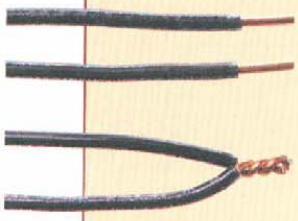
To estimate the amount of wire or cable you will need for a project, measure the distance between the new switch, receptacle, or fixture box and the main panel. Because you will probably not be going in a straight line, remember to allow for curves and offsets. Add 1 foot for every junction you will make; then provide a margin of error by adding 20 percent to the total calculated distance. If, for example, you measure 13 feet from an existing receptacle to a new receptacle, add 1 foot for each electrical box, bringing the total to 15 feet. Add 20 percent, or 3 feet, to this distance for a total length of 18 feet that you should have on hand.

Splicing Wires

According to the NEC, all wire splices must be enclosed in a switch, receptacle, fixture, or junction box. To make a wire splice, you must first strip insulation from the end of the wires. Although it may be used for this, a utility knife will most likely nick the wire. Instead, use an electrician's wire stripper or multipurpose tool. A wire stripper is operated either manually or automatically. (See "Stripping and Crimping Wires," page 29.) A manual wire stripper requires that you cut the insulation, without cutting the wire, and then pull the cut insulation from the end of the wire. Automatic wire strippers cut and strip the insulation in one motion.

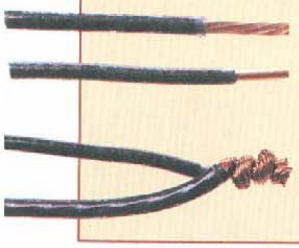
To splice solid wire to solid wire, strip approximately ½ inch of insulation from the end of each wire. Then, using pliers, spirally twist one piece of wire around the other in a clockwise direction. Make the twist tight but not so tight it will cause the wire to break. Cap the splice with a wire connector. (You can also cap the wires without twisting first.) Some people tape around the connector as an added precaution to ensure that the wires will not come out. Splice stranded wires in the same way, but do not strip either type of wire by circling the insulation with cutting pliers and then pulling off the insulation. This will cut into the conductors and cause them to break if they are bent.

To splice a stranded wire to a solid wire, strip the same ½ inch of insulation off the solid wire, but an inch from the stranded wire. Spirally twist the stranded wire clockwise around the solid wire. Cap the splice with a wire connector.

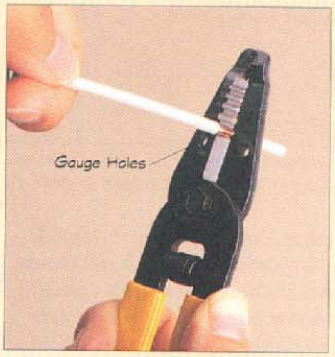


To splice solid wire to solid wire, *spirally twist one wire around the other in a clockwise direction. Cap the splice using a wire connector.*

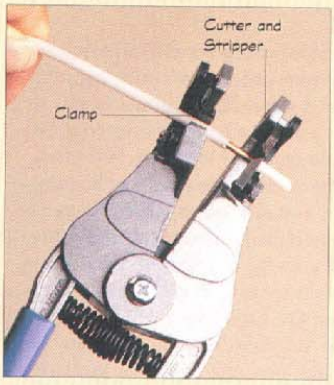
Splice a stranded wire to a stranded wire *in the same way as a solid wire to a solid wire, but be careful not to cut or break the individual wire strands. Strip stranded wires to expose 1" of bare wire before splicing.*



To splice a stranded wire to a solid wire, *spirally twist the stranded wire around the solid wire, and cap the splice using an appropriate-size wire connector. Before splicing, solid wire needs to be stripped to ½".*



To use a manual wire stripper, *insert the wire into the matching gauge hole, close the stripper to cut the insulation, and pull it toward the end of the wire.*



Though more expensive, *an automatic wire stripper combines both steps, cutting and stripping the wire insulation, in one motion.*

Amperage Ratings for Residential Cable

AWG Size	Insulation Type	Copper		Aluminum/Copper-Clad Aluminum	
		Ordinary Use	Service Entrance	Ordinary Use	Service Entrance
4/0	THW, THWN	230	250	180	200
2/0	THW, THWN	175	200	135	150
1/0	THW, THWN	150	175	120	125
1/0	TW	125	NA	100	NA
1	THW, THWN	130	150	100	110
2	THW, THWN	115	125	90	100
2	TW	95	NA	75	NA
4	THW, THWN	85	100	65	NA
4	TW	70	NA	55	NA
6	THW, THWN	65	NA	50	NA
6	TW	55	NA	40	NA
8	THW, THWN	50	NA	40	NA
8	TW	40	NA	30	NA
10	THW, THWN	35	NA	30	NA
10	TW	30	NA	25	NA
12	THW, THWN	25	NA	20	NA
14	THW, THWN	20	NA	NA	NA

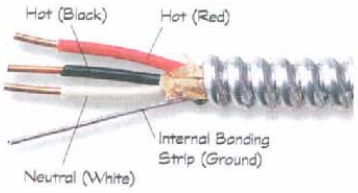
Wires sheathed *in thermoplastic insulation (cable) have maximum amperage capacities (ampacities) for which they are rated. The ratings above are for typical residential wires. (NEC Table 310.16)*

12-gauge wire, 20 amps; and 14-gauge wire, 15 amps. If a wire is too small for the current it carries, it will present a greater-than-normal resistance to the current flowing around it. This will generate enough heat to destroy the wire insulation, possibly causing a fire.

Armored Cable

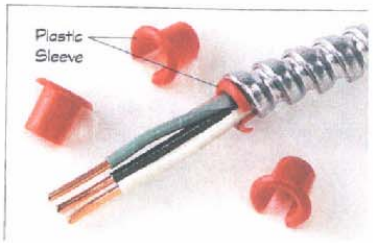
Wire enclosed in metal sheathing is called armored cable (AC). It is sometimes called by its trade name, BX. Inside the flexible metal sheathing are insulated hot and neutral (grounded) wires and a bare bonding wire. BX is restricted to use indoors in dry locations. It is rarely used in new construction (except in high-rise buildings) because it is expensive and difficult to install. Nevertheless, it is often found in older homes. Metal-clad cable (MC) is a more common type of armored cable. The two cables look alike but are easy to tell apart if you know what to look for. MC cable includes a green grounding wire while AC cable does not. The metal covering on MC cable is not permitted to be the grounding conductor. The wires in MC cable are wrapped in a

Armored cable (AC) *is sometimes called by its trade name, BX. It consists of hot, neutral, and grounding wires in a protective metal (armor) sheathing.*



Metal-clad (MC) cable *is similar to AC cable, but the wires are wrapped in plastic tape instead of paper.*

All types *of armored cable require a plastic sleeve placed between the sharp metal edges of the cut cable and the emerging wires.*



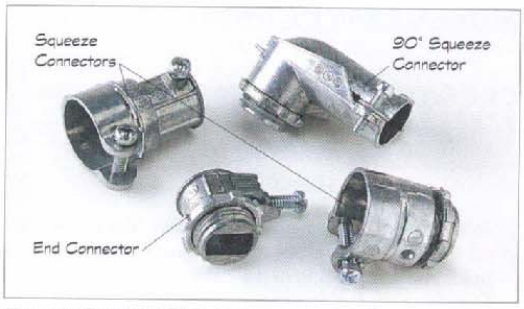
plastic tape to protect them from chafing against the armored sheathing. Be sure to insert a plastic sleeve between the wires and the armor wherever wires emerge from the armored cable.

For BX, different fittings are used to attach the cable to electrical boxes. All BX fittings work the same way—the cable goes through center of the fitting. The armor itself is connected within the fitting and is held in place by one or two clamps or a twist-on mechanism. As stated, BX is not easy to work with. To splice one BX cable into another requires cutting the armor sheathing without harming the wires inside. This can only be done using a hacksaw or a specialized tool that cuts any type of armored cable. The tool just barely cuts through the armor, which is then twisted to break cleanly, exposing the wires inside. Another drawback to BX is that it cannot turn a tight radius because of the metal sheathing. Too tight a turn will kink the armor, creating a sharp edge. Sharp edges are also created wherever armored cable is cut. This is why it is so important to always install a protective sleeve on the cut ends of the cable to protect the wires inside.

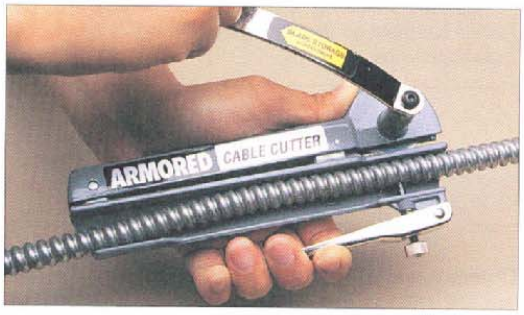
Nonmetallic Cable

Nonmetallic (NM) cable is the most common type of cable used in residential work. Again, NM cable consists of wires encased in a thermoplastic sheathing. The wires include one or more hot wires, a neutral wire, and a grounding wire. The most common type is two wires with a ground—one hot wire in black insulation, one neutral in white, and a bare copper grounding wire. Three-wire cable is commonly used for house circuits to wire three-way switching or where an extra hot wire is needed, such as for wiring a switch-operated outlet. The third wire is typically encased in red insulation. In some cases, the grounding wire in NM cable may not be included. This is particularly true of older-style NM cable (prior to 1960).

When you work with NM cable, be sure to avoid two common errors: first, putting a kink in the wires by bending the cable too sharply and, second, damaging the cable sheathing by pulling it through too small an opening. A kink may damage the copper wire inside the cable and can cause it to overheat and create a fire hazard. This also applies to working with the individual wires—never bend them at a right angle but rather bend them gradually. As for sheathing, if it is torn by pulling it through a tight opening, around a sharp turn, or getting it caught on something, the cable may be taped as long as the insulation on the individual wire within the cable is not damaged. Otherwise it must be replaced.

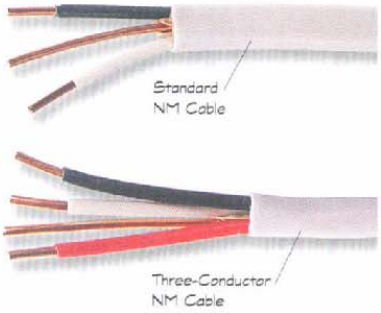


To comply with code requirements, *use the correct type of connector to properly connect BX armored cable to an electrical box.*

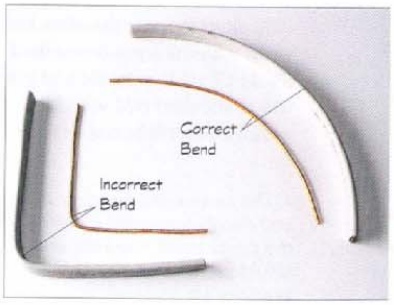


To cut armored cable easily, *use a specialized cutting tool. Insert the cable in the tool, and turn the knob clockwise to tighten down on and cut the armor.*

A standard NM cable *contains two insulated wires and one bare copper grounding wire. The hot wire is encased in black insulation and the neutral in white. In a three-conductor NM cable, the additional hot wire is encased in red insulation.*



To prevent damage to wires, *never bend individual wires or NM cable at a sharp angle. Always make gentle bends and turns. Because of its fragility, even the sheathing on NM cable will easily rip if it is caught on or scraped against something sharp.*



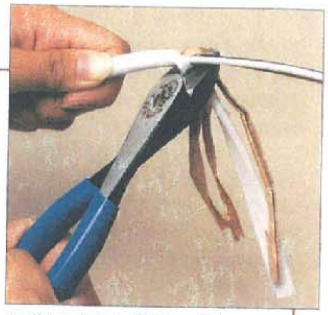
CREATIVE HOMEOWNER®

SMART TIP

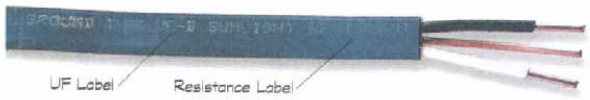
Removing NM Cable Sheathing

To remove the sheathing on NM cable, insert the cable into a cable ripper, and squeeze the cutting point into the flat side of the cable 8 to 10 inches from the end. Pull lengthwise down the center of the cable. Because the center wire is the bare grounding wire, if you accidentally cut too far into the cable you will not be likely to cut into the insulation on the conductor wires. Peel back the thermoplastic sheathing and the paper wrapping; then cut them off using diagonal-cutting pliers or aviation snips.

Use a cable ripper *to slice open the center of the sheathing on NM cable. This will protect the insulated wires from being cut.*



Pull back *8 to 10 in. of the sheathing; then cut away the paper wrapping and excess sheathing, using diagonal cutting pliers or aviation snips.*



Underground feeder and branch-circuit cable *is marked with the letters UF. The label also indicates whether the cable is corrosion- and/or sunlight-resistant.*

Underground Cable

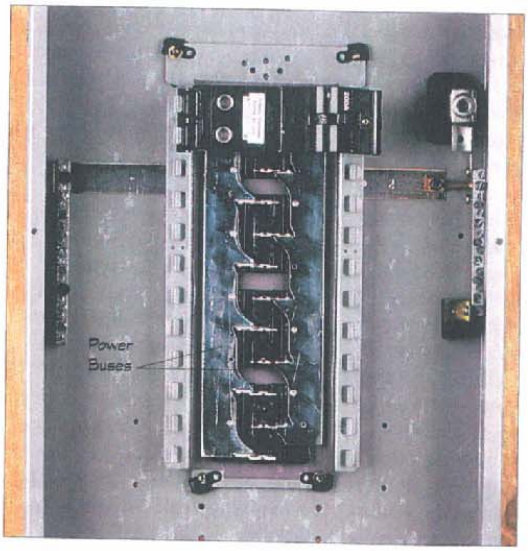
Underground feeder and branch-circuit cable, or UF cable, can be used for interior wiring wherever NM cable is permitted. However, it is primarily approved for wet locations, such as direct burial underground. This kind of cable is suitable for direct burial where type NM cable is not approved for this use. It must be buried 1 foot underground if it is a 120-volt circuit and is GFCI-protected to keep it from damage. If it is not protected by a GFCI or the circuit exceeds 20 amps, bury it at least 2 feet underground. Check local code regarding direct-burial cable before you do any work.

The outer sheathing on UF cable is solid thermoplastic, encasing the inner wires completely. This makes it more difficult to separate the wires from the sheathing, as compared with the wires in standard NM cable. The wires inside UF cable are solid and can be spliced in the same way as standard NM wire, but all splices must be made within a watertight box or with approved splicing devices.

Service Panels

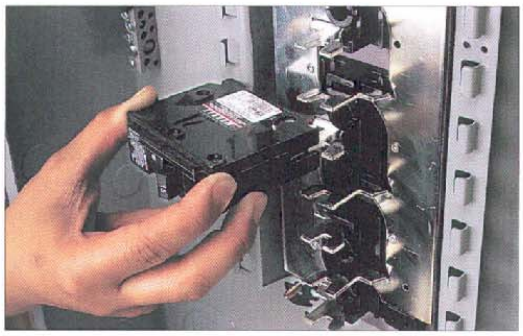
Types and How They Work

The service-entrance panel (SEP) is the main house panel. It serves two primary purposes. First, the main panel is the only location in or outside the house where all electrical power can be cut off at once. Every adult member of your household should know the location of this panel and how to cut the power in case of an emergency. Second, the main panel is the distribution point and protection center for all of the circuits. All the branch circuits, ones that go to the receptacles, switches, and appliances throughout your house, originate here.

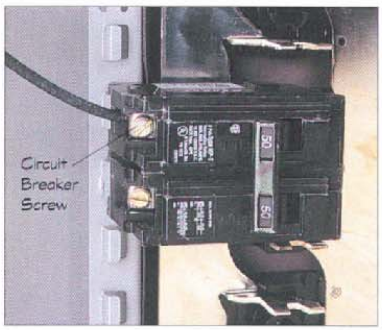


▸ ***The service-entrance, or main, panel*** *is both the entry and distribution point for all the circuits in your home. If the panel cover, breakers, and wires were removed, you would see the two power buses into which all of the circuit breakers are plugged.*

The main breaker *controls power entering the hot buses. Turn off the power by moving the handle to the* OFF *position on the main disconnect. It trips automatically if the circuit shorts or is overloaded.*



To install an individual breaker, *first turn off the main power; then hook the notched end onto the hot bus tab, and snap it firmly in place.*



A circuit's hot wire *is secured beneath a circuit breaker screw. Insert the bare wire end in the terminal hole, and tighten the screw over the wire.*

Under the panel cover, circuit breakers, and wires are two copper or aluminum strips. These are the power buses, called hot buses. Each bus is connected to a hot incoming main cable. The circuit breakers are all plugged into these two buses, which provide the breakers with power. Neutral and grounding wires from each circuit are connected to the aluminum neutral/grounding buses on each side of the hot buses. Dead center in the upper part of the panel is a very large breaker, called the main breaker. This breaker controls all of the house power. Its purpose is to monitor the current being drawn, opening the circuit when there is a short or an overload. It also provides manual control over the house power. When the handle is in the ON position, power is on. If you want power off, simply push the handle to the OFF position. Never forget that the power buses remain hot whenever the handle is in the ON position.

Panel Sizes. A typical house panel may provide 100, 150, or 200 amps. Today, 200 amps is most common, although larger all-electric-power homes may use up to 400 amps. These houses usually have two 200-amp panels. Though the most common service panel for today's homes is 200 amps, it is possible that your home has a smaller panel. The smallest panel permitted by code is 100 amps. Your house's power capacity is noted either on the panel or on the main breaker.

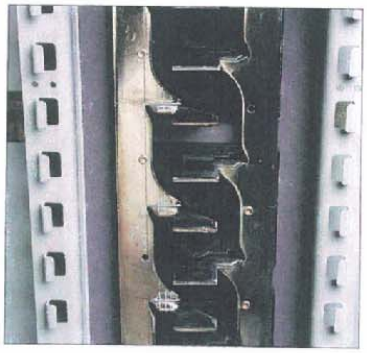
Panels rated for the same maximum current capacity, such as 200 amps, are subdivided by the number of breakers they can hold. The maximum number of breakers a residential panel can hold is 40 breakers plus the main breaker. This type of panel is called a 40/40 panel. It is the proper size panel for 200-ampere residential service. The first number refers to the number of full-size breakers the panel can hold, and the second number refers to the maximum number of breakers the panel can hold regardless of breaker type. The next panel size below a 40/40 is a 30/40 panel. It can hold only 30 full-size breakers. To increase the panel to 40 breakers, half-size breakers must be used. It is preferable to use full-size breakers for safety reasons. The smallest panel size that can fit 40 breakers is a 20/40 panel. Smaller panels may hold a maximum of 20 or 30 breakers. Avoid these panels because they may not have sufficient breaker space to serve the house and aren't likely to provide for future expansion.

Circuit-Breaker Sizes. The individual breakers within the main panel distribute power from the hot buses to individual circuits. Each breaker snaps over an angled tab on one of the hot buses. Once pushed onto the tab (the main panel turned on), the breaker provides power through the wire that is connected to its terminal screw. A standard-tab hot bus will accept only standard full-size breakers; a split-tab hot bus can accept either twin (dual) or half-size breakers. A twin breaker consists of two breakers installed within the space usually occupied by a single breaker.

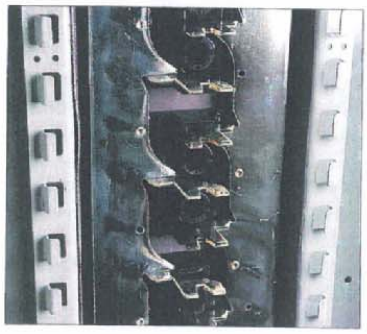
Twin breakers are used when you don't have enough room in a panel for all the breakers you need. New panels physically limit the number of twin breakers that may be used.

Hot Buses

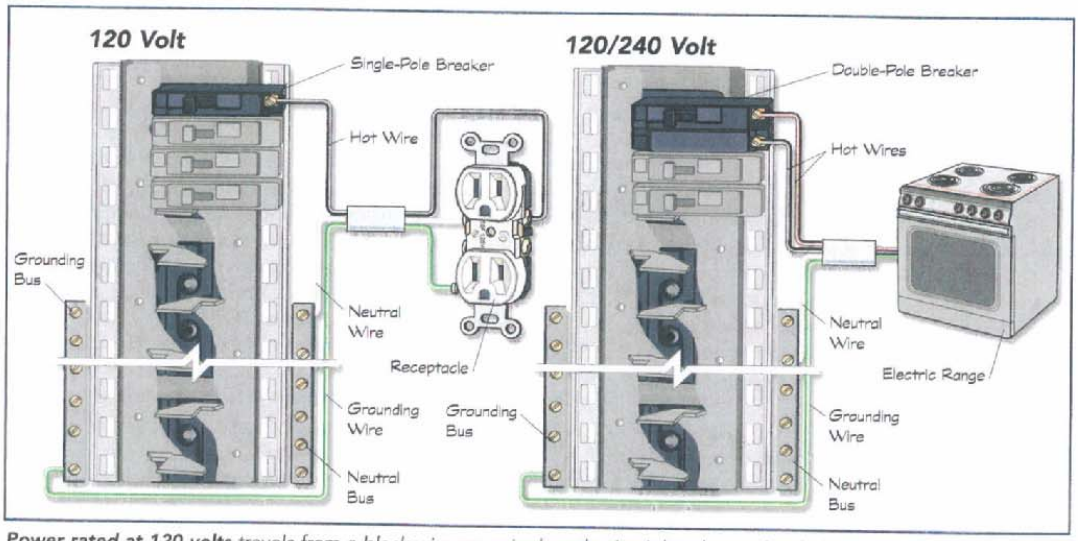
When the main breaker is turned on, electricity flows through the two hot buses, or legs. These two vertical metal strips, normally aluminum or copper, extend below the main breaker to the bottom of the panel. They are electrically isolated (separated) from the panel frame. The voltage between one of the buses and the grounded bar equals 120 volts. The voltage from bus to bus equals 240 volts. This is the same voltage level that comes from the utility transformer. The main breaker acts like an on-off switch. When the breaker is on, power is carried through the circuit breaker that serves the fixture, appliance, etc. If it is a 120-volt light fixture, the current will leave the breaker and go through the black hot wire to the light. It returns through a white wire from the light, directly to the neutral bus. If an appliance requires 240 volts, such as a baseboard heater, then current flows through one side of the double-pole breaker, goes through the heating element, and returns through the other hot wire to the second pole on the breaker. No neutral is required. In either case, if the wire is carrying more current than is safe, the circuit breaker will automatically trip.



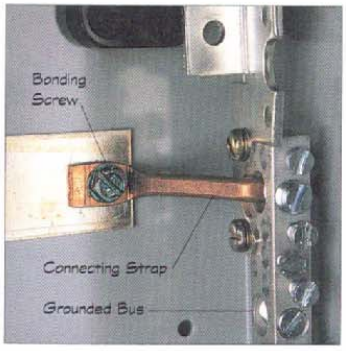
A standard hot-bus tab *will only accommodate a full-size breaker.*



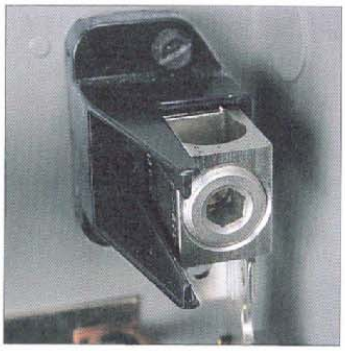
A split tab can *accommodate a twin breaker or a full-size breaker. Do not attempt to fit a twin breaker in a standard hot-bus tab.*



Power rated at 120 volts *travels from a black wire on a single-pole circuit breaker to the device. It returns through a white wire from the device to the neutral bus. In a 120/240 volt circuit, 240-volt power flows from one pole of a double-pole circuit breaker to the appliance and back to the second pole on the breaker. Additionally, 120-volt power that runs the lights, clock, and timer travels through a hot wire and back on a neutral white wire.*



***A panel frame** is usually bonded (connected) to a grounded bus by a short metal strap running between the green bonding screw on the panel and a terminal on the bus.*



***A large lug** on the neutral bus connects the neutral cable from the utility line to the main panel.*

Neutral and Grounding Buses

As mentioned earlier, the two aluminum bus bars running parallel to the hot buses are known as the neutral and grounding buses. All white insulated neutral wires connect to the neutral bus, while all bare or green grounding wires connect to the grounding bus. In the main panel, the NEC also requires that the metal panel frame be connected to the neutral and grounding buses. This is commonly done using a bonding (connecting) screw and strap supplied with the panel box. The strap grounds the panel frame; if a bare hot wire touches it, the breaker will trip, preventing electrocution.

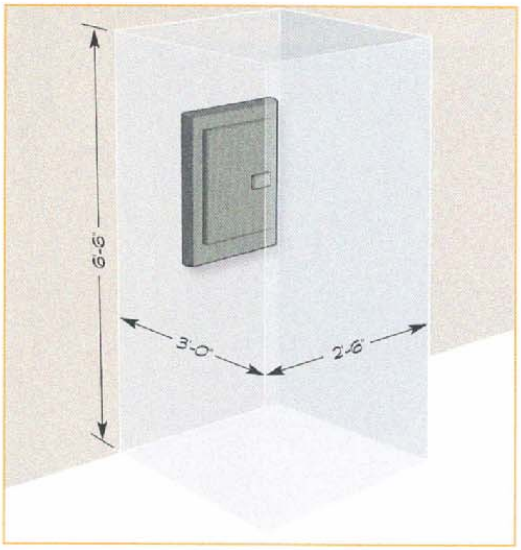
On all 120-volt circuits, when power returns from the device or appliance, it reenters the main panel through a white neutral wire. The white neutral wire is connected to the grounded neutral bus, which is connected to the grounded neutral conductor in the service entrance cable. From here the current returns through the meter to the utility transformer.

The neutral bus contains two large lugs, in addition to the many smaller screw terminals. The neutral service conductor that comes from the meter is connected to the larger lug. The other lug provides a terminal for any neutral conductor that is too large to fit under one of the smaller screws on the bus.

Installation

In new installations, a main panel is mounted back-to-back with the utility meter. This saves the expense of running cable and having to install a second cutoff panel near the meter base, as required by most local codes. Maintain clearances at front of the panel at least 3 feet deep by 2 feet 6 inches wide by 6 feet 6 inches high. The panel must be readily accessible in an emergency.

***Use other large lugs** to connect any neutral wire that is too big to fit into a standard screw terminal.*

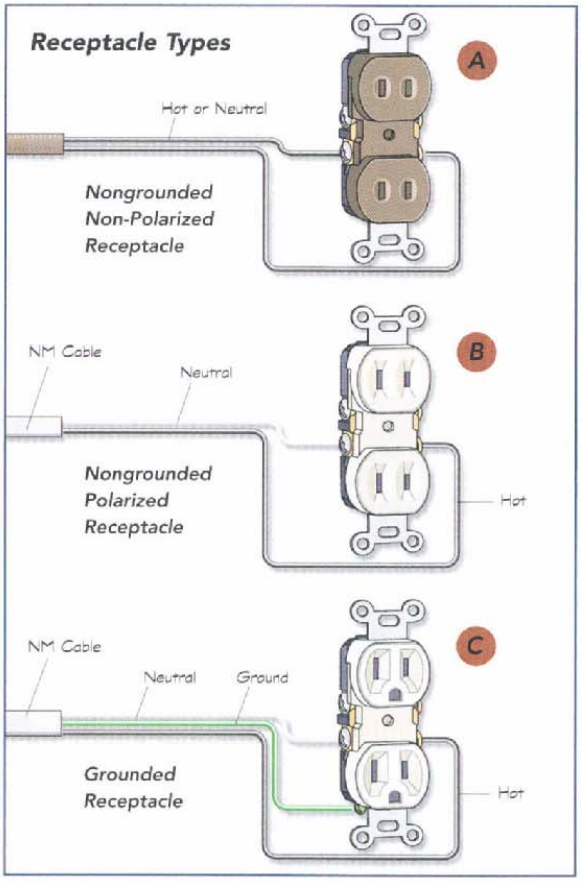


***An area** 3 ft. deep by 2 ft. 6 in. wide by 6 ft. 6 in. high must be kept clear in front of a service panel so that the panel will be readily accessible in an emergency.*

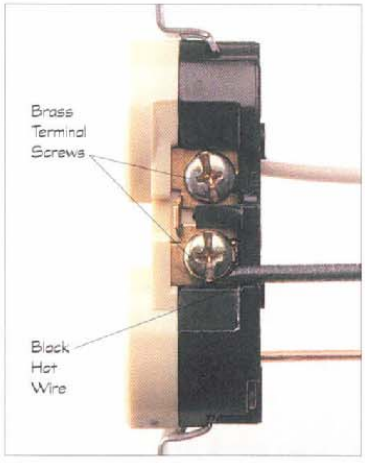
Receptacles

Duplex Receptacles

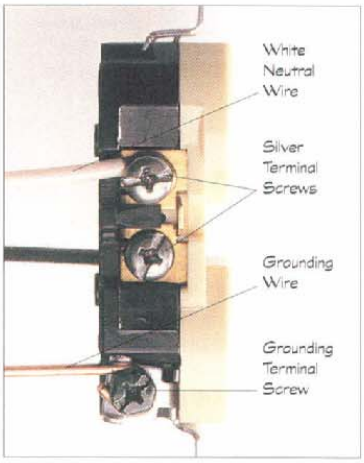
Although there are two basic types of receptacles—single and duplex—only duplex receptacles are commonly found in modern homes. A duplex receptacle accommodates two plugs at the same time. Originally, receptacles were neither grounded nor polarized; later, they became polarized but not grounded. Today, receptacles include a screw terminal for a grounding connection. These receptacles have a total of five terminal screws: two brass screw terminals on the right side for black/red hot-wire connections; two silver screw terminals on the left side for white neutral-wire connections; and one green screw terminal on the left side for a bare copper or green grounding-wire connection. How many wires are connected to a receptacle is determined by whether the connection occurs at the end or in the middle of a wiring run. An end-of-run receptacle will have only one cable entering the box, while a middle-of-run receptacle will have two.



► ***Early receptacles*** *had two nonpolarized connections (**A**). For this type of receptacle, the colored wires could go to either screw terminal. Later, manufacturers made polarized receptacles (**B**). These require that a specific color wire be connected to a specific screw terminal, but they are not grounded. Today, receptacles also include a green grounding screw terminal (**C**).*



◄ ***Receptacle, right side.*** *The hot black or red wires are connected to the brass terminal screws on a receptacle.*



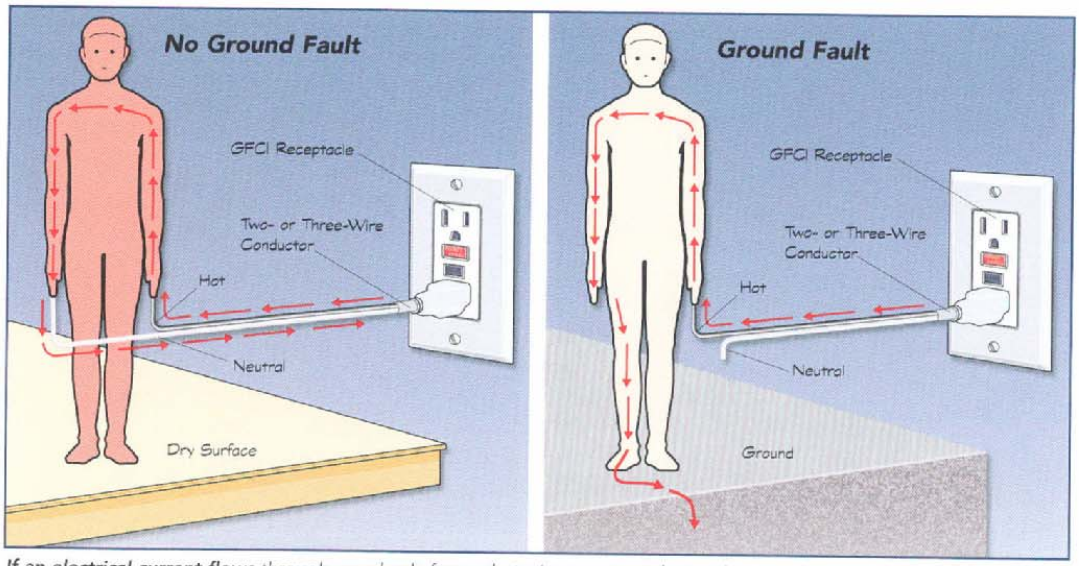
◄ ***Receptacle, left side.*** *The silver terminal screws on a receptacle receive the white neutral wires, while the green terminal screw receives the grounding wire.*

GFCI Receptacles

A ground-fault circuit interrupter (GFCI) is an electrical device that prevents electrocution caused by an accident or equipment malfunction. In a general-purpose, 120-volt household circuit, current moves along two insulated wires—one white and one black. Power is brought to the device or appliance by the black wire and returns from it by the white wire. As long as these two current flows remain equal, then the circuit operates normally and safely. However, if a portion of the return current is missing, or "faulted," a GFCI will immediately open the circuit in ⅛th to ⅙th of a second—25 to 30 times faster than a heartbeat. In this fraction of a second, you may receive a mild pinprick of a shock, rather than the dangerous or potentially lethal shock that would otherwise occur in a circuit without the protection of a ground-fault circuit interrupter.

A GFCI receptacle, however, is not foolproof. For a ground-fault circuit interrupter to succeed, a ground-fault must first occur. This happens when current flows out of the normal circuit to a ground pathway, causing the imbalance between the black and white wires mentioned earlier. In this instance, if you place your body between the black and white wires, and you are not grounded, the GFCI will not function properly because it has no way of distinguishing your body from any other current-drawing device. The number of electrons entering the circuit is equal to the number of electrons returning from the circuit, except that they are passing first through the resistance within your body—causing your heart to go into fibrillation, beating erratically. If your heartbeat is not quickly restored to normal, then you will die. Even if the circuit is connected to a breaker panel, the breaker will not trip unless the internal current exceeds 15 or 20 amps—2,500 times more than is necessary to cause electrocution. A breaker or fuse is only designed to protect your household wiring against excessive current—it is not designed to protect you.

Required GFCI Locations. Even though GFCI circuits are not foolproof, they are nevertheless required in certain locations within a dwelling unit, specified by the NEC (Section 210.8). These locations include, but are not strictly limited to, bathrooms, garages, outbuildings, outdoors, crawl spaces, unfinished basements, kitchens, and wet-bar sinks. A good general rule to follow is that if you are working in a damp or wet environment, then the receptacle you use should be GFCI-protected. If no GFCI receptacle is located nearby, then use an extension cord that has a built-in GFCI.



If an electrical current flows *through your body from a hot wire to a neutral wire, this completes an electrical circuit—just as though you were an appliance or fixture. In this case, a ground-fault circuit interrupter cannot save you from being electrocuted because it cannot distinguish you from your microwave. If you hold only one wire, however, the resulting imbalance in current entering and leaving the circuit will trip the GFCI and protect you from serious shock or electrocution.*

Switches

Single-Pole Switches

An electrical switch controls the flow of power in an electrical circuit. It provides an open circuit in the OFF position and acts as a short, or closed, circuit in the ON position. A switch having two screw terminals is known as a single-pole switch; it can control a circuit from one location only. Most residential switches are single-pole switches. Power is connected to one side of the switch at all times. When the switch is on, electricity flows from the wire attached to the powered screw terminal, through the switch, and into the fixture or appliance wiring connected to the other screw terminal. If the switch is at the end of a circuit, power will flow through the black hot wire and return through the white neutral wire, taped black to classify it as hot. (Neutral current in the white wire equals that in the black wire; in the ON position, either wire can cause an electric shock.) If the switch is in the middle of a run, two black hot wires connect to the switch and the two white neutral wires are spliced together with a wire connector in the switch box. Splice together the bare copper grounding wires, and then pigtail them to the green grounding screw on the switch and in the box, if it is metal.

HOW TO: Wire a Middle-of-Run Single-Pole Switch

Difficulty Level:

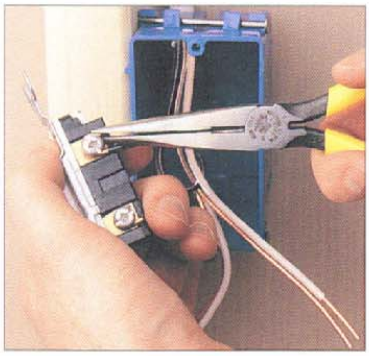
Tools and Materials

**For metal boxes*

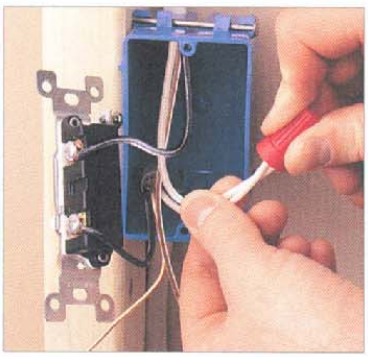
- Insulated screwdriver
- Switch box and switch
- Long-nose pliers
- 12/2G NM cable
- Cable clamps*
- Wire connectors
- Multipurpose tool
- Cable ripper
- Grounding pigtail and screw*

Connect the Switch Hot and Neutral Wires. After you've installed the box, pulled the cable, and stripped the wires, connect the black hot wires to the switch. **(Photo 1)** Loop each wire left to right over the screw terminals to prevent them from unraveling. Splice the white neutral wires in the switch box. **(Photo 2)**

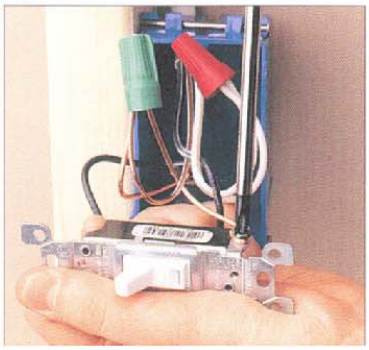
Install and Test the Switch. Splice together the bare copper grounding wires and pigtail them to the green grounding screw on the switch or in the box, if it is metal. **(Photo 3)** Screw the switch into the box, with the ON in the up position, install the cover plate, and turn on the circuit. Test the switch to be sure that it operates the connected fixture. **(Photo 4)**



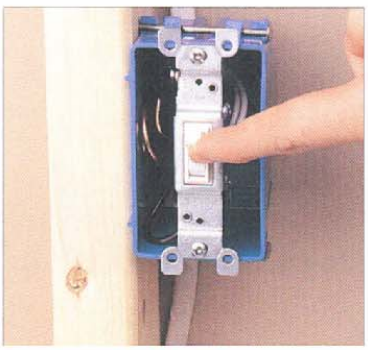
1 *In a middle-of-run switch circuit, connect both of the black hot wires to the screw terminals on the switch.*



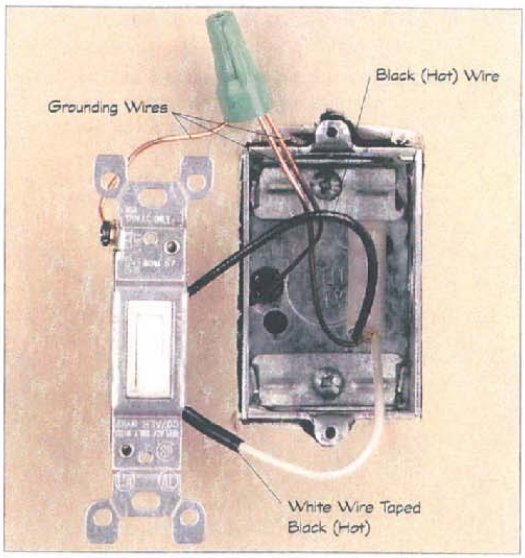
2 *Splice together the white neutral wires in a middle-of-run switch circuit inside the switch box.*



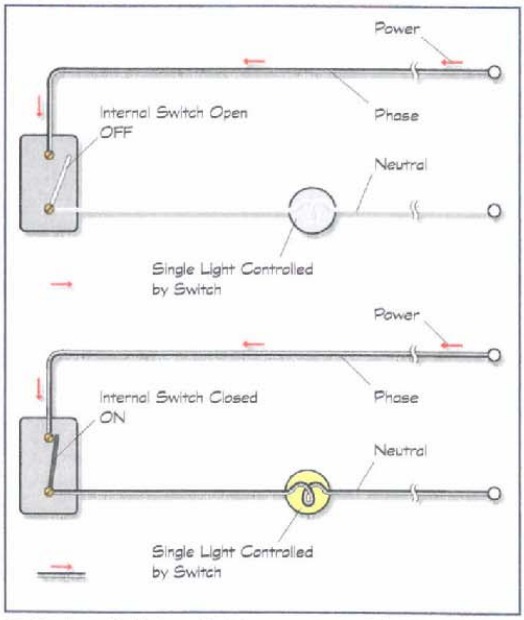
3 *Braid the grounding wires together; then pigtail them to the switch and metal box grounding screw.*



4 *Push the wiring and the switch carefully into the switch box, screw the switch in place; then test the circuit.*



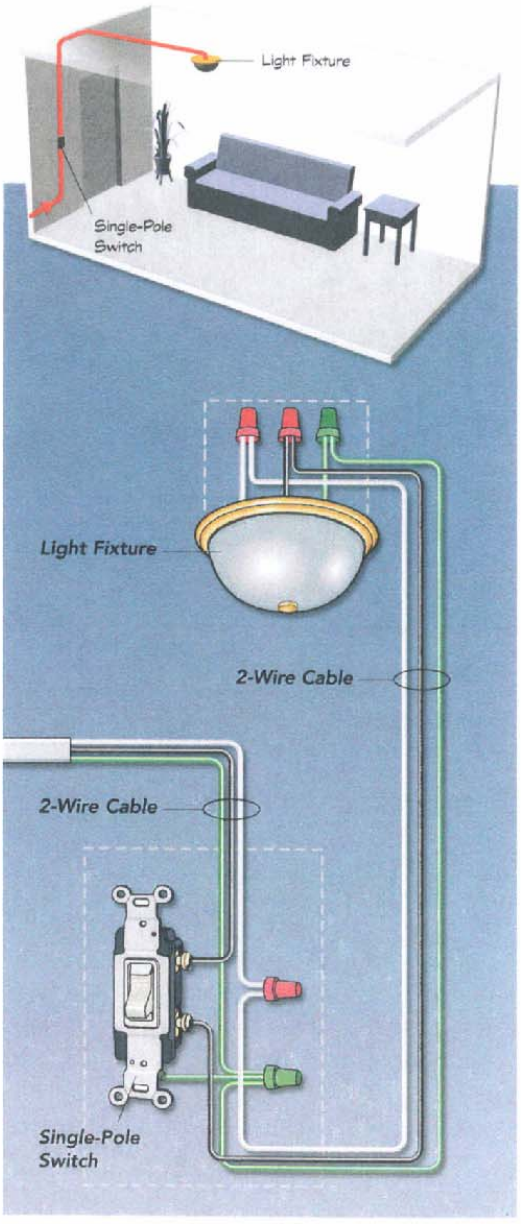
At the end of a circuit, *both the black and white wires connecting to a switch are hot. To indicate this, wrap the white wire with black tape.*



A single-pole light switch *has one operable contact and one fixed contact. In the* OFF *position, the switch is open; in the* ON *position, the switch is closed and the circuit is complete.*

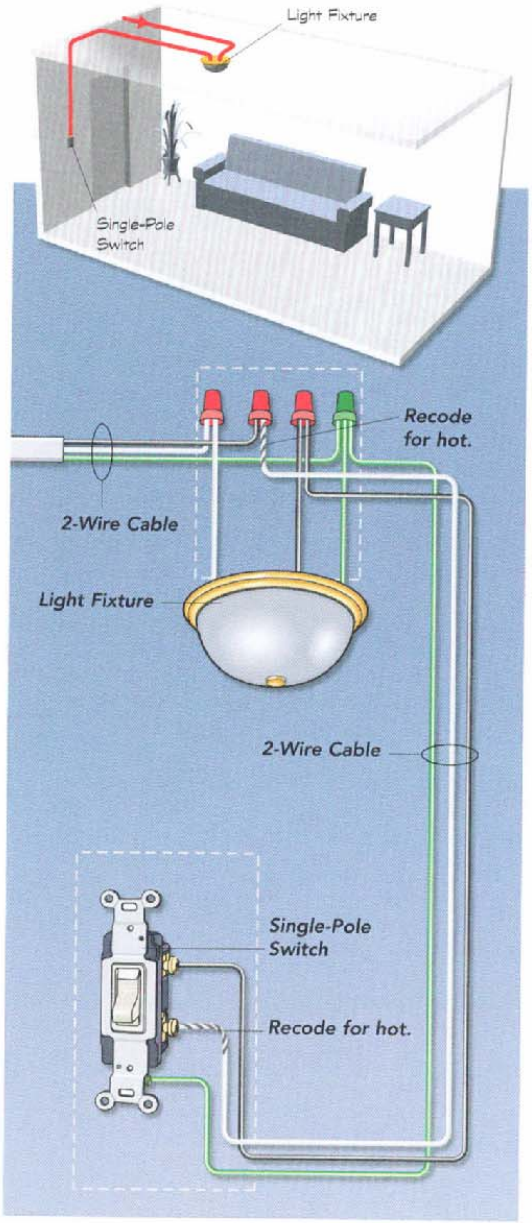
Single-Pole Switch to Light Fixture

In a standard lighting circuit, the power is supplied by a two-wire cable with a grounding wire. In this configuration, the light fixture is located at the end of the cable run.



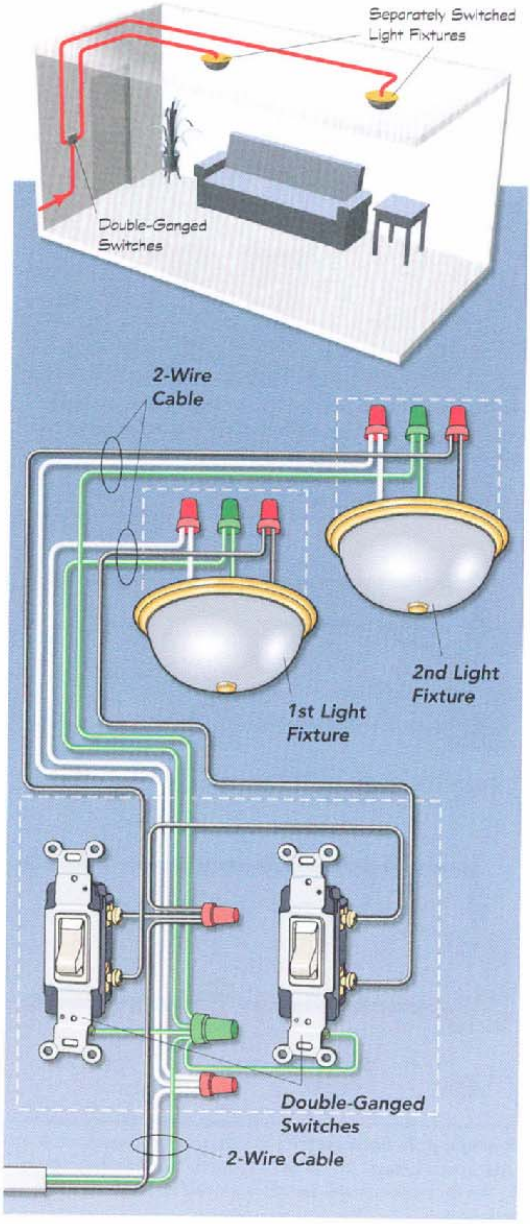
Light Fixture to an End-of-Run Single-Pole Switch

Use two-wire cable to wire a light fixture where the switch comes at the end of the cable run. This configuration is known as a switch loop. Mark the white neutral wire with black tape to indicate that it is hot.



Double-Ganged Switches to End-of-Run Light Fixtures

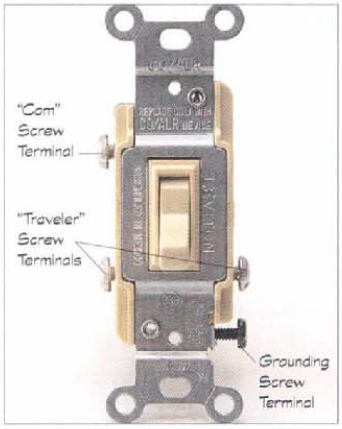
In this setup, power is fed first through the switches and then to the light fixtures. Only two-wire cable is needed for the wiring connections. The switches occupy one double-ganged electrical box.



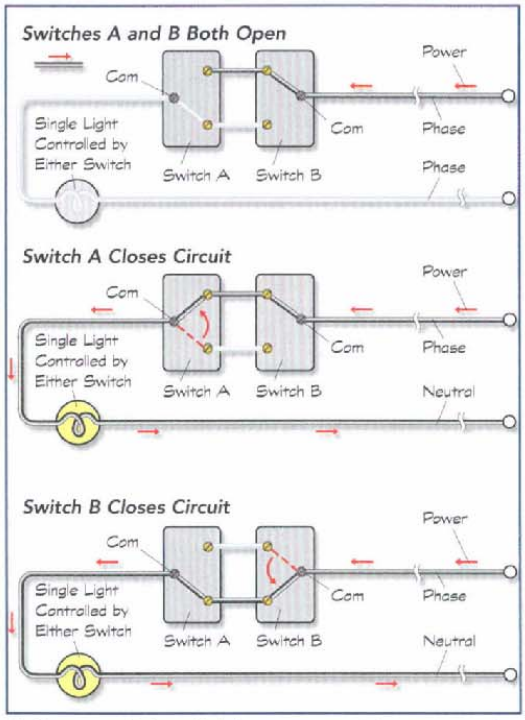
Three-Way Switches

Like a single-pole switch, a three-way switch controls the flow of power in an electrical circuit, but from two different locations instead of just one. This type of switch is useful, for example, when you want to be able to turn on a stairway light from either the top or bottom of the stairway, or a detached garage light from either the house or the garage. Such switching requires special three-conductor or three-way switch cable with ground. This type of cable is usually round, rather than flat like conventional nonmetallic (NM) cable, and it contains an additional, insulated conductor—a red wire.

Three-way switches also differ from single-pole switches in that they have three screw terminals instead of two: a COM terminal (dark screw), and two traveler screws to connect wires that run between switches. The switch also has a grounding screw. The switch does not have either an ON or an OFF marked position because the COM terminal alternates the connection between two different switch locations, allowing either position to potentially close the circuit.



***A three-way switch** has three terminal screws and no ON/OFF positions. The dark colored screw terminal screw is the COM, or common, terminal. The two light screw terminals are switch leads, known as "travelers."*



***A three-way light switch** has one operable contact and two fixed contacts. In the first position, the switch is open; in the second position, the switch is closed and the circuit is completed through switch box A; in the third position, the switch is also closed but the circuit is completed through switch box B.*

You must consider three different cables when wiring a three-way switch: the feeder cable, the fixture cable, and the three-wire cable. The typical wiring method is to run the two-wire hot feeder cable into the first switch box, and then the three-way switch cable between the first and the second switch box. You can then run a second two-wire fixture cable between the second switch box and the fixture box. An alternative method is to run the hot feeder into one switch box; then run the three-way switch cable from the first switch box to the light fixture and then to the second switch box. Either method initially requires that you run the hot feeder to a switch box. It's also possible to run power first to the light fixture, but this method is not preferred because it's more difficult to troubleshoot if there's a problem in the circuit.

HOW TO: Wire a Three-Way Switch

Difficulty Level:

Tools and Materials

- Insulated screwdriver
- Switch boxes
- Wire connectors
- Two-wire cable
- Wire stripper
- Cable ripper
- Long-nose pliers
- Three-way switches
- Cable clamps
- Three-way switch cable
- Copper wire
- Diagonal-cutting pliers
- Multipurpose tool (optional)

A note from your instructor:

In our efforts to give class attendees the best practical experience possible within the time given, it will be important to review and understand the theories and practices you learned in Basic Electrical Skills. Break out those notes and handouts and get yourself back up to speed. If it's been awhile or you are coming into Intermediate Electrical Skills without having attended Basic, you can use the links and handouts indicated below to understand:

- Magnetism www.howstuffworks.com/electromagnet1.htm
- DC and AC Electricity www.howstuffworks.com/electricity.htm
- AC generation http://micro.magnet.fsu.edu/electromag/java/generator/ac.html
- Electrical Units http://science.howstuffworks.com/question501.htm
- Ohms Law Calculations www.the12volt.com/ohm/ohmslaw.asp
- Basic Electrical Circuits www.play-hookey.com/dc_theory/basic_circuit.html
- Basic Wiring Materials (handout)
- Basic Wiring Connection Methods (handout)
- Lockout/Tagout http://ehs.sc.edu/modules/Lockout%20Tagout/loto_intro.htm
- Multimeters http://mechatronics.mech.northwestern.edu/design_ref/tools/multimeter.html
- Basic Troubleshooting www.thecircuitdetective.com/tsing.htm

Note : The websites noted are just a few of many excellent sources available. Many are great starting points for cybersurfing more info…

We will be briefly reviewing Theory and Practices in class as we move into the new territories ahead. Safety is our prime objective and will rely on your existing knowledge of Basic Skills…

Looking forward to working with all of you,
Lawrence Ross
(aka Sparky Ohmz)

INTERMEDIATE ELECTRICAL SKILLS

PRE-TRAINING ASSIGNMENT

A working knowledge of basic wiring practices is necessary for satisfactory performance in this training program. The pre-training assignment has been developed to maximize your training experience by providing a review of materials covered in the introductory level "Basic Electrical" training program.

Completion of the pre-training assignment will require the attached Study Guide. Completion of the pre-training assignment and bringing the proper Personal Protective Equipment to the class is mandatory and will count for 20% of your program grade.

Complete the following:

1. Discuss the Intermediate Electrical Skills program agenda and objectives with your supervisor.

2. Use all resources given (websites, text, scanned pages) as well as your experience to answer the questions on the following pages. Print these questions out, write in your answers and have them with you the first day of class.

The answer sheet will be collected by the instructor during registration.

If you have any questions or need help, call the Program Coordinator, Chuck Combs at (831) 649-7124. He will be happy to offer suggestions.

INTRODUCTION TO ELECTRICAL CODES

All work performed on facilities within the California State Park System must comply with State law. Two bodies of law that directly affect maintenance workers performing electrical wiring projects are the California Electric Code and the Public Resources Code.

The California Electric Code is included in Title 24 of the California Administrative Code. The California Electric Code is based on the National Electric Code and is the electrical standard for all state owned buildings. Because Title 24 adopts many portions of the NEC by numerical reference, it is necessary to refer to both Title 24 and the NEC whenever modifying or constructing a park structure. The code requirements in Title 24 are not suggestions, they are law, and must be fully obeyed. Title 24, and the National Electric Code should be available in your unit's maintenance library.

The Public Resources Code gives the Department of Parks and Recreation responsibility for preserving California's irreplaceable natural and cultural resources. Two processes which help the maintenance worker fulfill that responsibility are commonly referred to as "CEQA" and "5024". CEQA stands for California Environmental Quality Act which essentially says that nothing will be done on public property to adversely affect the environment. 5024 refers to a section of the Public Resources Code which, briefly stated, says that nothing will be done to alter the character of historic structures.

The Department of Parks and Recreation has developed policies based on CEQA and 5024 which can be found in the Resource Management chapter of the Departmental Operations Manual. The Maintenance Chief is generally responsible to see that the CEQA or 5024 requirements have been met before work begins. When in doubt, however, ask! The Public Resources Code and Departmental Operations Manual should be available in your unit's maintenance library.

Reading Assignment: Title 24,
Introduction to the California Building Code

Departmental Operations Manual:
Resource Management Chapter,
Sections 1600 - 1622, and 1631

Departmental Notice No. 81-25,
Historic Preservation Policy

1. _____ is based on the National Electric Code and is the electrical standard for all state owned buildings.

2. _____ stands for California Environmental Quality Act and basically says that nothing will be done that will adversely affect the environment.

3. _____ basically interpreted to says that nothing will be done to alter the character of historic structures.

4. The code requirements in Title 24 are not suggestions, they are _____, and must be fully obeyed.

INTRODUCTION TO ELECTRICAL CIRCUITS

Many training books make the traditional comparison of flowing electricity to flowing water. Although the comparison isn't exact, electricity does have some similarities to water flowing through a plumbing system.

Water moves through a pipe because the pressure at one end of the pipe is greater than the pressure at the other end. Pressure is created in the system by drawing water from the earth with a pump and forcing it into the pipe. Even though the water in the pipe is pressurized, no water flows until the faucet at the other end is opened. When the faucet is opened, a path is created for the water to escape the pressure in the pipe and return to the earth.

In electrical distribution systems electricity flows because an energy source creates a "difference in potential" between the source and “ground” or earth. The difference in potential is the "pressure" in an electrical system. Because the difference in potential is measured in volts, it is commonly referred to as "voltage".

Just as water will not flow until a faucet is opened, electricity will not flow until a path is created to conduct it back to earth, or "ground". The flow of electricity is called "current" and is measured in amperes, or "amps". As water flows through a pipe it encounters resistance due to friction. Electrical current also encounters resistance as it moves through the circuit. Electrical resistance is measured in Ohms.

As moving water can be used to perform work by directing it through a water wheel during it's return to the earth, electricity can be used to perform work by conducting it through a "load" on it's trip to ground. The measure of work done by electricity passing through a load is measured in "watts".

When discussing water distribution systems, we generally think of moving water from one place to another. With DC (Direct Current) electrical systems, we must think of moving electricity in a circle, or loop, which begins and ends at the source. A good visual for this is a circular saw blade The electrical path from the voltage source, through a load, and back to earth/ground through conductors such as wire is called a "circuit loop", or simply, a "circuit". In AC (Alternating Current) systems this movement of electricity acts more like a jigsaw, reversing it’s direction many times per second but able perform work both directions through a circuit. When a circuit is continuous and uninterrupted, it is said to have "continuity".

5. In an electrical system the "pressure", or "difference in potential", is measured in _____ and is commonly referred to as _____.

6. The flow of electricity, or current, is measured in _____.

7. Work done by electricity passing through a load is measured in "_____".

8. When a circuit is continuous and uninterrupted, it is said to have "_____".

ELECTRICAL SAFETY

The single most important thing to consider in electrical wiring is safety. Electrical accidents occur relatively infrequently, but when they do occur they often result in serious injury or death. Although your supervisor or project lead person is responsible for identifying special precautions to be taken when working with electricity, the responsibility for safety ultimately rests with you, the person actually doing the work.

Title 8 of the California Administrative Code sets minimum standards of safety for all phases of industrial activity, including an entire chapter devoted to electrical safety. Article 3, Section 2320.1(a) of the Electrical Safety Orders states that "only qualified persons shall work on electrical equipment or systems". The safety orders in Title 8 are not suggestions, they are law, and must be fully obeyed. Before undertaking any electrical project, know what you're doing! Check the safety orders in Title 8. They should be available in your unit's maintenance library.

Reading Assignment: Electrical Safety Orders,
Pages 305-306 (Sections 2320-2340.16)
http://www.dir.ca.gov/Title8/sub5.html

Departmental Administration Manual:
Safety Chapter,
Sections 1215.3 & 1230.2 - 1230.5

9. Under the Department's Injury and Illness Prevention Program, all employees are expected to work together to implement the Department's District/Section Programs; and to identify and eliminate conditions and practices that reduce the benefits of a safe and healthy work environment.

10. To meet this responsibility, each employee must report any unsafe job _____, _____,_____, or _____ to the supervisor.

11. Title 8 of the _____ _____ _____ sets minimum standards of safety for all phases of industrial activity.

12. The safety orders in Title 8 are not suggestions, they are _____.

13. When a cord is poorly connected to it's plug, it may _____.

14. It is important to remember that electricity can return to the source through any conducting body - including _____.

15. The first rule of working with electricity, after any needed live testing, is to _____ _____ the power.

16. Before starting any repair work, kill the circuit at the _____ _____.
17. Padlock the circuit breaker in the "open" (OFF) position whenever possible. Which authority must be complied with? _____.

18. The final step before starting work is to _____ the circuit to make sure it is actually dead.

19. Even after the main panel breaker has been opened, there is still power from the utility company to the panel. When a circuit breaker is opened to kill a circuit, there is still power to the bus bars and other _____.

INTRODUCTION TO ELECTRICAL SYSTEMS

A building's AC electrical system is simply several individual circuits which share a common voltage source. Sometimes all circuits originate at a metered panel. In larger systems metered main panels feed subpanels or “loadcenters” located closer to the loads. The key to understanding these systems is to focus on one circuit at a time The voltage source for any circuit begins at one of the panel "hot" bus bars, is directed to the circuit through the circuit breaker and can be travel back and forth through the load and white “grounded” wire wich is connected to ground.

Many older installations only used a two-wire “hot and “neutral/grounded” system. In modern installations, however, there is a third wire. This third wire is a green or bare "ground" or “grounding” wire which is installed to reduce the possibility of electric shock when using electrical appliances. Should a current carrying wire come into contact with an appliance case (short circuit to ground), the ground wire will provide a current path which is lower in resistance than a human body. Since electricity will always follow the path of least resistance, the current will return to ground through the ground wire, instead of a person touching the appliance.

When electricity finds a path to the source without traveling through the entire circuit loop, it is referred to as a "short circuit". Short circuits allow current to flow at a high rate resulting in excessive heat build-up and circuit failure. Short circuits can cause fires, equipment damage, and personal injury.

Subpanels in older installations allowed combining white and ground wires to a single grounded bar. The current code requires a separate grounding bar to be installed in the circuit breaker panel and prohibits using the insulated "neutral" bar as the system ground. The grounding bar allows every appliance and device to be connected directly to the building ground.

Recent code changes have changed the way some common terms can be used. We wil be discussing differences between the terms “neutral” , “grounded” and “grounding” conductors in class.

20. If a current carrying wire short circuits to ground, the _____ _____ will provide a current path which is lower in resistance than a human body.

21. Electricity will always follow the path of _____ resistance.

22. Short circuits allow current to flow at a high rate, resulting in excessive _____ build-up.

23. Short circuits can cause fires, equipment damage, and _____ _____.

24. Current code does not allow the "_____" bar to be used as a ground.

25. The symbol for a duplex receptacle is _____.

26. The symbol for a ceiling light is _____ or _____.

27. The symbol for a single-pole switch is _____.

WIRING TECHNIQUES

Switches are a simple way to control circuits. When installing switches code requires that you only switch “hot” wires. This is to prevent anyone getting injured while working on the circuit. If white wires were mistakenly used to switch the circuit, the circuit would be interrupted but it would not disconnect the load from the circuit breaker.

When electric current flows through a circuit it encounters resistance and generates heat. As the temperature of a conductor rises, it's resistance to the flow of electrical current increases. If any component of the circuit is unable to dissipate the heat rapidly enough, the component will fail. Electrical engineers have determined the rate at which electrical devices and conductors are able to dissipate heat in a variety of applications. This information is expressed by the electric code in terms of safe wiring practices, such as the

maximum amperage allowed for a specific conductor, or the maximum number of wires allowed in a box.

Poor wiring practices can result in damaged components, loose connections, and circuit overloading. These conditions greatly increase resistance and generate excessive amounts of heat. When wiring electrical circuits, it is imperative for the electrician to comply with all code requirements and to be constantly alert for conditions which may cause fire or injury. Code requires 6 to 8 inches of wire to work with at devices to guaranty ample working material. Doing such simple things as using an “underwriters knot” to prevent cords from pulling out of their plugs or “tinning” fine stranded wire with solder greatly improves connections, reliability and safety.

28. A poor electrical connection will generate excessive amounts of _____.

29. If an electrical component is unable to dissipate heat rapidly enough, the component will _____.

30. Switches are installed only in _____ wires.
31. A switch in the _____ wire swould also interrupt a circuit, but it would not disconnect the device from the circuit breaker.

32. Wires that are black, red, or any color other than white, gray, or green, are always _____.

33. A white wire in a switch or fixture box which has had the end taped or painted black is a _____ wire.

34. When making a wire-to-screw-terminal connection, hook the wire _____ round the screw terminal.

35. _____ stranded wire improves connections.

36. A single pole switch has _____ terminals of the same color.

37. Three-way switches have three terminals: two brass or silver colored terminals and a third "odd" colored terminal, called the _____ terminal.

38. _____ to _____ inches of wire must be left in each box to allow easy wiring of switches, receptacles, etc.

39. Maintain at least _____ inches of clearance in front of any panel.

40. Receptacles have three different colors of screw terminals. The _____ colored screws are hot terminals.

41. _____ colored screws are neutral/grounded terminals.

42. Grounding systems must have a resistance of not more than _____.

43. Only devices identified by the letters CO-ALR may be used with aluminum wiring. Backwiring _____ allowed with aluminum wire.

44. Ampacity refers to the current carrying capacity of a conductor. According to the ampacity tables for insulated copper conductors, the smallest wire size approved for carrying 15 amps is #_____.

45. Circuit breakers must have _____ampacity rating than the conductors they protect.

46. Ground fault circuit interrupters are required whenever a receptacle is located in a damp location. GFCI's open _____to _____ times faster than a heartbeat.

REPAIRS

Most repairs will consist of replacing fuses, circuit breakers, switches, receptacles, light fixtures, cords, and plugs. Many of these devices can be tested with your continuity or voltage tester. After any required testing remember to open the circuit by turning off the circuit breaker or removing the fuse. Don't forget to "lock out" the circuit. Also, remember that turning off a circuit breaker does not turn off the power to the bus or other breakers.

If you must replace a cartridge type fuse, open the switch before opening the fuse enclosure. Opening the knife switch does not turn off the power on the "source" side of the fuse holder. To avoid injury, remove the fuse with a "fuse puller". After removing the fuse from the fuse holder, use your continuity tester to determine if the fuse removed is "blown". If the buzzer sounds when the tester leads are touched to the fuse ends, the fuse is still good. The fuse has "blown" if the buzzer is quiet. Good fuses will sometimes blow when the switch is returned to the closed position. When cartridge fuses blow, they have been known to blow molten metal through the cartridge case. Protect yourself. Close the enclosure before turning the switch back on.

Switches can be easily tested with a continuity tester. After turning off the power, clip the continuity tester leads to the switch terminals. Turning the switch on and off should cause the buzzer to sound, and then be silent. If this does not happen, replace the switch. WARNING: Open the lighting circuit by turning off the circuit breaker or removing the fuse at the distribution panel. Turning off the switch will not turn off the power to the circuit.

47. An _____ knot is used to prevent a cord from being accidentally pulled out of its plug.

48. The black wire is always connected to the _____ colored plug screw terminal.

49. A _____ tester is never used on a live ("hot") circuit.

50. Turning off a circuit breaker _____ turn off the power to the bus.

Name (please print): _____

District: _____

INTERMEDIATE ELECTRICAL SKILLS
TOOL AND EQUIPMENT CHECKLIST

Participants in Intermediate Electrical Skills are required to safely use the tools and equipment items listed below. Either the participant's supervisor, or supervisor's designee, must validate that the participant has demonstrated acceptable proficiency in the use of these items. The participant must read the owners manual and be instructed in the care and operation of each item before being asked to operate the equipment. To validate that the training was accomplished, the supervisor must note the date and approximate time spent demonstrating each item.

Tool	Date	Time	Initials
Circular saw (worm drive or “sidewinder”)			
Electric drill, with 1/2” chuck or larger and gear reduction (“Hole Hawg”)			
Reciprocating saw (Sawsall)			

Supervisor (print and sign): _____

INTERMEDIATE ELECTRICAL SKILLS-EXPECTATIONS

Supervisor

After completing this training program I expect the participant to be able to:

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Participant

After completing this training program I need to be able to:

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Participant Name & District (print): _____

Supervisor (print & sign) _____

INTERMEDIATE ELECTRICAL SKILLS
ANSWER SHEET

1. _____
2. _____
3. _____
4. _____
5. _____ _____
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