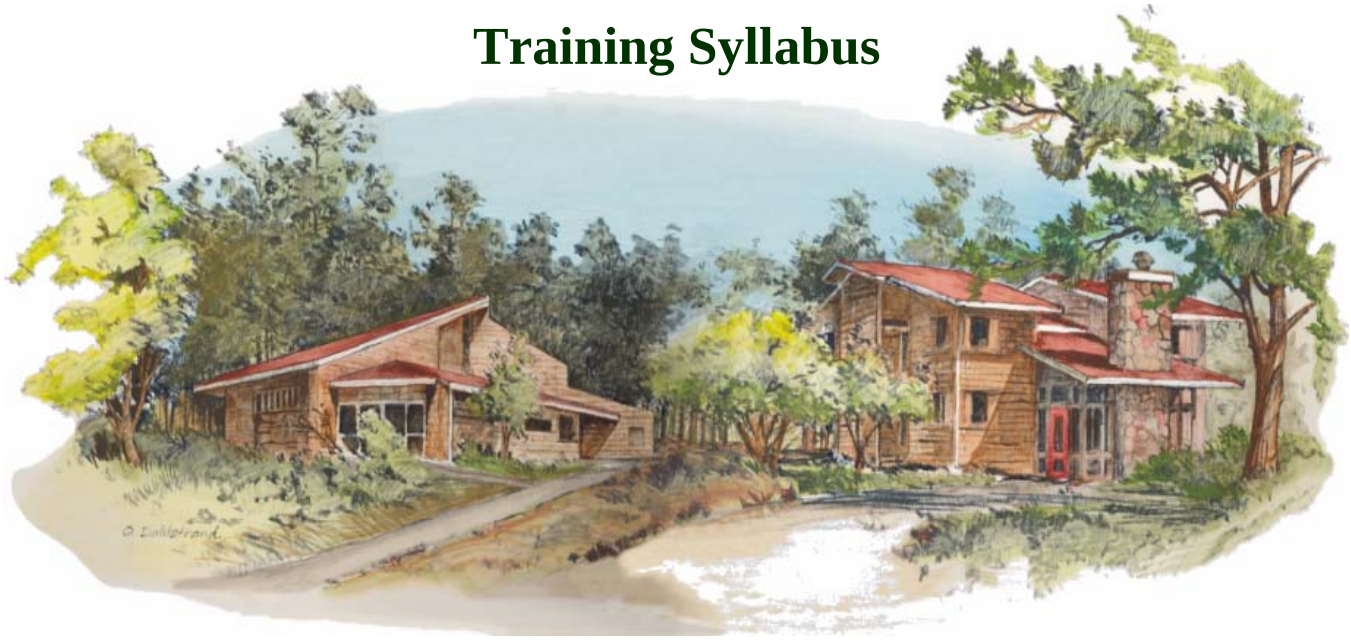
State of California . The Resources Agency . Department of Parks and Recreation

BASIC ELECTRICAL SKILLS

November 12-17, 2006

Training Syllabus



William Penn Mott Jr. Training Center

State of California

M e m o r a n d u m

Date: October 18, 2006

To: Supervisor

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

Subject: Employee Attendance at Formal Training
Basic Electrical Skills Group 17

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 the supervisor 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 login 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.

Broc E. Stenman
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

Broc Stenman .....Department Training Officer
Michael Green..... Assistant 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.

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 Basic Electrical Skills Program Syllabus prior to your arrival at the Training Center.

_____2. Complete the following pre-training assignments:

- ❑ Review and complete the Basic Electrical Skills pre-training assignment and the excerpts from *"Ultimate Guide to Wiring"* included with your syllabus. Bring them with you to training.
- ❑ Discuss the Basic Electrical Skills program with your supervisor. What specific changes in your abilities and performance are expected to result from your attending this training? List these expectations along with your own under "Expectations" on the back of the "Equipment Check Sheet."
- ❑ If possible, bring with you a hand held, 120VAC, ≤ 15 amp., portable power tool with a cord set that is in need of repair/replacement. We will use these tools for our small appliance repair segment of the training and attempt to return them to a safe operable condition.
- ❑ 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 (Equipment Check Sheet and Expectations) will be collected during the program orientation on **November 13, 2006**. Completion of the pre-training assignment and bringing your personal safety gear is mandatory and will count for 20% of your program grade. If you have questions or need help, contact the Program Coordinator, Chuck Combs at (831) 649-7124 or email **chuck@parks.ca.gov**.

____3. Remember to bring the following with you to training:

- ❑ Program syllabus and workbook.
- ❑ Personal safety equipment (eye, ear, and hand protection).
- ❑ Coveralls or appropriate work clothing.
- ❑ Proper field uniform, see Formal Training Guidelines #7.
- ❑ Coffee cup, pens, pencils.

POST-TRAINING ASSIGNMENT

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.

BASIC ELECTRICAL SKILLS GROUP 17 – Agenda – November 12-17, 2006

Assistant Program Coordinators: Anthony Galvez and Jeff Beach

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		
November 12		
1500-	REGISTRATION: *Check in at the Asilomar Administration Building.*	All
Monday		
November 13		
0830-0930	Orientation/MPC Registration/Pre-Training Check In	Combs
0930-1030	Expectations/Introduction to Electrical Circuits	Ross/Fridrich
1030-1100	Electrical Theory	Dall
1100-1200	ADA	Bielecki
1200-1230	Lunch	
1230-1400	Wiring Project (Continuity Tester/Wiring Station)	Fridrich/Ross
1400-1600	Introduction to Electrical Systems	Dall
1600-1630	Electrical Materials	Ross/Dall
Tuesday		
November 14		
0830-0930	Quiz	Ross/Fridrich
0930-1100	Residential Wiring Techniques	Dall
1100-1200	Buy Recycle	Livingstone
1200-1230	Lunch	
1230-1330	Wiring Project Demonstration	Fridrich/ Ross
1330-1530	Wiring Project (Lab)	All
1530-1630	Study Guide Session	All

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Wednesday
November 15

0830-0930	Quiz	Ross/Fridrich
0930-1200	Wiring Project (Lab)	All
1200-1230	Lunch	
1230-1530	Wiring Project (Lab)	All
1530-1630	Study Guide Review	All

Thursday
November 16

0830-0930	Quiz	Ross/Fridrich
0930-1200	Wiring Project Group Application (Lab)	All
1200-1230	Lunch	
1230-1430	Small Appliance Repair	Ross/Fridrich
1430-1630	Performance (Practical) Exam	All

Friday
November 17

0830-0930	Final Exam	Ross/Fridrich
0930-1030	Exam Review	All
1030-1130	Material Handling and Storage	Ross/Fridrich
1130-1230	Program Summary and Evaluation	Combs
1230-	Lunch & Departure	All

TRAINING PROGRAM: BASIC ELECTRICAL SKILLS **36 HOURS**

Program Outline	Total Hours
Program Orientation and Overview	1.0
Electrical Systems	4.5
Electrical Wiring	10.0
Examination & Labs	20.0
Program Summary and Evaluation	0.5
Total Hours	36.0

BASIC ELECTRICAL SKILLS

PROGRAM ORIENTATION

Purpose: Participants will meet one another and the program coordinator and facilitator. 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.

INTRODUCTION TO ELECTRICAL CIRCUITS

Purpose: To develop an understanding of electrical circuits and systems which will enable the park maintenance worker to safely repair park structures and small appliances.

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

1. Identify the basic components of typical residential electrical systems.
2. Know the function of components in a typical residential electrical system.
3. Demonstrate safe working practices when working with electricity.

INTRODUCTION TO WIRING

Purpose: To familiarize park maintenance workers with the materials, tools, and techniques used in residential electrical circuits and small appliance wiring.

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

1. Recognize electrical devices and loads commonly found in residential electrical circuits.
2. Know the correct use of electrical tools and test equipment.
3. Identify the correct application of electrical materials.

SHOP APPLICATIONS

Purpose: To provide the participant with hands-on instruction and opportunity to practice acquired electrical knowledge and skills.

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

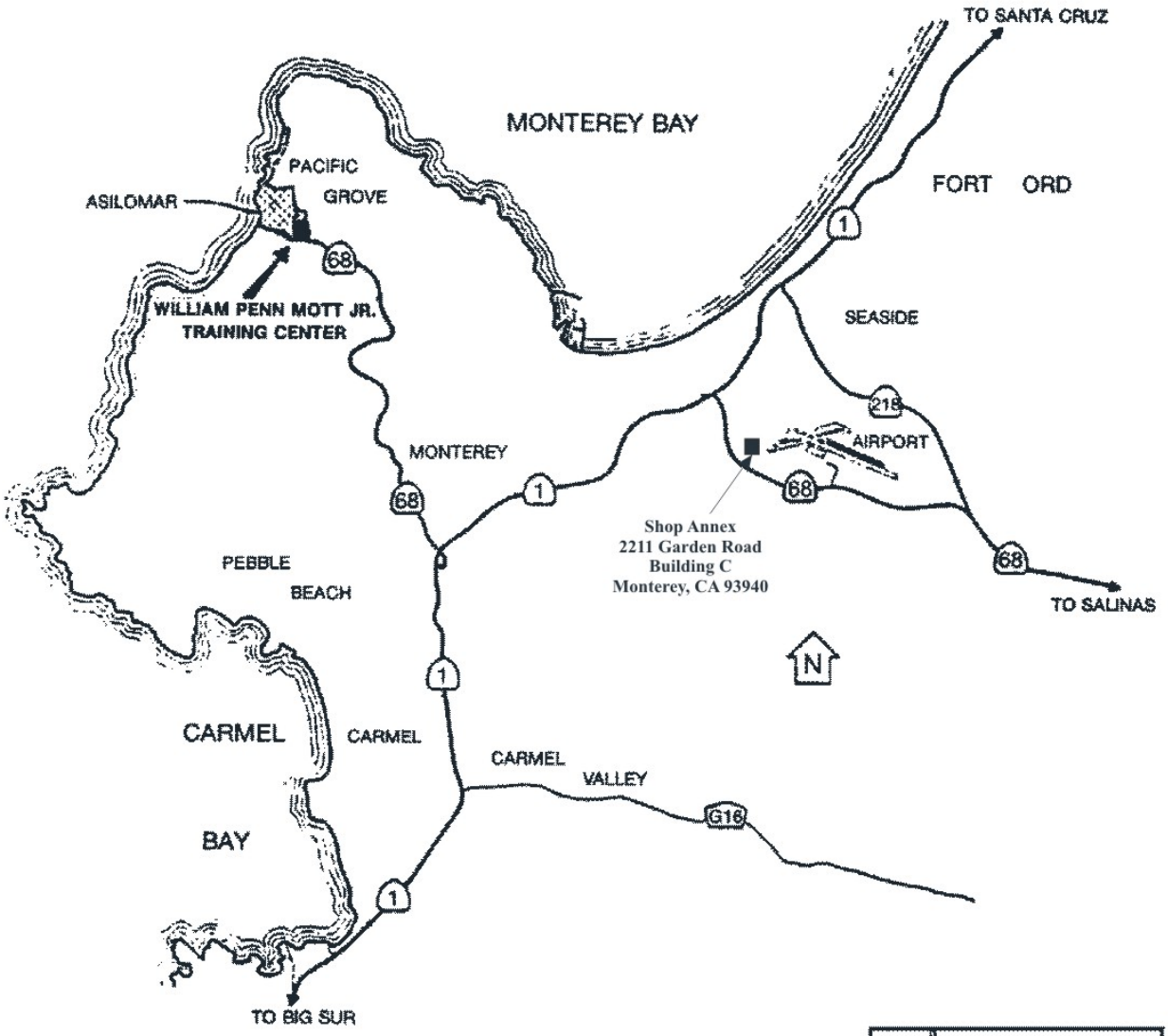
1. Perform basic troubleshooting on residential electrical systems and small appliances.

2. Make basic repairs to residential electrical systems and small appliances.

3. Demonstrate the ability to work effectively, safely and harmoniously with other class participants in a simulated work environment.

location map for

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



Name (please print): _____

District: _____

DUE DATE: November 13, 2006

BASIC ELECTRICAL SKILLS
TOOL AND EQUIPMENT CHECKLIST

Participants in Basic 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	Initial's
Electric soldering gun or iron			
Half inch whole Hawg/right angle			

Supervisor (print and sign): _____

BASIC 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) _____

BASIC ELECTRICAL SKILLS
ANSWER SHEET

1. _____
2. _____
3. _____
4. _____
5. _____ _____
6. _____
7. _____ _____
8. _____ _____
9. _____
10. _____ _____
11. _____
12. _____
13. _____ _____
14. _____ _____
15. _____ _____ _____ _____
16. _____
17. _____
18. _____ _____
19. _____
20. _____
21. _____
22. _____ _____
23. _____

24. _____ _____

25. _____ _____ _____

_____

26. _____

27. _____ _____

28. _____

29. _____ _____ _____

30. _____

31. _____ _____ _____

_____

32. _____

33. _____

34. _____ _____

35. _____

36. _____

37. _____

38. _____

39. _____ _____ _____

_____ _____ _____

_____ _____

40. _____ _____

41. _____ _____

42. _____ _____

43. _____

44. _____

45. _____

46. _____

47. _____

48. _____

49. _____ _____

50. _____ _____ _____

_____ _____

51. _____ _____ _____

52. _____ _____

53. _____ _____

54. _____

55. _____ _____ _____

56. _____

57. _____

BASIC 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 structured 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 is mandatory and will count for 20% of your program grade.

Complete the following:

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

2. Read the course material contained in the workbook. At the end of the introduction, you will find a series of study questions. Answer the questions on both the workbook and the answer sheet.

The instructor will collect the answer sheet during registration on the first day of class.

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

Included Excerpts from
Ultimate Guide to Wiring

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.

5. An _____, or _____, measures the rate, or quantity, of electrical flow.

6. A _____ measures the pressure exerted by electrical power

7. The _____ rating of a circuit is the amount of _____ the circuit can deliver safely.

8. Electrical _____, measured in _____ restricts the flow of current.

9. The “MAX” ampacity that a 12 gauge cooper wire may carry is _____ amps.

10. _____ current flow can be defined as the flow of _____ through a conductor.

11. _____ is, without question, the most important aspect of any electrical Work.

12. Before working on any circuit, _____ it to be sure that the power has been turned off.
13. A _____-_____ device can be life-threatening if you come into physical contact with it.

14. When doing electrical work with a ladder, always use a _____ or a _____ ladder. “NEVER” use a metal ladder.

15. G.F.C.I. stands for _____ _____ _____ _____.

16. A _____ system is absolutely indispensable for an electrical safety.

17. A plug-in receptacle analyzer _____ grounded outlets for correct/incorrect wiring.

18. Most electrical tools are designed to perform given tasks. These tools make work _____ and _____.

19. What is the Maximum number of 14 gauge wires can you splice together with a “Yellow” wire nut? _____

20. To properly connect a wire, first strip the wire; then wrap it _____ two-thirds of the way around the terminal screw.

21. Use electrical _____ for “temporary” emergency wire splices.

22. A multi-tester is required to measure _____ and _____.

23. A continuity tester is only used when the _____ to a circuit is turned off.

24. The _____ the number of wire size (gauge), the _____ the diameter and current-carrying capacity of the wire.

25. If aluminum wire is used in a device designed for copper wire, the wires will _____ and _____ as it _____ and _____, eventually working loose from the terminal screws.

26. Wires are coded by color. _____ Wires are always hot, as are the Red, Blue, and Yellow.

27. _____ or _____ wires are Neutral wires.

28. _____ Colored wires are used for grounding “ONLY”.

29. According to the National Electrical Code (NEC), all wire splices must be enclosed in a _____, _____, _____, or junction box.

30. To splice solid wire to solid wire, spirally twist one wire around the other in a _____ direction.

31. AFCI stands for _____ _____ _____ _____.

32. The Black or Hot wires are connected to the _____ colored screws on a receptacle.

33. The White or Neutral wires are connected to the _____ colored screws on a receptacle.

34. A single-pole switch has one operable contact and one fixed contact. In the off position, the switch is _____; in the on position, the switch is _____ and the circuit is complete.

35. A three-way switch has three screws, one “com Terminal” (dark screw), and two _____ screws to connect wires that run between switches.

36. A four-way switch has _____ terminal screws.

37. Four-way switches are used sandwiched between two _____ switches.

38. Use a _____ tester to check the integrity of a single pole switch.

39. GFCI circuits are required in certain locations within a dwelling unit, specified by the NEC. These locations include, but are not strictly limited to, _____, _____, _____, _____, _____, _____, _____, and _____ sinks.

40. A GFCI will immediately open the circuit in _____ to _____ of a second.

41. A GFCI receptacle for multiplications protection will have one set of hot and neutral wires connected to the _____ terminal screws and the other to the _____ terminal screws.

42. When doing electrical work of any kind, you should always wear safety _____ or _____.

There are five basic type of metal conduit, they are:

43. a._____

44. b._____

45. c._____

46. d._____

47. e._____

48. The maximum number of THHW 12 gauge wires that is permitted in 1" EMT tubing is_____.

49. A manual pipe or conduit bender is used for bending metal conduit _____ and _____.

50. Markings on a cable jacket (ROMEX) indicate the _____ and _____ of wires in the cable, the _____ listing, _____ rating, and whether a _____ wire is included.

51. The most common insulation categories used in residential wiring are _____, _____, and _____.

52. To prevent damage to wires, never bend individual wires or NM cable at a _____ angle. Always make _____ bends and turns.

53. Wire enclosed in metal sheathing is called _____ _____.

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

55. A typical house panel may provide _____, _____, or _____ amps.

56. The _____ was the most common type of circuit protection in homes prior to World War II.

57. A single grounding electrode composed of a rod or pipe must have a resistance to ground not to exceed _____.

CHAPTER 1

Understanding Electricity

Possessing a basic knowledge of electricity may not seem essential to doing electrical work, especially if you are using a "how-to" book with simple step-by-step instructions. However, nothing could be farther from the truth. Not every step in a process may be obvious, and very often knowing the basic theory behind a practice may enable you to figure out how to do something you have never done before. The purpose of this chapter is to give you a basic understanding of electricity—what it is, how it is provided, how it works, and how you can work with it safely.

Fundamentals of Electricity

Electricity Defined

Electricity is nothing more than an organized flow of electrons and protons behaving in response to the attraction of oppositely charged particles and the repulsion of like-charged particles. If you can get enough electrons to break free of their orbits and start flowing in one direction or another, you have a flow of current. This current, or power, is defined as electricity. The device that frees the electrons from their orbit is called a power generator. To create vast amounts of electrical power, large generators must be turned on a massive scale. (See "How Electricity is Provided," page 12.)

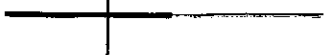
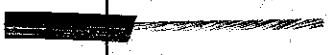
Terminology of Electricity

As with most subjects, electricity has its own vocabulary. For this book, however, it is important to know the meaning of only four key terms: ampere (amperage), volt (voltage), watt (wattage), and ohms (resistance). By mastering these terms, you will better understand electricity.

Ampere: An *ampere*, or *amp*, measures the rate, or quantity, of electrical flow. A typical contemporary home, for example, might have an electrical system of 150 to 200 amps. *Amperage*, in contrast, is the actual measure of current flowing in a circuit to an appliance. Although this can be measured only when the circuit is turned on, the rating of an electric appliance, in volts and amperes, or volts and watts, is required by the National Electrical Code (Section 422.60) to be marked on the identifying nameplate of the appliance. Amperes are designated by the letter A.

Ampacity is the amount of current in amperes a wire can safely conduct. Determining the correct ampacity of a wire is important because using an incorrect-size wire can create a fire hazard. Each wire carries a limited amount of current before it will heat to the point of damaging its insulation. For example, a 14-gauge wire can take a maximum current of 15 amps, a 12-gauge wire 20 amps, and so on. If a wire is too small for a job, generated heat can destroy its insulation, causing a fire. Amperage ratings are also important when you buy fuses or circuit breakers. Amperage of fuses or breakers, circuits, and appliances must match. Too little fuse or circuit-breaker amperage will cause these protection devices to blow or trip. Too much will permit a dangerous amount of overcurrent, or flow, which occurs when too many appliances are used on the same circuit or during a power surge. The result is overheating of the circuit, which will create a potential for fire.

American Wire Gauges

Wire Diameter (Gauge)	Ampacity (Current Capacity)	Volts (Power Capacity)	Typical Usage
 18	7 Amps	**24 Volts** (134 Watts) Continuous load	**Low-Voltage Wiring** Bells, chimes, timers, thermostats, etc.
 16	10 Amps	**24 Volts** (192 Watts) Continuous load	**Light-Duty Wiring** Low-voltage lighting, etc.
 14	15 Amps	**120 Volts** (1,440 Watts) Continuous load	**Common House Wiring** Receptacles, lights, some A/Cs
 12	20 Amps	**120 Volts** (1,920 Watts) **240 Volts** (3,840 Watts) Continuous load	**Common House Wiring** Receptacles, lights, small appliances
 10	30 Amps	**120 Volts** (2,880 Watts) **240 Volts** (5,760 Watts) Continuous load	**Large Appliances** Clothes dryers, room A/Cs
 8	40 Amps	**240 Volts** (7,680 Watts) Continuous load	**Large Appliances** Central A/Cs, electric ranges
 6	50 Amps	**240 Volts** (9,600 Watts) Continuous load	**Large Appliances** Central A/Cs, electric ranges, furnaces

The NEC requires *that all conductors and cables be marked, to indicate their AWG size, at intervals not to exceed 24 inches (Section 310.11). Each wire size can carry a limited amount of current* under continuous load *(80% of its maximum), which is defined as operating for 3 hours or more. The measure of how much current a wire can safely conduct is called its ampacity.*

Volt: A *volt* measures the pressure exerted by electrical power. *Voltage* is the moving (electromotive) force that causes current to flow in an electrical circuit. A generator creates the pressure that keeps the electrical current flowing through conductors, known as *wires*.

Voltage, designated by the letter V, pushes a current that alternates between positive and negative values. This is known as an *alternating current* (AC). It periodically reverses, or alternates, direction in cycles, called *Hertz*. One cycle takes ⅙₀ second to complete. This is usually expressed as a rate of 60 cycles per second. The average voltage on this cycle is measured at 120 volts on the return, or neutral, wire and 240 volts across both of the two hot utility wires entering a home.

Contemporary three-wire residential wiring carries both 120- and 240-volt power. Large appliances like air conditioners, electric ranges, and clothes dryers typically use 240-volt wiring. Electrical devices must be labeled with their operating voltage level. This means that the product has been designed to operate at the listed voltage only. Do not, for example, hook up an electrical device rated at 125 volts to a circuit that supplies 220 to 240 volts. You'll burn it out.

Watt, Wattage: In practical terms, *wattage* is the amount of energy used to run a particular appliance. The wattage rating of a circuit is the amount of power the circuit can deliver safely, which is determined by the current-carrying capacity of the wires or cables. Wattage also indicates the amount of power a fixture or appliance needs to work properly.

To calculate the wattage, or *power*, available in a circuit, first determine its amperage (amp rating). It will be marked on the circuit breaker or fuse for that circuit in the service-entrance, or main, panel—15 or 20 amps for

How Electricity Works

Electric Current Flow

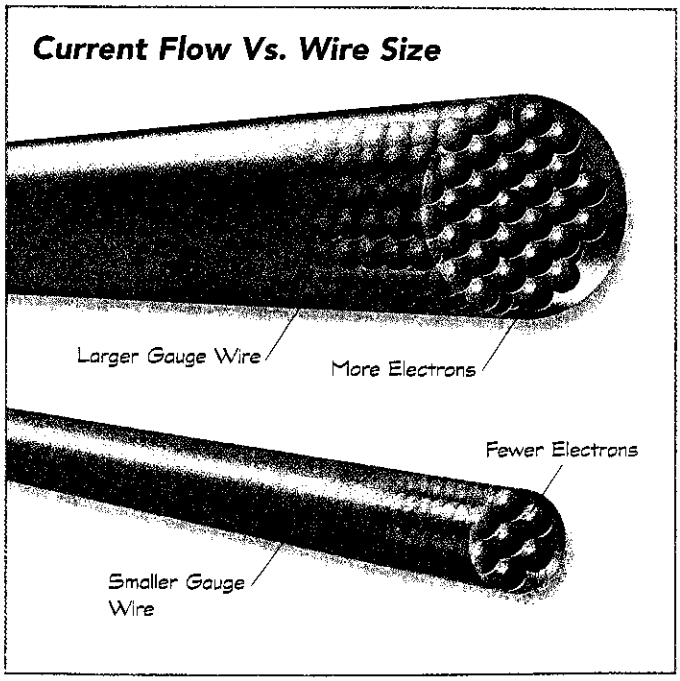
Electric current flow can be defined as the flow of electrons through a conductor (wire) or circuit. This passage of electrons is often described as being analogous to the flow of water in a pipe or hose. For example, water flows through a pipe or hose because it is under pressure. Similarly, electric 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.

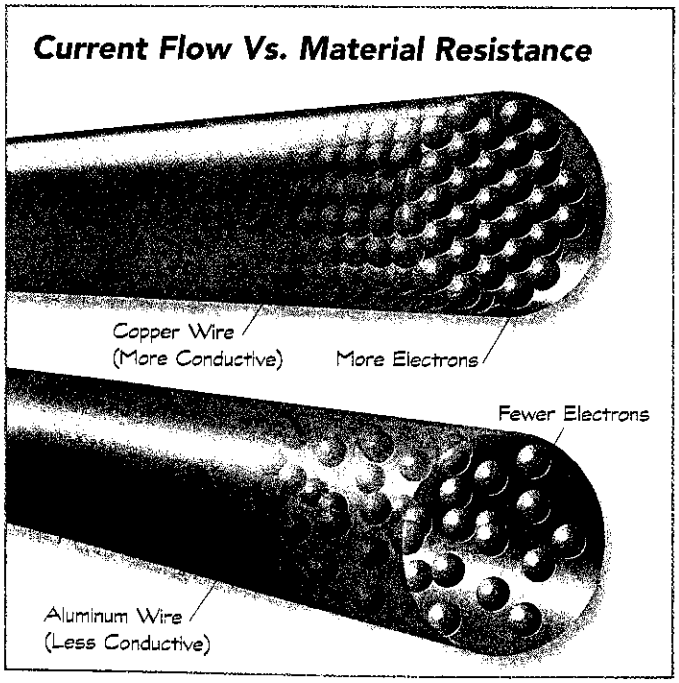
Flow Resistance

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.*



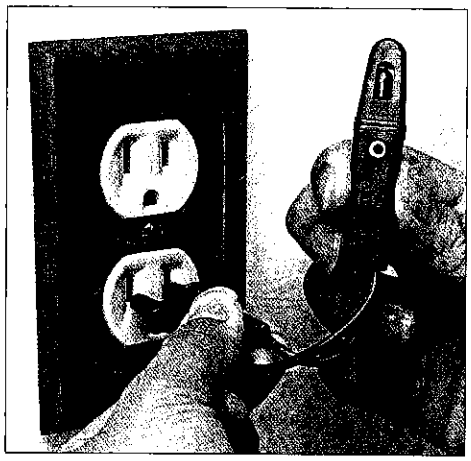
Conductive materials *allow more current to pass through them than less conductive materials of the same size.*

Working Safely with Electricity

Basic Rules of Safety

Safety is, without question, the most important aspect of any electrical work. One split-second mistake can result in serious injury or even death. Many errors are made because of impatience, ignorance, or unnecessary risk-taking. If you consider the potential cost of not following simple, common-sense rules of safety when you are working with electricity, then you will certainly realize the importance of avoiding such mistakes.

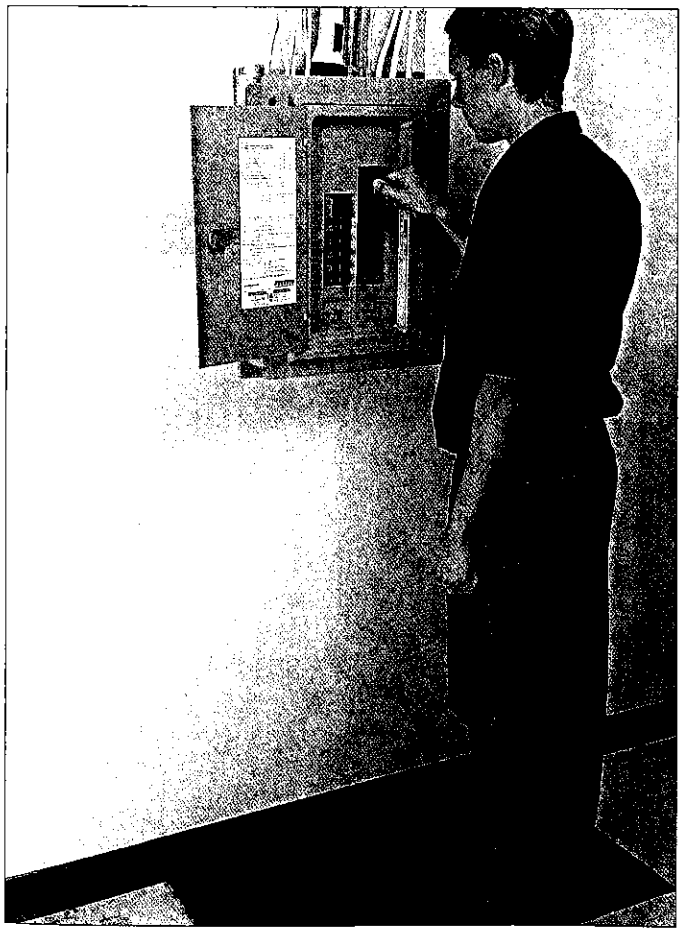
The first rule of working with electricity is to shut off the power at your main service-entrance panel before working on a circuit. Always keep a well-maintained flashlight near the panel so that when power is cut off you will not be left standing in the dark. Also, be sure to stand on a rubber mat or dry boards, especially if your utility room is damp, and use only one hand to remove or replace a fuse or flip a circuit-breaker switch. After shutting off the power, secure the panel so that no one else will accidentally turn the circuit back on while you are working on it. All circuits should be clearly marked to avoid confusion as to which circuit to shut off. Nevertheless, whenever you do work on a circuit, be doubly sure that it is not hot by testing it, using a circuit tester.



Before working on any circuit, *test it to be sure that the power has been turned off. Test both receptacles on an outlet. It may be a split circuit.*

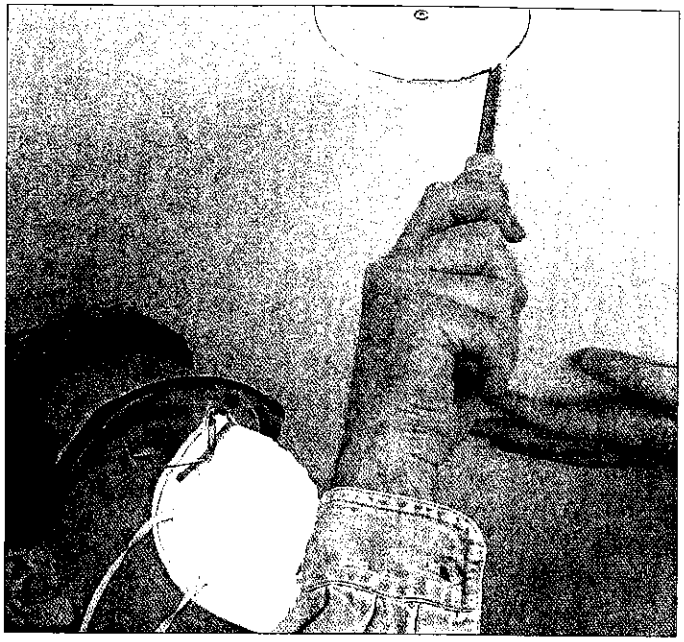
Second, be absolutely positive that you have carefully planned your work, that you know every step you'll take, and that you are not in over your head. For this reason, it is probably best to limit yourself to doing work outside your electrical panel. Leave adding circuits and making panel repairs to a licensed electrician.

Third, when doing actual wiring and electrical repairs, take precautions to use the correct tools, equipment, and techniques. For example, use a wooden or fiberglass



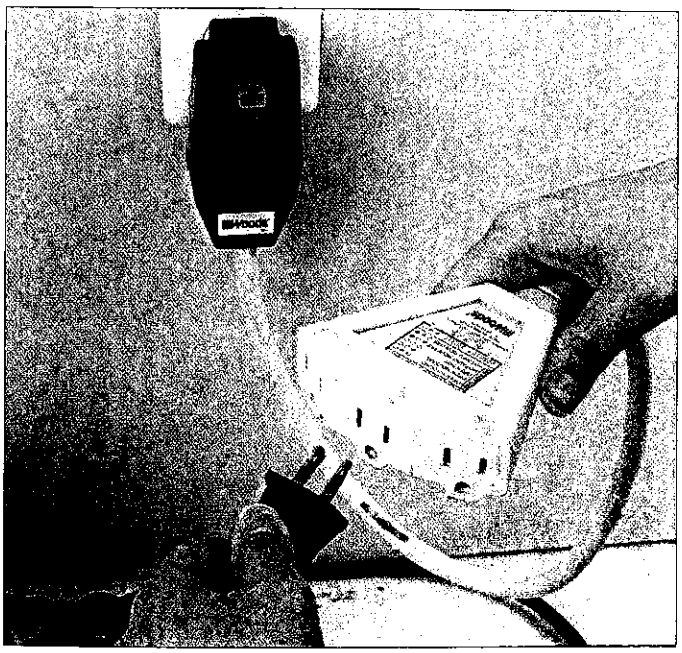
Keep a well-maintained flashlight *near your service-entrance panel, and always stand on a rubber mat or dry boards when working on the panel.*

To prevent a ladder *from slipping out from under you when working outside, swivel the feet into a vertical position; then dig them into the ground.*



Always wear *comfortable, adjustable safety glasses when doing electrical work, to protect yourself from flying debris or sparking wires.*

ladder, never one that is made of metal; always wear safety glasses to protect yourself against sparks and flying debris; and make sure that all of your tools are properly insulated for electrical work. Be conscious of details, like properly wrapping wire terminals with electrical tape and using the correct-size electrical boxes for the work you are doing. And, especially if you are working with power equipment outside, be certain that the electrical circuit is thoroughly protected by a ground-fault circuit interrupter (GFCI), or use a GFCI extension cord. (See page 21.) If a tool malfunctions and has a fault to ground, this type of protection can save your life. For portable power tools, be sure to use heavy-duty 12-gauge extension cords. Under-gauged cords are a potential fire hazard. In addition, all electrical supplies should be UL-listed—which means that they carry the symbol of the Underwriters Laboratories, your assurance that the product meets the minimum safety standards set by this and other governing agencies.



AC power tools *carry enough electrical current to cause electrocution. To be safe, use a heavy-duty extension cord that has a GFCI built directly into it.*

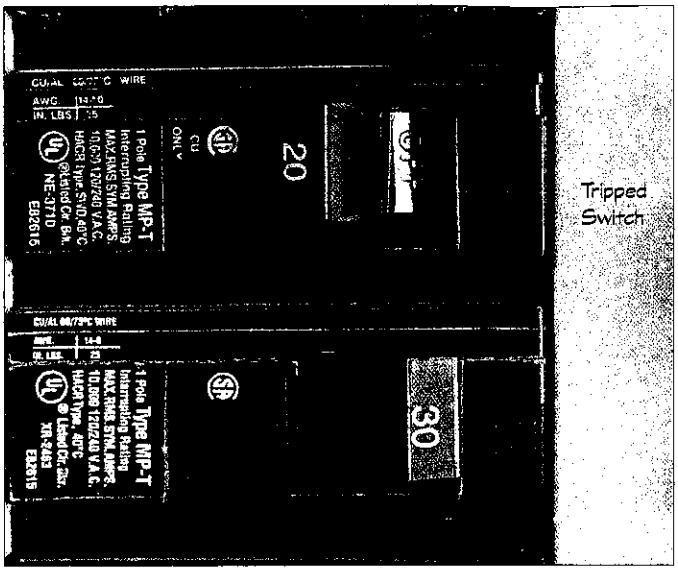
Lastly, observe the rules and regulations established by your local, state or regional safety, building, electrical, and fire codes. These codes are written for your protection as well as the health, safety, and welfare of the general public. Some codes may, in fact, prohibit you from doing certain types of electrical work or using a particular type of electrical cable. Most requirements are based on the National Electrical Code, which provides requirements for safe electrical installations.

Short Circuits

When an accidental connection is made between two hot wires or one hot wire and a grounded wire, and excess current flows across the connection, this is known as a short circuit. A short-circuited device can be life-threatening if you come into physical contact with it. Because electrical current travels along the path of least resistance, you can literally become part of the electric circuit—the part through which the current attempts to flow back to its original source. Normally, this is done through a neutral wire in the circuit. However, for safety's sake, an alternative route is usually provided by a grounding wire, or circuit, leading to the earth, where the misdirected current is harmlessly dissipated.

Grounding

The grounding circuit typically connects all of the electrical devices, including fixtures, switches, receptacles, electrical boxes, and so on, to a terminal, or bus bar, in the main panel. The bus bar is in turn connected to a metal cold-water pipe and a grounding rod driven into the earth "such that at least 8 feet of length is in contact with the soil" [NEC Section 250.52(c)]. (See illustration, "Grounding Rods," page 22.) Individual appliances or tools that are metal-clad are connected to this grounding system through the third prong on a three-prong plug. (For further information, see "Grounding Systems," page 21.)



***A circuit breaker** switches off (trips) when the flow of current exceeds the breaker's capacity.*

Overload Protection

The excessive current that is created by a short circuit, or by connecting equipment that overloads the circuit, can easily cause irreparable damage to electrical equipment. An electrical system must have some type of overload protection. This type of protection is provided by fuses and circuit breakers. (See "Service Panels," Chapter 3, page 48.) A fuse guards against overload by melting when too much heat is caused by excessive current in the line. Once the metal wire in the fuse melts, the circuit is effectively broken. A circuit breaker, on the other hand, is an automatic switch designed to cut off the flow of electric current in a circuit that exceeds its rated capacity. Unlike a fuse, it doesn't have to be replaced; the switch, once "tripped," simply needs to be reset.

Ground-Fault Circuit Interrupters (GFCI)

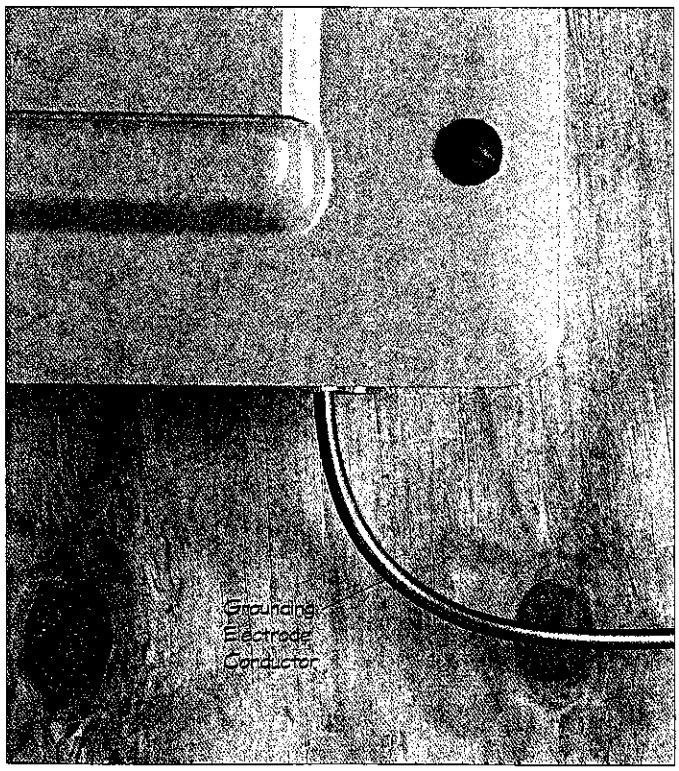
Although a powerful current surging through a grounding system will melt (blow) a fuse or switch off (trip) a circuit breaker, a less powerful current may not be sufficient to do this. Nonetheless, such a current may be forceful enough to cause serious injury, or worse. The risk of this happening is especially great in moisture-prone locations, such as outdoors or in bathrooms. A way to protect against the danger of this type of electric shock is by using what is called a ground-fault circuit interrupter, or GFCI. This device can detect minute amounts of current leakage in a circuit. If the amperage flowing through the black and white wires is equal, then the circuit is operating properly. But if the GFCI detects as little as a 0.005-amp difference between the two wires, then leakage is presumed and device breaks the circuit—rapidly enough to prevent a hazardous shock.

Grounding Systems

Main Panel Ground

As noted above, a grounding system is absolutely indispensable for electrical safety; it provides the fundamental means by which an irregular electric current can be safely brought to ground, or zero voltage. It is also a requirement of the NEC for all 120- and 240-volt circuits (Article 250).

The main service-entrance ground is the principal ground in a home. It is an easily seen copper grounding wire, known as the grounding electrode conductor, attached to a bus bar in the main service panel. Two such wires are visible if your water pipes are metal. One service ground runs from the terminal bus bar to the grounding-rod system, while the other goes to the main metal plumbing pipe. (Be aware that the metal plumbing pipes beyond the first 5 feet of entrance are not part of the grounding system but are, rather, grounded to the system by the grounding rod.) Minimum size requirements for grounding electrode conductors are specified by the NEC (Section 250.66).



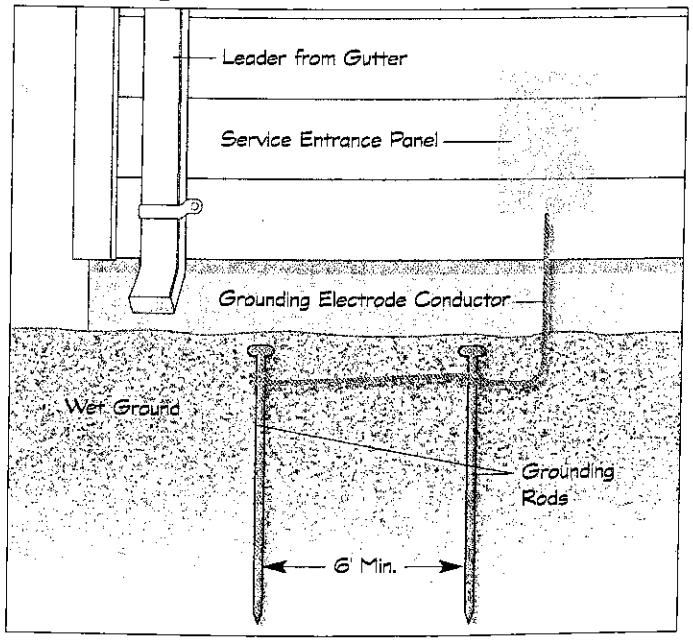
***The main service-entrance ground,** known as the grounding electrode conductor, is a copper grounding wire attached to a bus bar in the main service panel. If your water pipes are metal, there will be two wires—one running from the terminal bus bar to the grounding rod, and another running to the main metal cold-water pipe.*

Grounding Rods

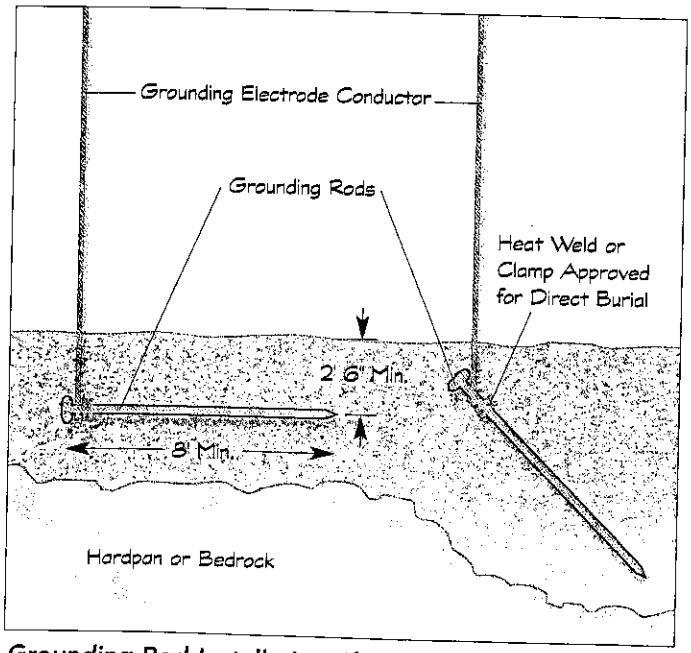
Grounding rods are usually composed of galvanized or copper-clad metal ⅝ inch in diameter and typically 8 feet long or longer. A good grounding system may include several grounding rods. A single grounding electrode composed of a rod or pipe must have a resistance to ground not to exceed 25 ohms (NEC 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.*

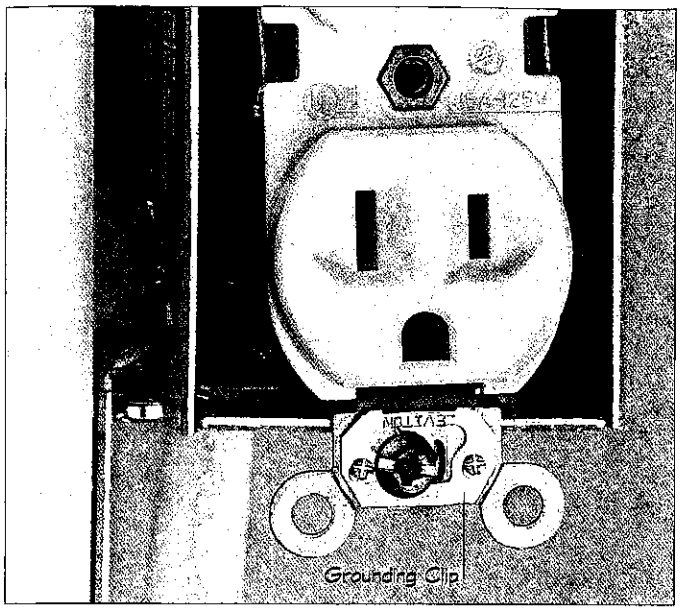
Grounding Rods



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.*

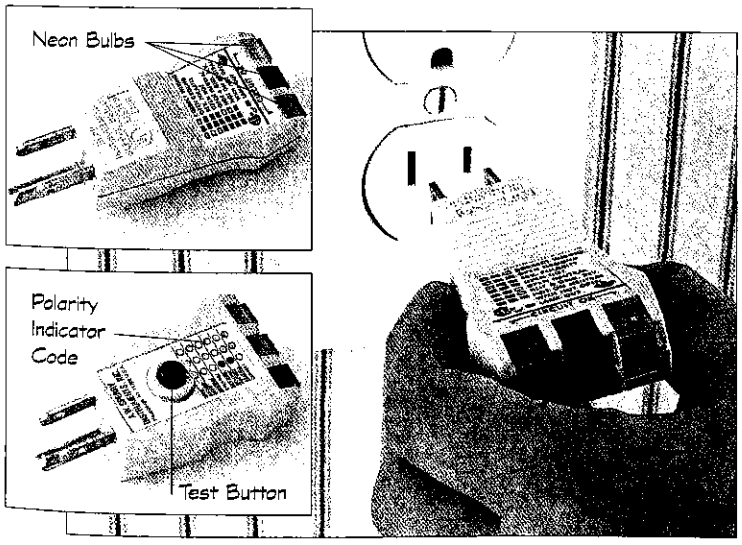


Higher-quality receptacles *feature an automatic grounding clip on one of their attachment screws, which provides a grounding path through any grounded metal electrical box.*

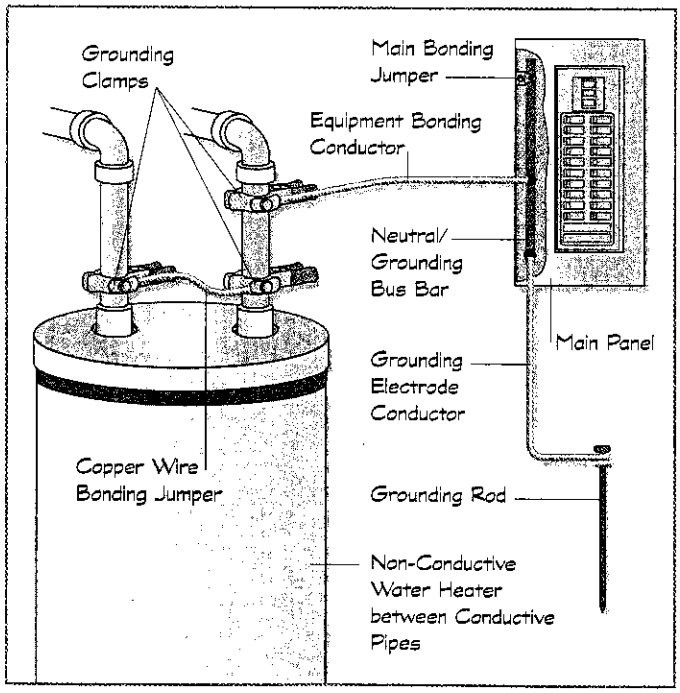
Common grounding problems that occur at or near the main electrical panel include grounding connections made to rusted rebar or pipe, cut or loose grounding wires, or improper connectors on a grounding rod. Be sure that the clamp used on your rod is a listed (approved) connector, which must be cast bronze, brass, or plain or malleable iron. A heat-welded connection is also acceptable (NEC Section 250.70). The grounding rod itself, if iron or steel, must be at least ⅝ inch in diameter. Stainless-steel and nonferrous metal rods must be at least ½ inch in diameter [Section 250.52(A)(5)]. The use of improper materials may lead to corrosion and result in a high-resistance connection.

Bonding Jumper

Homeowners frequently make the mistake of thinking that they can ground an electrical system or appliance by connecting it to metal plumbing pipes. Nothing could be further from the truth! All metal pipes must themselves be connected to the grounding system. If the water pipes are connected to the grounding system by means of a clamp and bonding wire to the service panel grounding/neutral bus bar, then the circuit breaker will trip off whenever a bare wire touches the metal pipes. Where there's a break in pipe continuity, such as when a water heater is not made of metal, for instance, a bypass, or bonding jumper, must be made to connect the incoming and outgoing pipes. Such bonding jumpers are required wherever necessary to ensure electrical continuity and the ability of the grounding system to safely direct any ground fault likely to be imposed upon it (NEC Section 250.90). The main service panel itself must be bonded by a connection from the neutral bus bar to a bonding screw on the metal frame of the panel, and the panel in turn connected to the grounding (electrode) rod.



A plug-in receptacle analyzer *checks grounded outlets for correct/incorrect wiring. Three neon bulbs light up in various combinations to indicate correct wiring, open ground, open neutral, open/hot, hot/ground reversed, or hot/neutral reversed.*



A bonding jumper *must be made to bridge any potential break in a ground circuit. Bonding jumpers are required to ensure electrical continuity, as well as the ability of a grounding system to safely direct any ground fault that might be imposed on it.*

CHAPTER 2

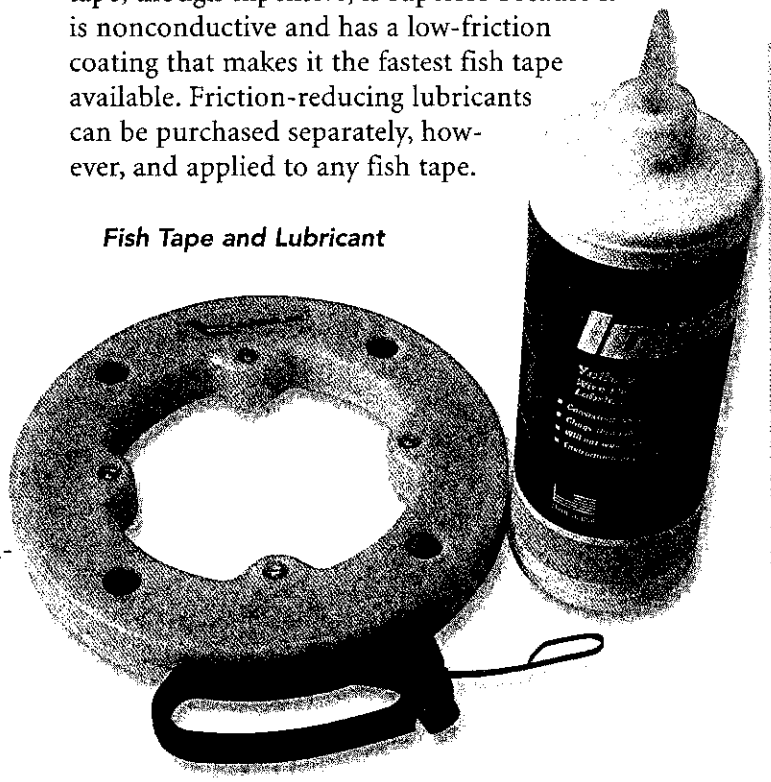
Tools & Their Uses

Some electrical work can be done using standard tools, many of which you may already have in your tool kit or workshop. Most tools used in electrical work, however, are specifically designed to perform a given task. These tools make work easier and safer. More importantly, even if you already own common tools—like hammers, chisels, utility knives, measuring tapes, screwdrivers, etc.—not all of these can be used safely. For example, screwdrivers and hammers, as well as other metal tools, must be insulated to prevent current from flowing into the user's hand, causing a shock. As for specialized work, the right tool is necessary to do the job properly, whether it's cutting and stripping wire or measuring current and voltage in a line.

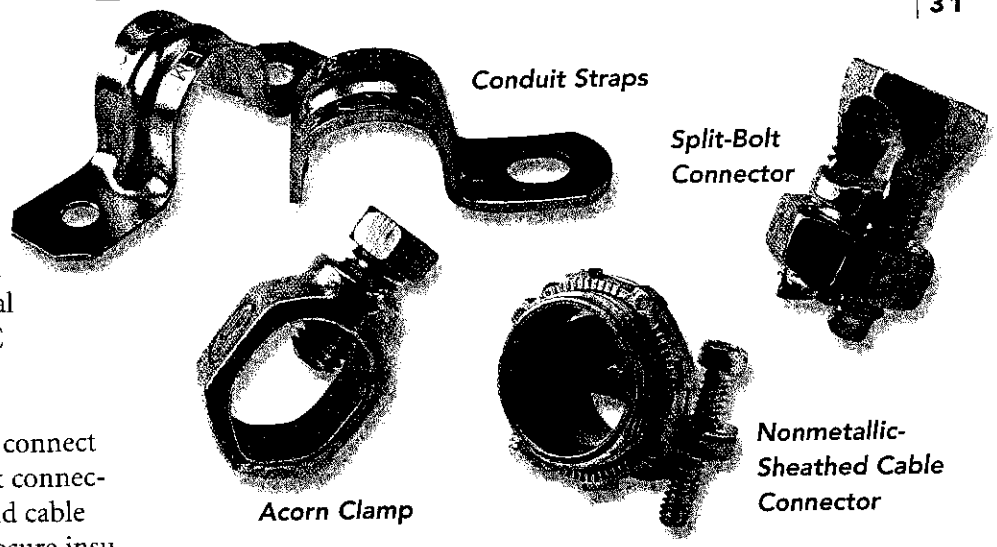
While safe electrical work requires the use of specific tools, it depends even more on the use of high-quality tools. Such tools are best purchased from a reputable home center or distributor of electrical supplies and equipment, rather than from a discount store. In the long run, a bargain is seldom a bargain if it endangers your life or property. Besides, well-maintained, high-quality tools will add to the versatility and reliability of your tool collection, and they can last a lifetime.

Pulling Wires and Fuses

Fish Tape. Also known as fish wire, fish tape is a flexible wire used by electricians to snake electrical cable through walls, ceilings, and other inaccessible spaces. Various wire "fishing" techniques use either one or two fish tapes to hook and pull wire. (See "Fishing Cable," page 86.) Fish tapes come in lengths from 25 to 250 feet and widths of ⅛ to ¼ inch. Usually, the tape, or wire, is wound inside a self-tensioning winder case with a handle grip for better control and ease of use. The tape is made either of steel, flexible steel, nylon, or fiberglass. Some flexible steel tapes, rather than consisting of a solid strand of steel wire, consist of multiple strands, while others are constructed of a solid spring-like steel. The drawback to steel tape is, of course, that it is conductive. Nylon tape is nonconductive and somewhat safer to use except for the tip and leader, which are made of steel. Fiberglass tape, though expensive, is superior because it is nonconductive and has a low-friction coating that makes it the fastest fish tape available. Friction-reducing lubricants can be purchased separately, however, and applied to any fish tape.

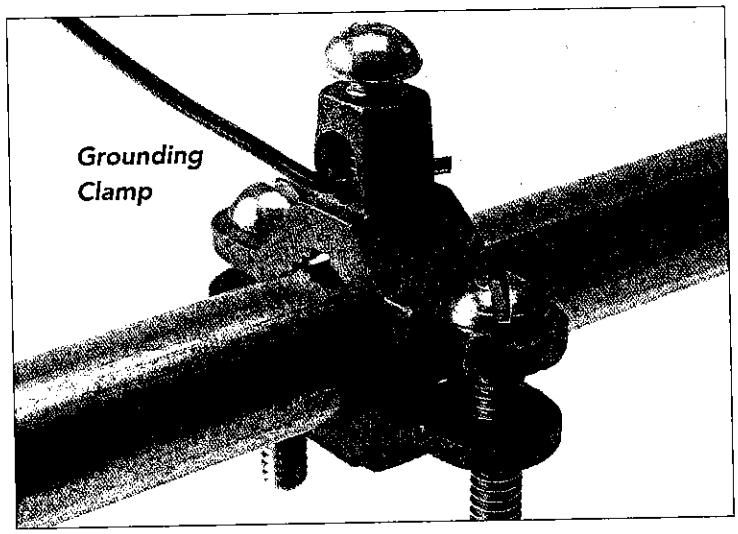


Fish Tape and Lubricant



Straps. Conduit straps, which are screwed into place, are used to support metal conduit where wiring is exposed, such as in a basement. Metal conduit must be supported at intervals not to exceed 10 feet and must be fastened within 3 feet of any electrical box or other conduit termination (NEC Sections 342.30, 344.30, and 358.30).

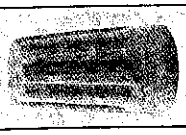
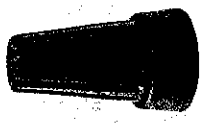
Clamps. Grounding and acorn clamps connect ground wires to ground rods; split-bolt connectors splice together larger wire sizes, and cable connectors with locknuts are used to secure insulated wire cable to electrical boxes. This way, the unsheathed wires from the cable are protected from fraying against the metal box.



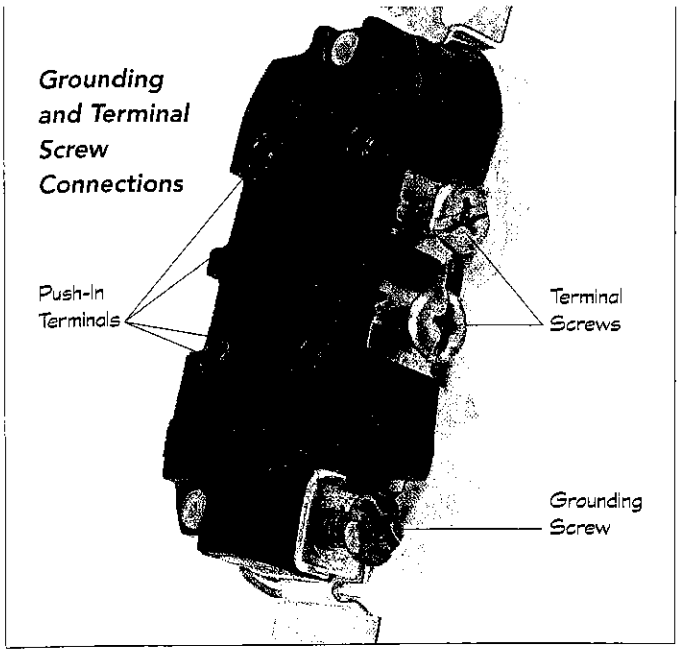
Wire Connectors. Whenever two or more wires are stripped to be spliced together, bare wires become exposed. They must be protected and prevented from coming into contact with other wires, connections, and metal surfaces that may cause a dangerous fault or short circuit. This is typically done using wire connectors or crimping ferrules.

When connecting wires using twist-on wire connectors, be aware of several things. Although the color schemes may vary from one manufacturer to the next, wire connectors are color-coded by size according to the minimum and maximum number of wires they can safely connect. Wire connectors should not be used to connect wires of dissimilar materials, unless so rated, and must completely encase the

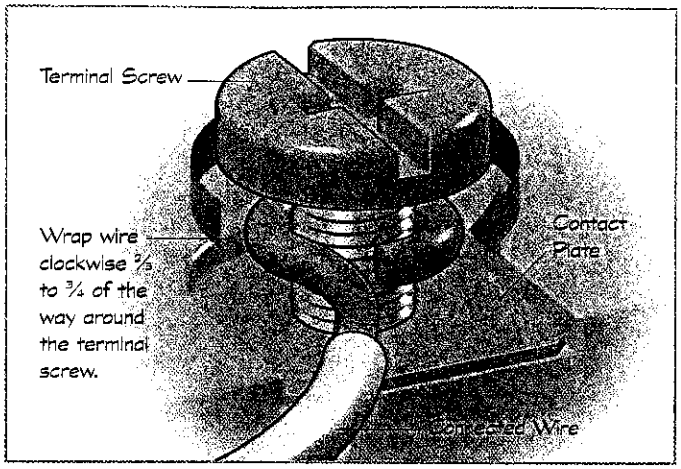
Wire Connector Ratings

Wire Connector	Color	Minimum		Maximum	
		Gauge	No. Wires	Gauge	No. Wires
	Orange	18	2	14	2
	Yellow	16	2	14	4
	Red	14	2	12 10	4 3
	Green	Green wire connectors are used for grounding wires only.			

Although they vary *from manufacturer to manufacturer, wire connectors are generally color-coded according to the minimum and maximum number of wires they connect. All wire connectors can be used for either conducting or grounding wires, but green wire connectors should only be used for grounding wires.*



Grounding and Terminal Screw Connections

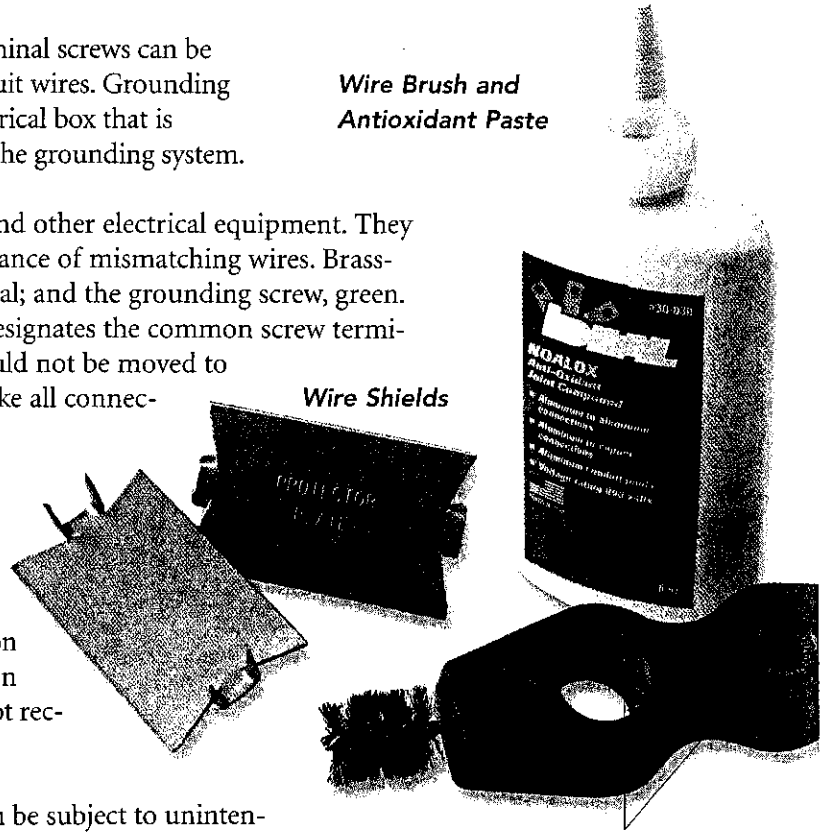


To properly connect a wire, *first strip the wire; then wrap it clockwise two-thirds of the way around the terminal screw. Tighten the screw until the wire is firmly and fully in contact with the contact plate.*

Grounding and Terminal Screws. Grounding and terminal screws can be thought of as tools for safely securing grounding and circuit wires. Grounding wires must be pigtailed to the grounding screw in an electrical box that is grounded, for example, in order to connect the circuit to the grounding system.

Terminal screws connect wires to receptacles, switches, and other electrical equipment. They are generally coded by color or material to reduce the chance of mismatching wires. Brass-color screws indicate hot terminals; white or silver, neutral; and the grounding screw, green. In a three-way switch, for example, a dark-color screw designates the common screw terminal connecting paired switches; the connecting wire should not be moved to either of the other two lighter-color terminal screws. Make all connections in accordance with NEC guidelines.

Some devices have terminal connections that allow you to simply push a wire into a hole rather than wrapping it around a screw. In this type of connection the bare wire must be totally pushed into the opening—no bare wire may be exposed. This type of screwless pressure connection can only be made with 14-gauge copper wire (NEC Section 110.14). These connections can be problematic and are not recommended. Use screw terminals wherever possible.



Wire Brush and Antioxidant Paste

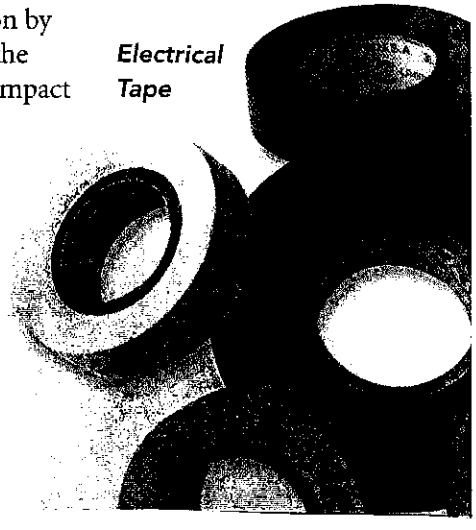
Wire Shields

To Clean Outer Surfaces of Wire and Conduit

Wire Shields. Even after a job is finished, wiring still can be subject to unintentional damage. It is difficult to know the exact location of wires inside the wall. Someone nailing into a wall stud could inadvertently hit a hot wire and receive a deadly shock. For this reason, when wires are run through framing members and are subject to penetration by nails or screws, you must place wire shields on the edges of the studs along the path of the wire (NEC Section 300.4). (See illustration, page 81.) If a nail hits this metal shield, the impact will be apparent and the nail or screw will be deflected from the path of the wiring run.

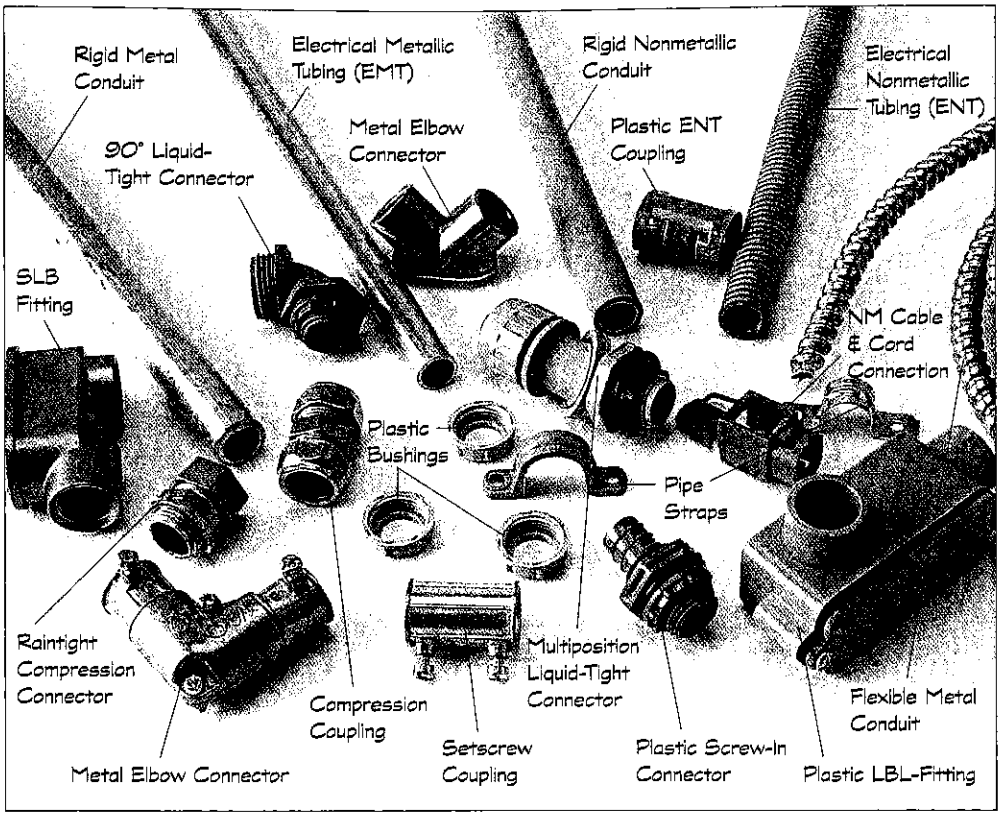
Wire Brush and Antioxidant Paste. You can use a wire brush to remove corrosion from wires or simply to clean wires. Aluminum wires should be treated with an antioxidant paste to prevent corrosion from recurring.

Electrical Tape. Use tape for temporary emergency wire splices; color-coding circuit wires; and attaching cables to fish tape for secure wire-pulling. It is also a good idea to tape the side terminals when pushing a receptacle into a metal outlet box.



Electrical Tape

Conduit and Accessories. Metal conduit, or tubing, is typically used to protect wires from damage and moisture in an exposed location, such as a basement or outdoors. If exposed to harsh atmospheric conditions, however, it must be corrosion-resistant. There are five basic types of metal conduit: EMT (electrical metallic tubing), and the similar IMC (intermediate metallic conduit) *not shown*, rigid metal conduit, flexible metal conduit in a nonmetallic PVC cover (liquid-tight) *not shown*, and flexible metal conduit (helically wound). There are also two types of nonmetallic conduit generally used in residential work—electrical nonmetallic tubing (ENT) and rigid nonmetallic conduit (Schedule 40). These are made of polyvinyl chloride (PVC). Conduit sizes permitted by the NEC range from a minimum of ½ inch to a maximum of 6 inches in diameter, depending on the type and use of the conduit. Various accessories are used to connect conduit, just as with water pipes, including bends, couplings, compression and screw connectors, conduit bodies, and pipe supports. Check your local code and the NEC carefully before doing electrical work involving conduit. Note, for example, that no wire splices are permitted within conduit itself but only in electrical boxes or wherever wires remain accessible. There's also a limit on the size and number of wires permitted in conduit. The table at right, for example, indicates the maximum number of conductors allowed in electrical metallic tubing.



Conduit is used to safeguard wire cable *where it is exposed to potential damage, such as in a basement workroom or outdoors. Shown here are some of the accessories used to extend and fasten conduit and protect cables wherever conduit changes direction.*

Wire Capacities of Electrical Metallic Tubing (EMT)

Wire Type	Gauge	Maximum No. of Wires Permitted in EMT				
		½ Inch	¾ Inch	1 Inch	1¼ Inch	1½ Inch
TW	14	8	15	25	43	58
	12	6	11	19	33	45
	10	5	8	14	24	33
	8	2	5	8	13	18
THW THHW THW-2	14	8	15	25	43	58
	12	6	11	19	33	45
	10	5	8	14	24	33
	8	2	5	8	13	18
THHN THWN	6	2	4	7	12	16
	4	1	2	4	7	10
	3	1	1	3	6	8
	2	1	1	3	5	7
	1	1	1	1	4	5

The NEC limits the total number *of individual wires of the same gauge in a conduit. (See NEC 2002, Annex C, Table C1.)*

Cordless Reciprocating Saw. You can quickly rough-cut through virtually any material, from wood to metal, using a reciprocating saw. Battery-operated models are perfect for doing electrical work safely without having to drag around tool wires. Be sure to have on hand appropriate blades for cutting through different materials.

Reciprocating Saw

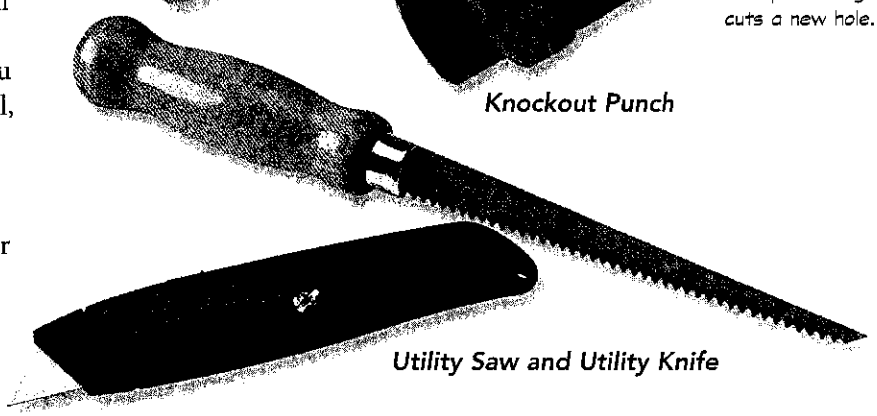
Electrician's Hammer. An electrician's hammer differs from a conventional curved-claw hammer in four important ways. First, the shaft is constructed of fiberglass to insulate against electric shock; second, the head is narrower and longer for better reach; third, the claw is flatter and longer, like that of a straight-claw or ripping hammer; and fourth, the head is designed to be non-sparking.

Electrician's Hammer

Knockout Punch. For twisting the slugs off of electrical boxes, a lineman's pliers will do in a pinch, but a standard round knockout punch will do a better, cleaner job of slug-splitting and removal. A heavy-duty model will also enable you to punch holes in thick sheet metal, stainless steel, plastic, fiberglass, and other similar materials.

Knockout Punch

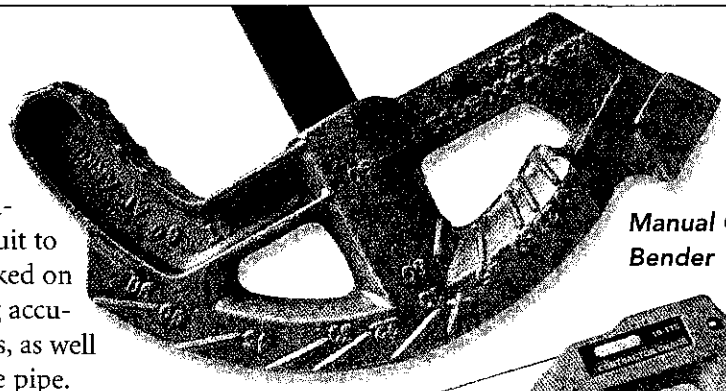
Utility Saw and Utility Knife. Utility saws and utility knives are ideally suited for cutting into or through drywall. You'll find a utility knife especially useful for slicing through drywall to reach stud framing that must be notched for wire-pulling behind a wall.



Utility Saw and Utility Knife

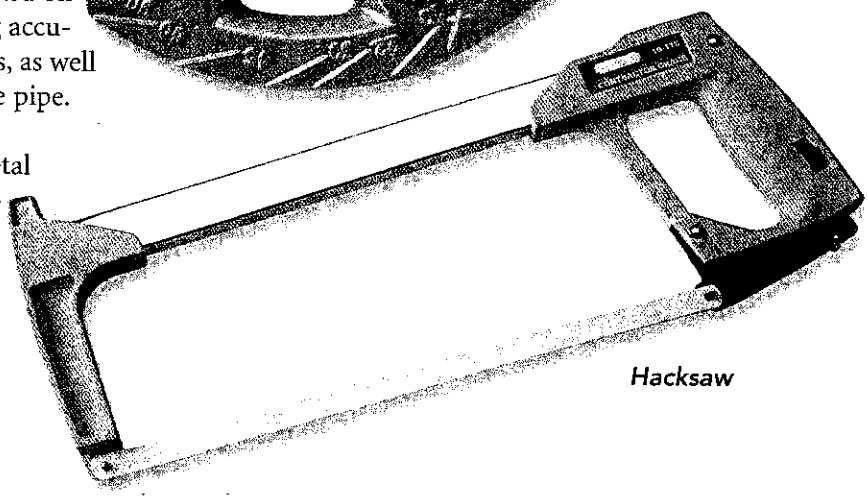
Working with Conduit

Manual Conduit Bender. A manual pipe or conduit bender is used for bending metal conduit smoothly and efficiently. You can operate a pipe bender by hand or by using foot pressure to bend conduit to a 10-, 22½-, 30-, 45-, 60-, or 90-degree angle as marked on the conduit bender. This tool is essential for making accurate saddle bends, stub-ups, and back-to-back bends, as well as simple up and down bends, without crimping the pipe.



Manual Conduit Bender

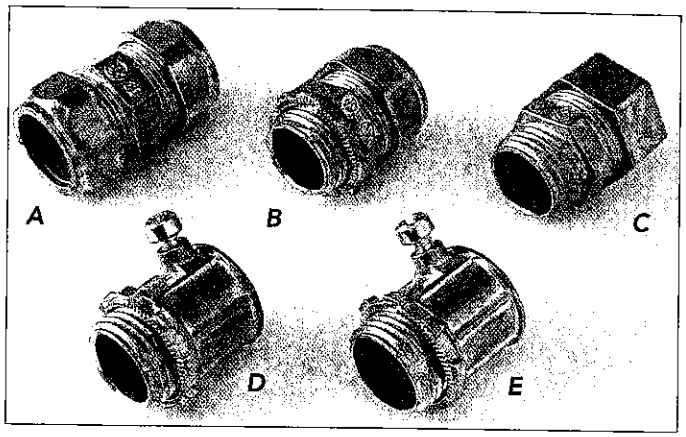
Hacksaw. You'll need a hacksaw to cut through metal pipe or conduit or metal-sheathed cable. The number of teeth in the blade determines the thickness of metal that can be cut. In general, thicker metals require coarser-toothed blades. A wing nut on the hacksaw handle allows you to remove the blade or adjust its cutting angle and tightness.

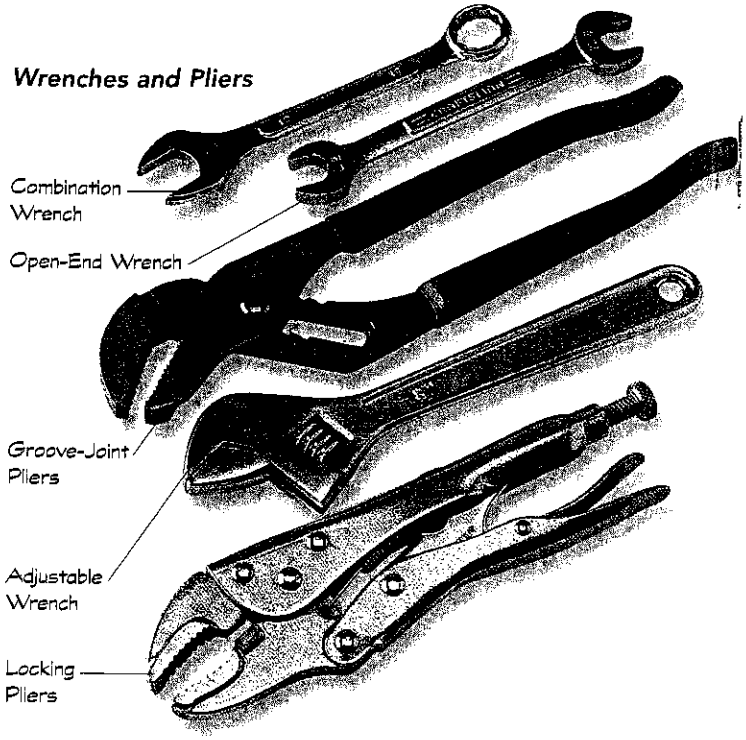


Hacksaw

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.*

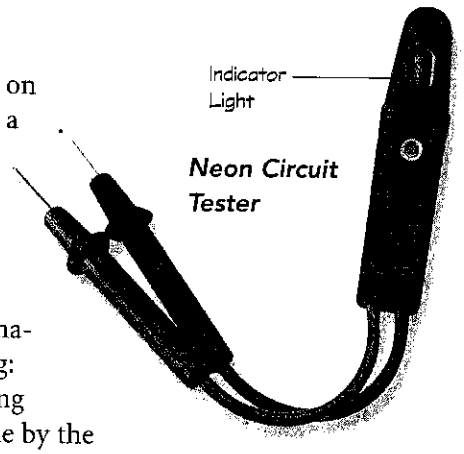




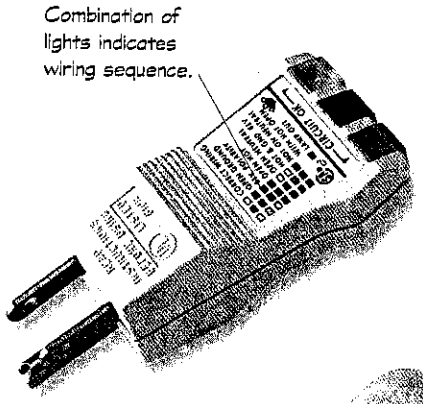
Wrenches and Pliers. Many conduit connections, as with conventional plumbing pipes, consist of compression fittings. You will need pliers and sized or adjustable wrenches to properly secure these connections.

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.

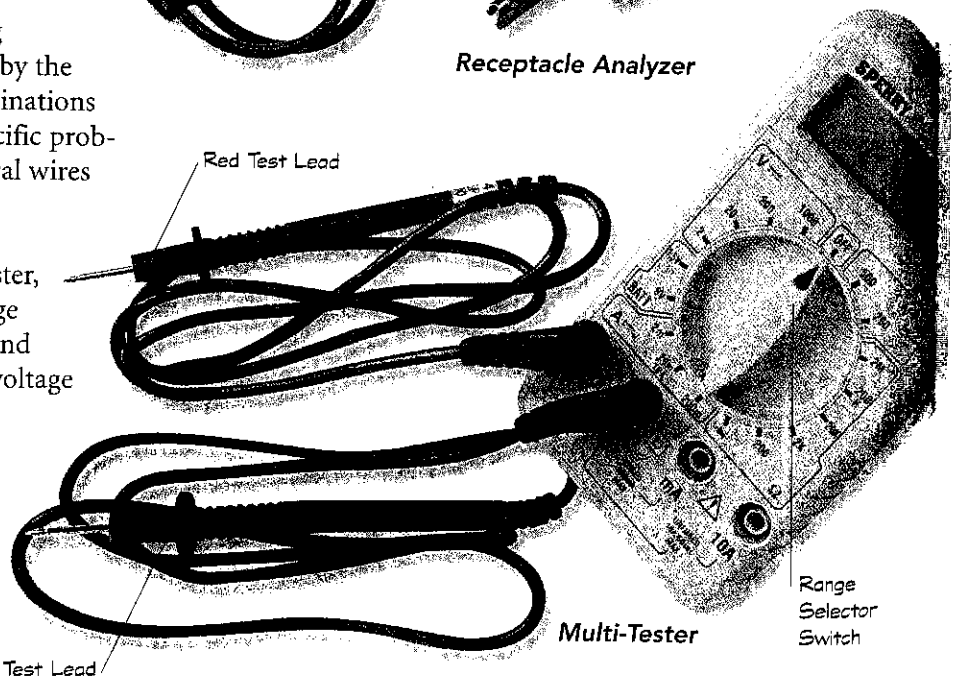


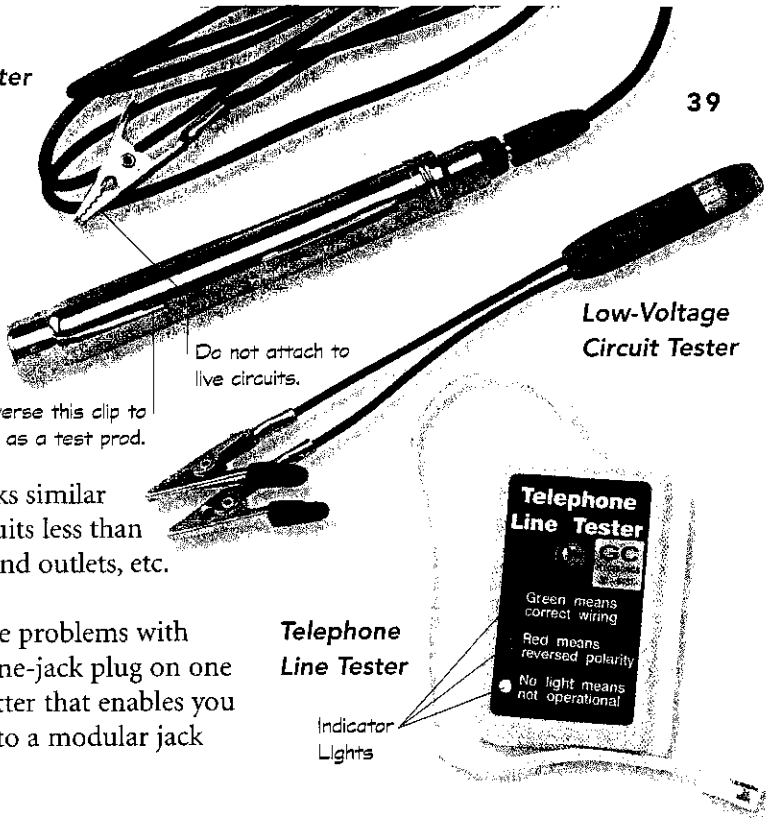
Receptacle Analyzer. Use a receptacle analyzer to identify faults in receptacle wiring: simply plug the device into the outlet being tested; then read the lighting pattern made by the three bulbs on the analyzer. Different combinations of lighted and unlighted bulbs indicate specific problems with the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





Continuity Tester

Low-Voltage Circuit Tester

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.

Telephone Line Tester

CREATIVE HOMEOWNER® SMART TIP

Using Ladders

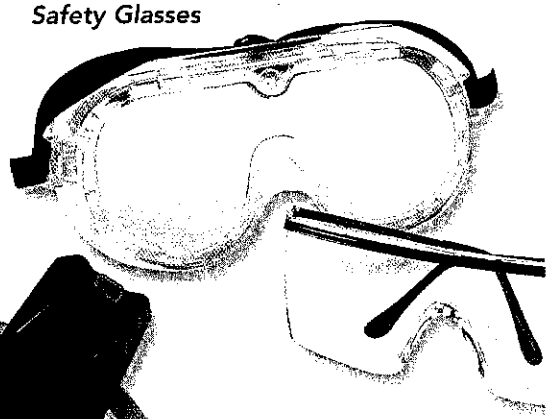
Always use nonconductive ladders—wood or fiberglass. Aluminum ladders can be an electrician's nightmare. Should you accidentally cut into a hot wire, you must be insulated from ground—not connected to it. Always wear rubber-soled shoes and electrician's gloves to serve as additional insulators. If you 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.

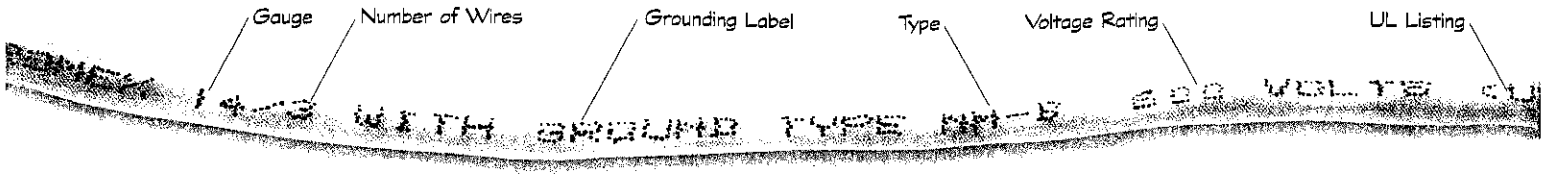
Safety Glasses. When doing electrical work of any kind, you should always wear safety glasses or goggles. A sudden spark or a bit of clipped wire could shoot out and burn or scratch your eye. When drilling overhead it is important to wear safety goggles to keep debris from falling into your eyes as you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

Safety Glasses



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.

GFCI Extension Cord



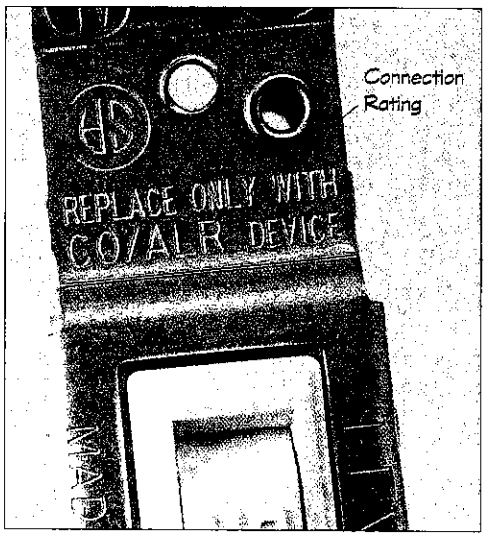
Markings on a cable jacket *indicate the gauge and number of wires in the cable, the UL-listing, voltage rating, and whether a grounding wire is included.*

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.

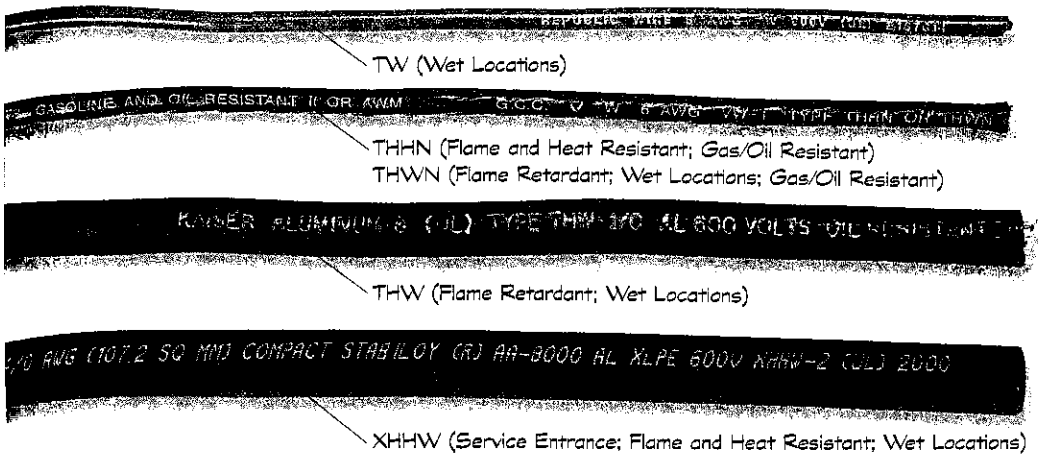
Aluminum cable is sometimes used for service-entrance cable and large appliances such as electric ranges and electric furnaces. If large diameter, multistranded aluminum cable is used, the ends must be coated with a noncorrosive compound. (NEC Section 110.14)



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.

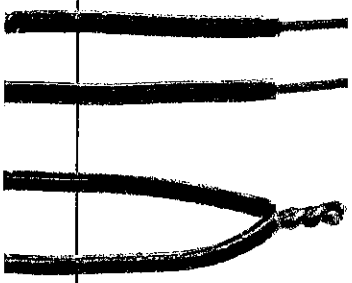
Cord Insulation. Wire designated as cord differs from cable. The type of wires sheathed in cord are stranded wires. The sheathing usually consists of some type of

Splicing Wires

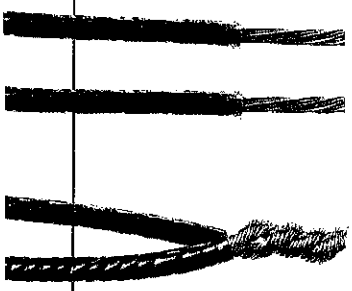
According to the NEC, all wire splices must be enclosed in a switch, receptacle, fixture, or junction box. To make a wire splice, you must first strip insulation from the end of the wires. Although it may be used for this, a utility knife will most likely nick the wire. Instead, use an electrician's 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.

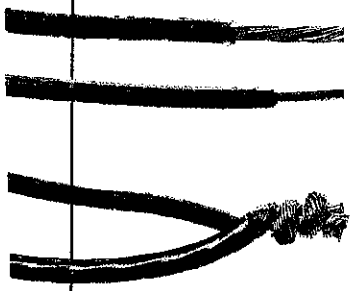
To splice a stranded wire to a solid wire, strip the same ½ inch of insulation off the solid wire, but an inch from the stranded wire. Spirally twist the stranded wire clockwise around the solid wire. Cap the splice with a wire connector.



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.*

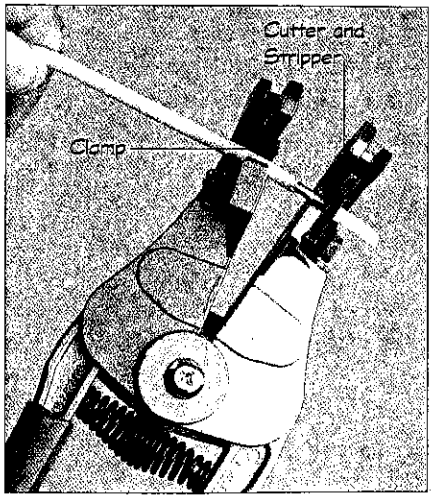


Splice a stranded wire to a stranded wire *in the same way as a solid wire to a solid wire, but be careful not to cut or break the individual wire strands. Strip stranded wires to expose 1" of bare wire before splicing.*



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

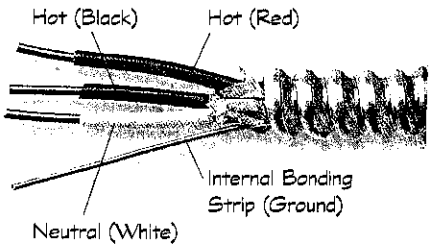
Wires sheathed *in thermoplastic insulation (cable) have maximum amperage capacities (ampacities) for which they are rated. The ratings above are for typical residential wires. (NEC Table 310.16)*

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.

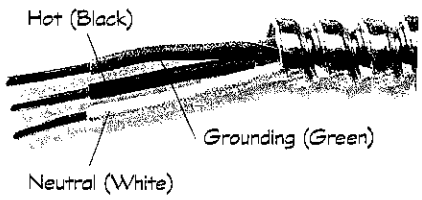
Armored Cable

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

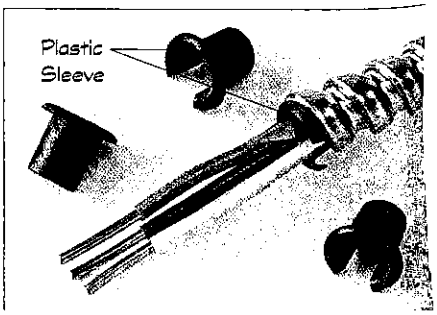
Armored cable (AC) *is sometimes called by its trade name, BX. It consists of hot, neutral, and grounding wires in a protective metal (armor) sheathing.*



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

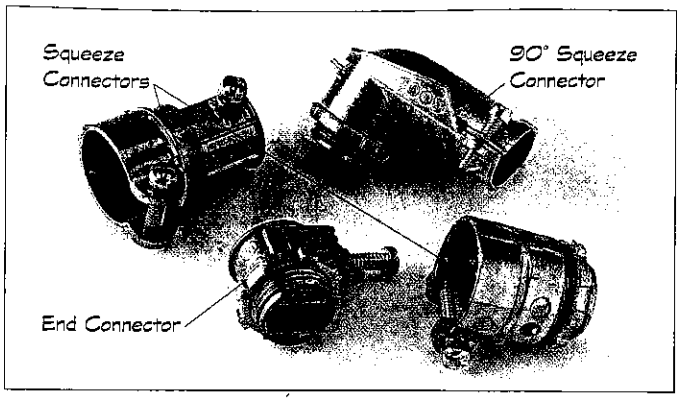


All types *of armored cable require a plastic sleeve placed between the sharp metal edges of the cut cable and the emerging wires.*

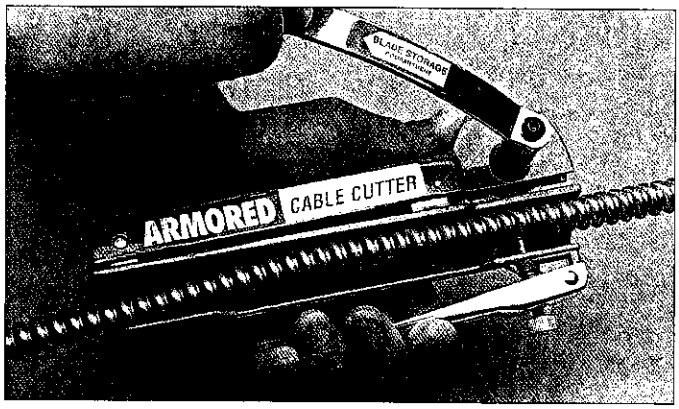


plastic tape to protect them from chafing against the armored sheathing. Be sure to insert a plastic sleeve between the wires and the armor wherever wires emerge from the armored cable.

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.



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

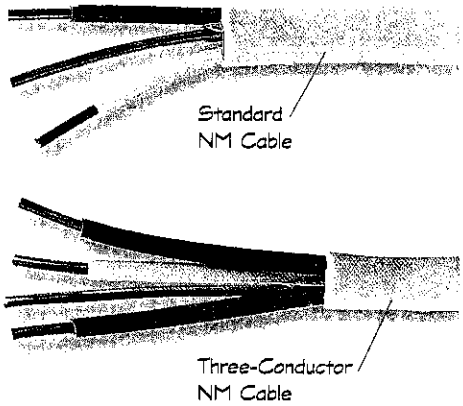


To cut armored cable easily, *use a specialized cutting tool. Insert the cable in the tool, and turn the knob clockwise to tighten down on and cut the armor.*

Nonmetallic Cable

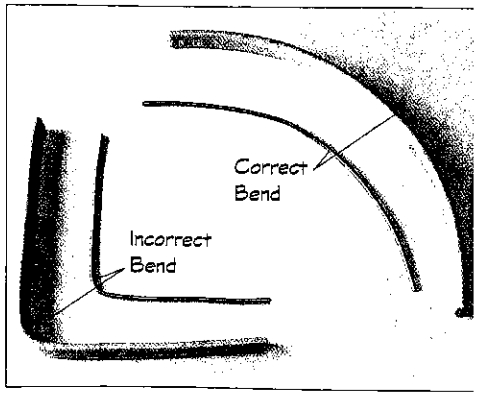
Nonmetallic (NM) cable is the most common type of cable used in residential work. Again, NM cable consists of wires encased in a thermoplastic sheathing. The wires include one or more hot wires, a neutral wire, and a grounding wire. The most common type is two wires with a ground—one hot wire in black 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).

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.*

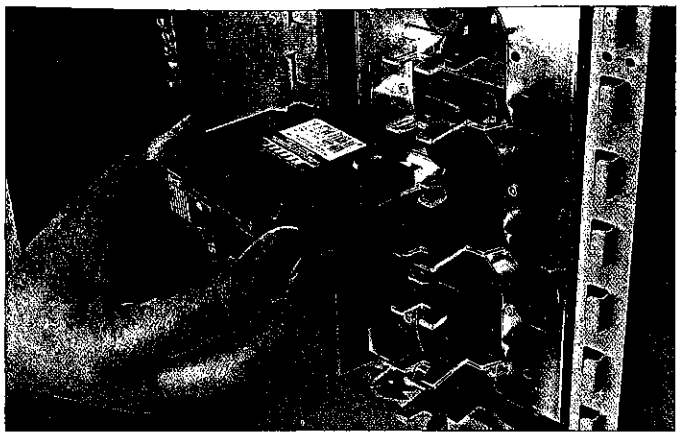


When you work with NM cable, be sure to avoid two common errors: first, putting a kink in the wires by bending the cable too sharply and, second, damaging the cable sheathing by pulling it through too small an opening. A kink may damage the copper wire inside the cable and can cause it to overheat and 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.

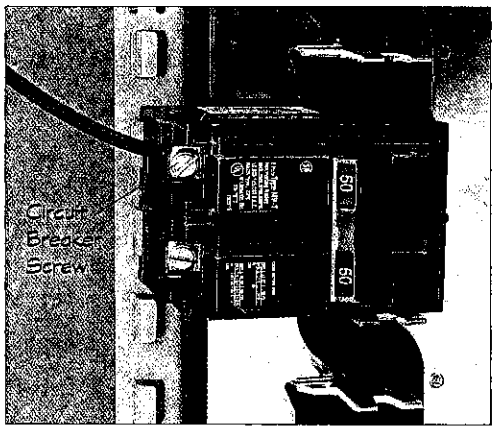
To prevent damage to wires, *never bend individual wires or NM cable at a sharp angle. Always make gentle bends and turns. Because of its fragility, even the sheathing on NM cable will easily rip if it is caught on or scraped against something sharp.*



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.

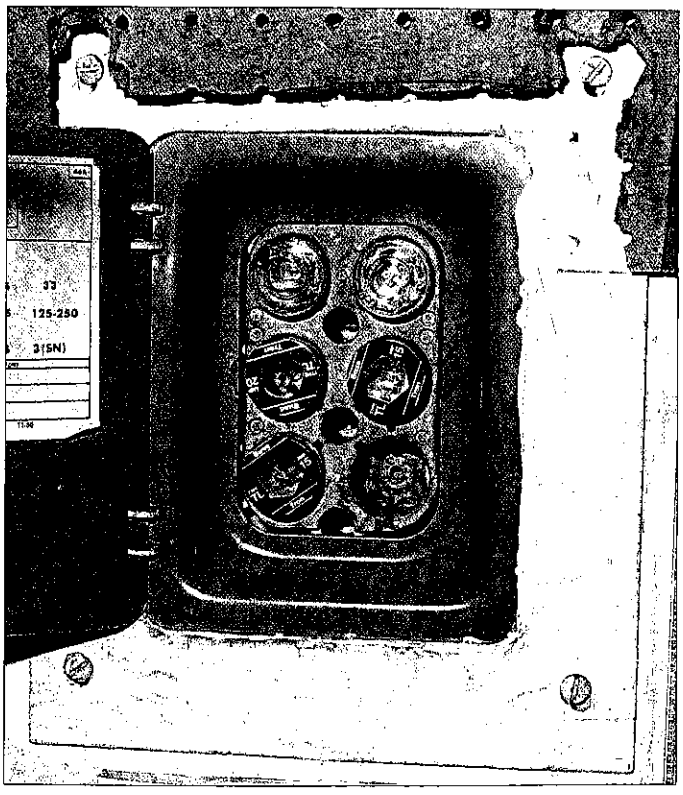
Circuit-Breaker Sizes. The individual breakers within the main panel distribute power from the hot buses to individual circuits. Each breaker snaps over an angled tab on one of the hot buses. Once pushed onto the tab (the main panel turned on), the breaker provides power through the wire that is connected 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.

Fuses and Circuit Breakers

Fuses

The fuse was the most common type of circuit protection in homes prior to World War II. Fuses are still used in many older homes. The two most common types of fuses are the plug, or glass fuse, and the cartridge fuse. Plug fuses control 120-volt circuits and are commonly available in sizes ranging from 15 to 30 amps. Inside a plug fuse is a metal strip that extends from the fuse's center contact to the threaded base. The narrow portion of the strip is called the element. If the circuit is overloaded, the element will burn, disconnecting the circuit and blowing the fuse. Cartridge fuses for residential use control 240-volt circuits and typically range in size from 30 to 100 amps. The element in a cartridge fuse runs down the center of the cartridge and is surrounded by a fireproof material that resembles sand.

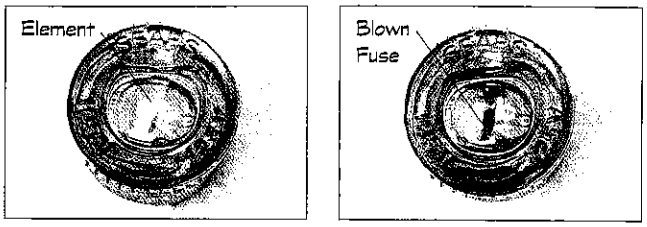
Most fuse panels in use today are probably quite old. It is rather common for fuse boxes like these to require troubleshooting. Loose connections in an old fuse holder may produce enough heat to instantaneously vaporize a fuse element. If a fuse or fuse holder is dis-



An obsolete fuse box, *such as the one shown here, is commonly found in older homes. Such boxes are frequently in need of troubleshooting or replacement.*

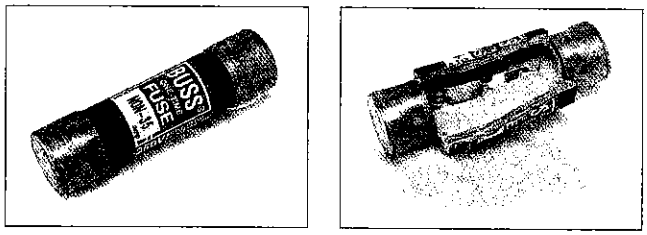
Fuse Types

Glass Fuses



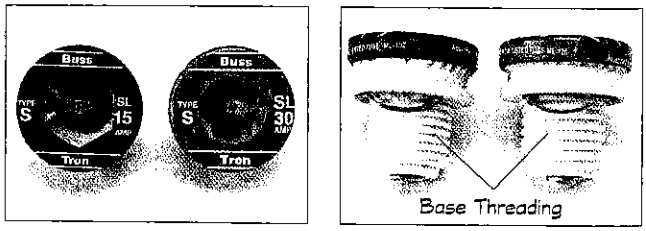
Glass, or plug, fuses *are commonly found in older homes. Never replace a fuse with one of larger capacity. It's a fire hazard because the fuse will allow enough current through the wire to damage the wire insulation. A metal element inside the fuse will burn and blow out a correctly sized fuse (right), indicating an overload or short circuit if the current exceeds capacity.*

Cartridge Fuses



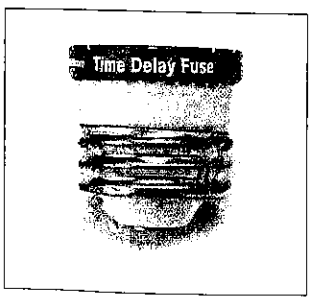
A 60-amp cartridge fuse *may be used as the main fuse in an older home. Cartridge fuses range from 30 to 100 amps. A cartridge fuse contains an element not unlike that in a glass fuse, except that it is embedded in nonflammable material (right).*

Type S Fuses



The Type S fuse *was designed to replace the standard glass fuse. Each Type S fuse size has a different base-threading configuration (right) to prevent a homeowner from installing a high-amp fuse in a low-amp fuse socket.*

Time-Delay Fuses



Some glass fuses *are designed to withstand a temporary surge in power without blowing. This type of fuse should be marked "time-delay" on the edge.*

HOW TO: Install an Arc-Fault Circuit Interrupter in an Existing Circuit

Difficulty Level:

Tools and Materials

- Insulated screwdrivers
- Voltage tester
- AFCI Breaker
- Wire stripper or jackknife
- Long-nose pliers
- Flashlight

Arc-Fault Circuit Interrupters

The National Electric Code requires an arc-fault circuit-interrupter (AFCI) breaker be installed to protect branch circuits that supply 125-volt, 15- and 20-ampere outlet(s) in bedrooms. The requirement applies to all new construction, but switching existing circuits will supply this protection to existing buildings as well.

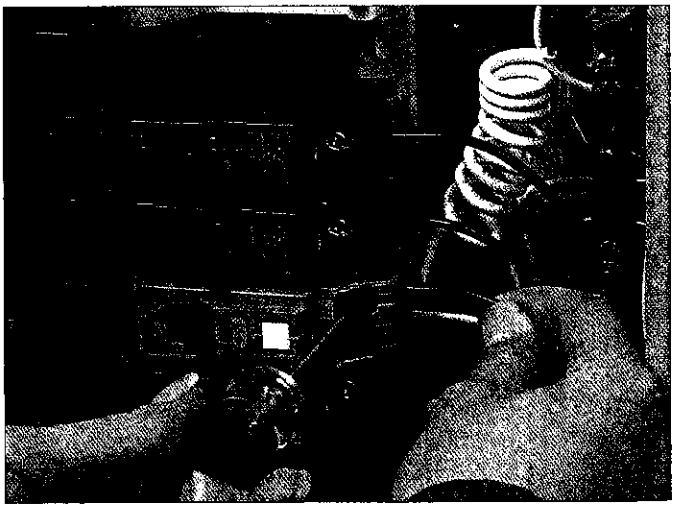
What Is an Arc Fault? When a live wire makes a solid contact with a grounded object or a neutral wire, the current drawn causes a short and trips a standard circuit breaker. But if the contact is intermittent because of loose or corroded connections or damaged insulation, an arc of current develops. The arc causes heat in the range of thousands of degrees F, which left to continue might ignite combustible material in the vicinity and cause a fire.

AFCIs prevent fires by shutting down the circuit once it detects an arcing situation. The AFCI recognizes normal arcing and sparking created by normal use of electrical equipment and devices, such as when you unplug an appliance that is still on. But when the AFCI detects abnormal sparking or arcing, it is programmed to shut down the power to the circuit.

AFCI Breakers. AFCI circuit breakers have a test button and look similar to ground-fault circuit-interrupter (GFCI) circuit breakers. The breaker is wired to the hot and the neutral of the branch circuit, with a pigtail from the breaker to connect to the neutral bus, similar to the wiring of a GFCI breaker. Some designs combine GFCI and AFCI protection.

AFCIs do not protect against all faults in older wiring where there is no ground. However, they will provide protection against some arcing in these homes. In all homes they would add to the level of protection against fires caused by arcs, and in modern wired homes, they would add a significant level of protection. The AFCI circuit breaker provides protection for the branch circuit wiring and limited protection for power cords and extension cords. Single-pole, 15- and 20- ampere AFCI circuit breakers are currently available. Before installing any electrical devices or equipment, always read the accompanying installation instructions and follow the sequence for installation and testing.

1 *Turn off the main circuit breaker to cut power to the panel. Disconnect the black power wire from the circuit breaker that you are replacing.*



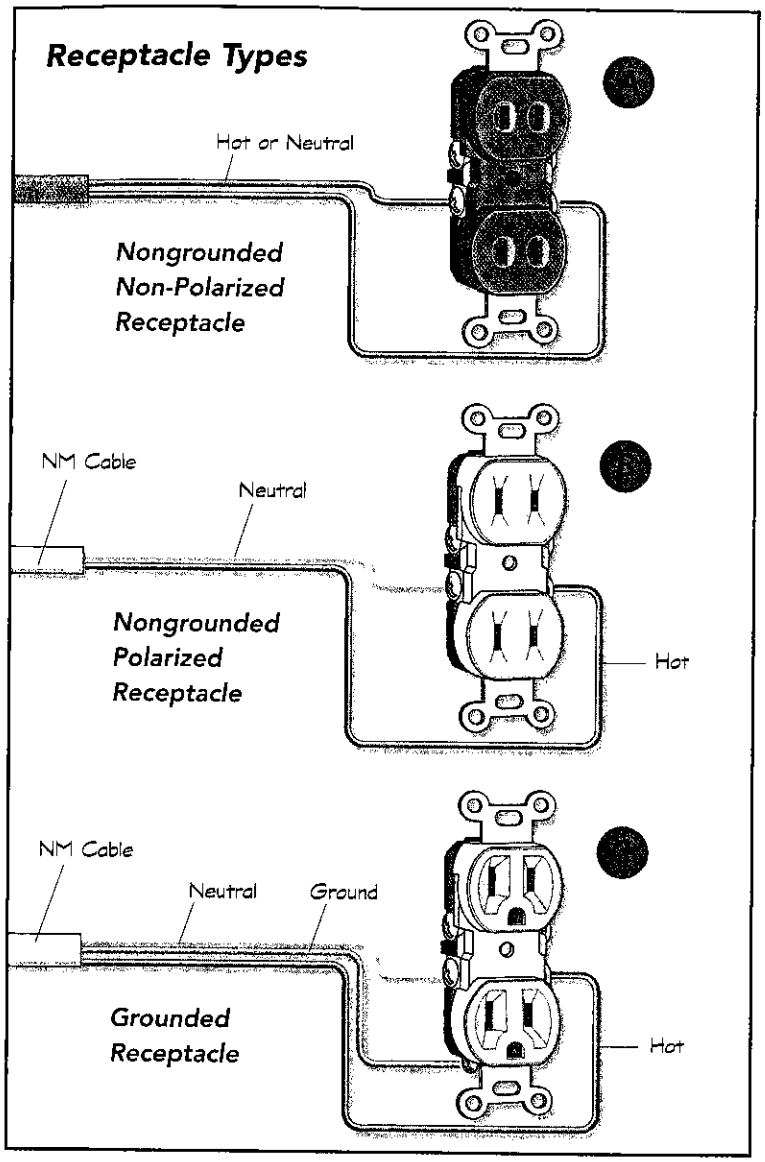
4 *Connect the neutral from the circuit in the slot labeled LOAD NEUTRAL. Connect the black power wire to the other terminal.*

Identify the Bedroom Circuits. Open the panel board door and read the circuit chart that identifies which circuit breaker(s) supply circuits in the bedroom(s). Turn the circuit breaker to the OFF position. Plug a lamp in the receptacles, or use a voltage tester to ensure that the correct circuit breaker is identified on the panel board chart. Turn off all other branch circuit breakers. Turn off the main circuit breaker last, it is normally located at the upper section of the panel board. Loosen or remove the panel board trim screws. Different manufacturers use different methods of securing the trim.

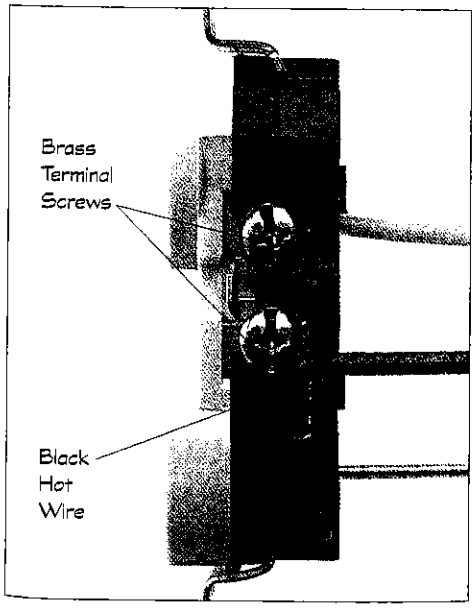
Receptacles

Duplex Receptacles

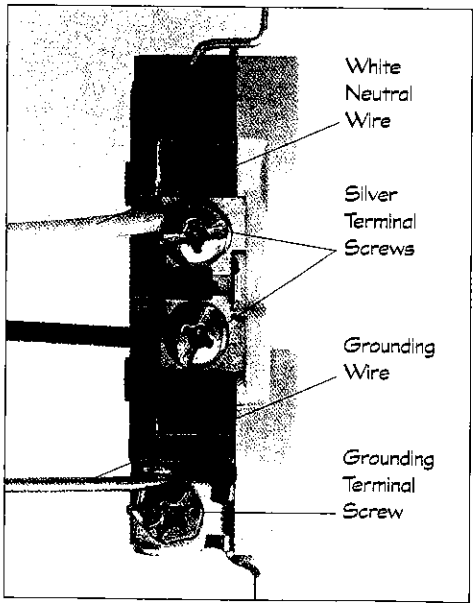
Although there are two basic types of receptacles—single and duplex—only duplex receptacles are commonly found in modern homes. A duplex receptacle accommodates two plugs at the same time. Originally, receptacles were neither grounded nor polarized; later, they became polarized but not grounded. Today, 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.*



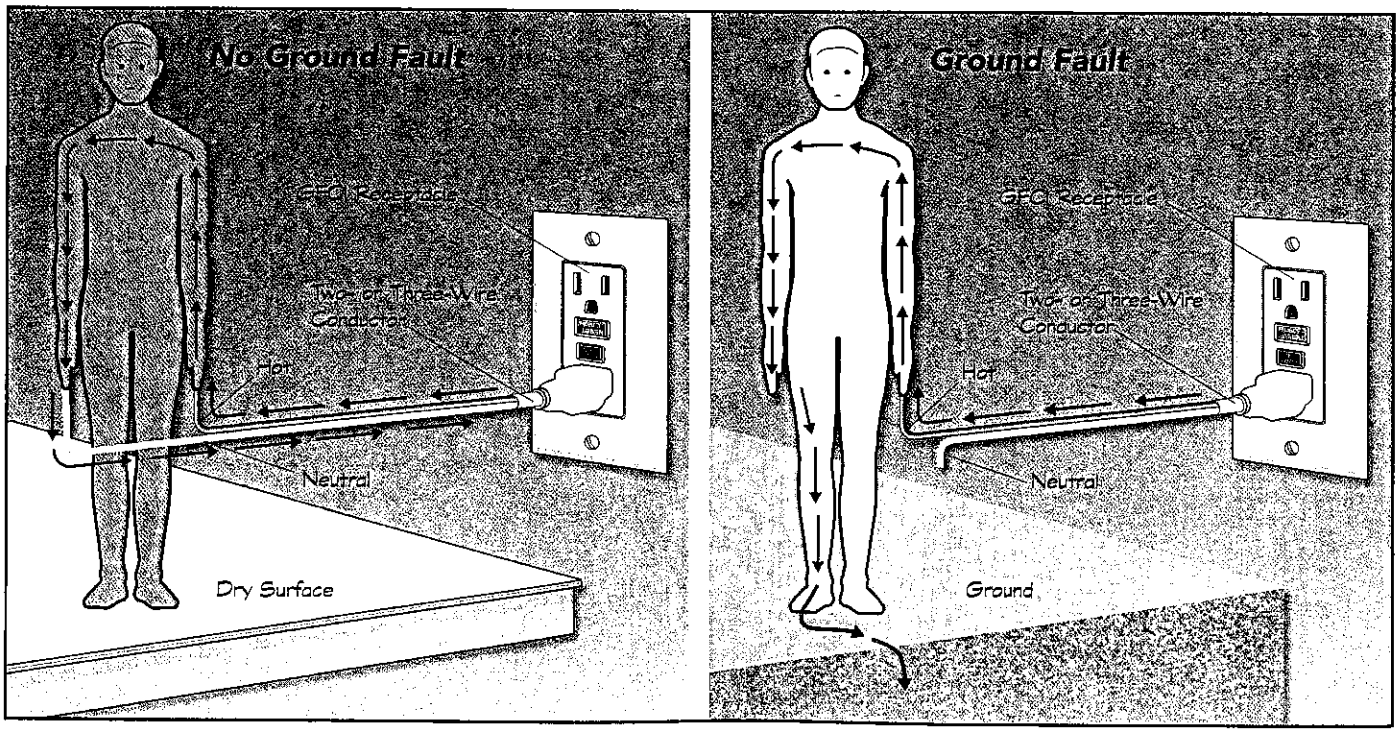
◂ ***Receptacle, left side.*** *The silver terminal screws on a receptacle receive the white neutral wires, while the green terminal screw receives the grounding wire.*

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 ⅟₂₅th to ⅟₃₀th 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.

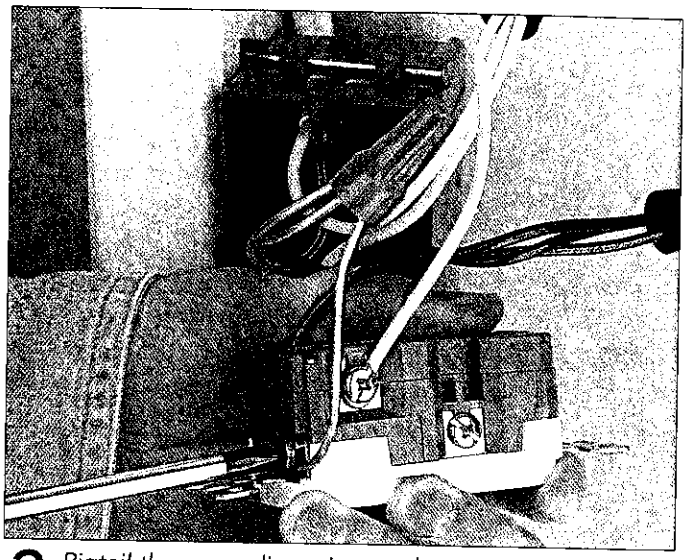
A GFCI receptacle, however, is not foolproof. For a ground-fault circuit interrupter to succeed, a ground-fault must first occur. This happens when current flows out of the normal circuit to a ground pathway, causing the imbalance between the black and white wires mentioned earlier. In this instance, 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.

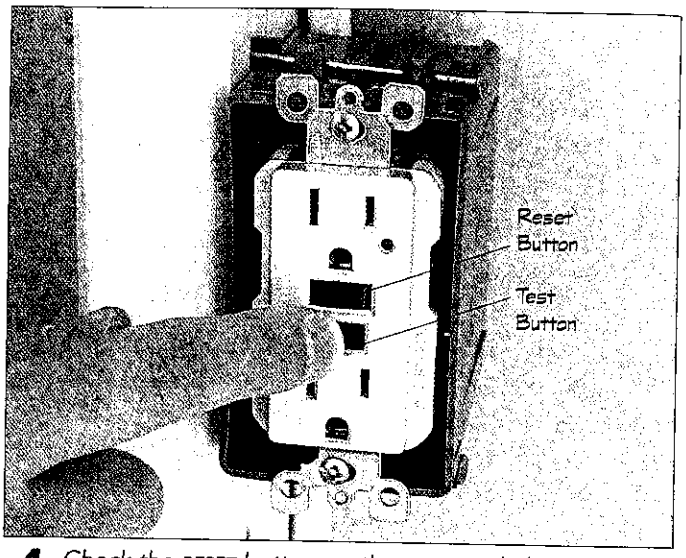


If an electrical current flows *through your body from a hot wire to a neutral wire, this completes an electrical circuit—just as though you were an appliance or fixture. In this case, a ground-fault circuit interrupter cannot save you from being electrocuted because it cannot distinguish you from your 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.*

Connect the GFCI Grounding Wires, and Install the Receptacle. Splice the bare copper cable grounding wires together, and then pigtail them to the green GFCI receptacle grounding screw. **(Photo 3)** Install the GFCI receptacle box and coverplate, and then turn on the power. Using a neon circuit tester, test the circuit for power. Press the TEST button to see whether or not the GFCI is operational; then reset it. **(Photo 4)**

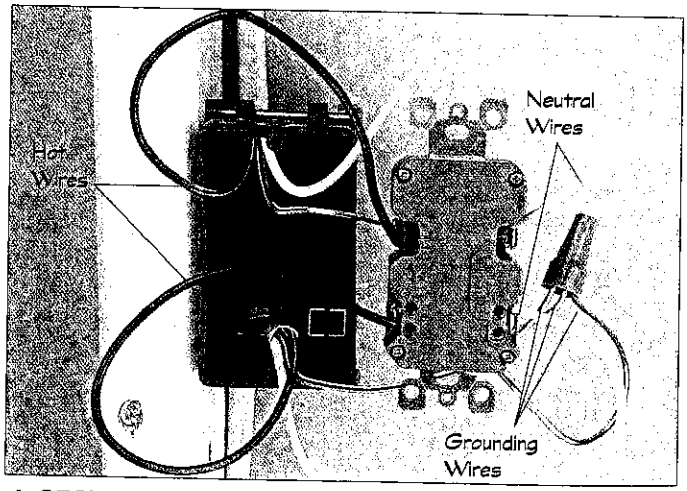


3 *Pigtail the grounding wires to the green GFCI receptacle grounding screw.*



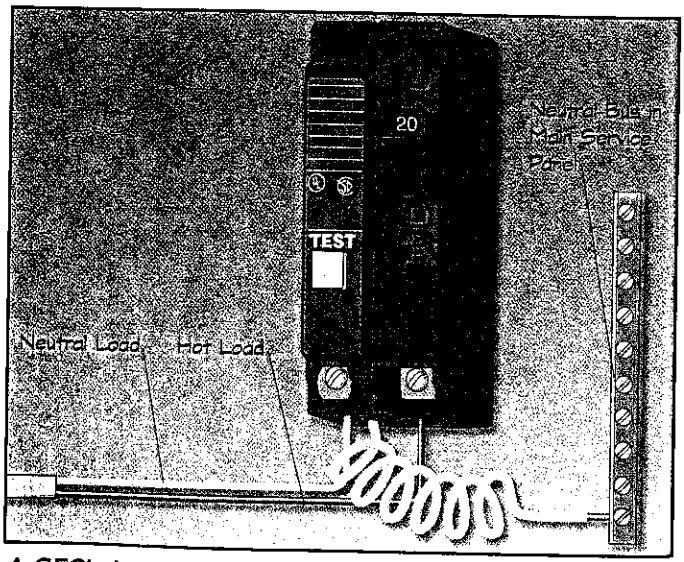
4 *Check the RESET button on the receptacle by pushing in the TEST button; the RESET button should pop out.*

Protecting Multiple Locations. If you want several receptacles farther down circuit, or *downstream*, from the GFCI receptacle to also have GFCI protection, then use the method of wiring for multiple locations. Wire the receptacle using a middle-of-run configuration, connecting the downstream hot and neutral wires to the screw terminals labeled LOAD. In this type of connection, any *upstream* receptacles will not be protected.

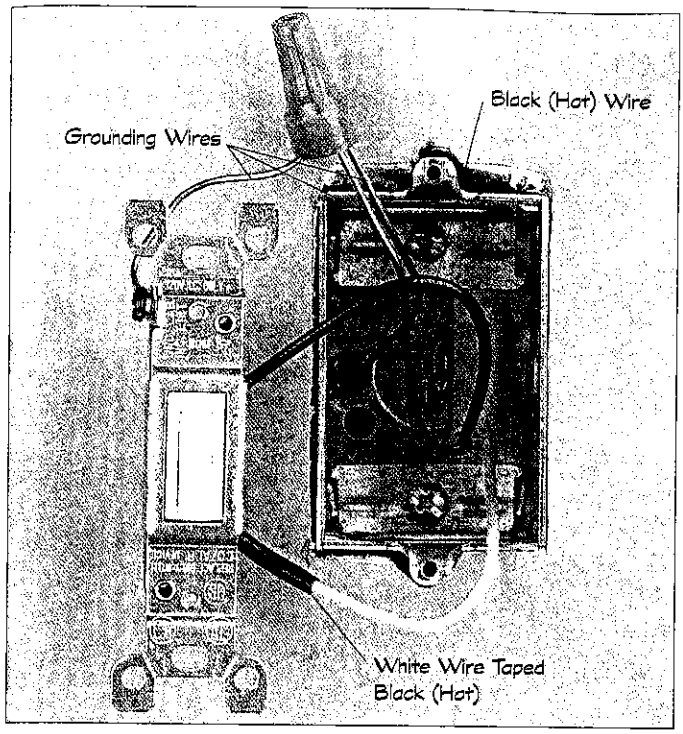


A GFCI receptacle *for multilocation protection will have one set of hot and neutral wires connected to the LINE terminal screws and the other to the LOAD terminal screws.*

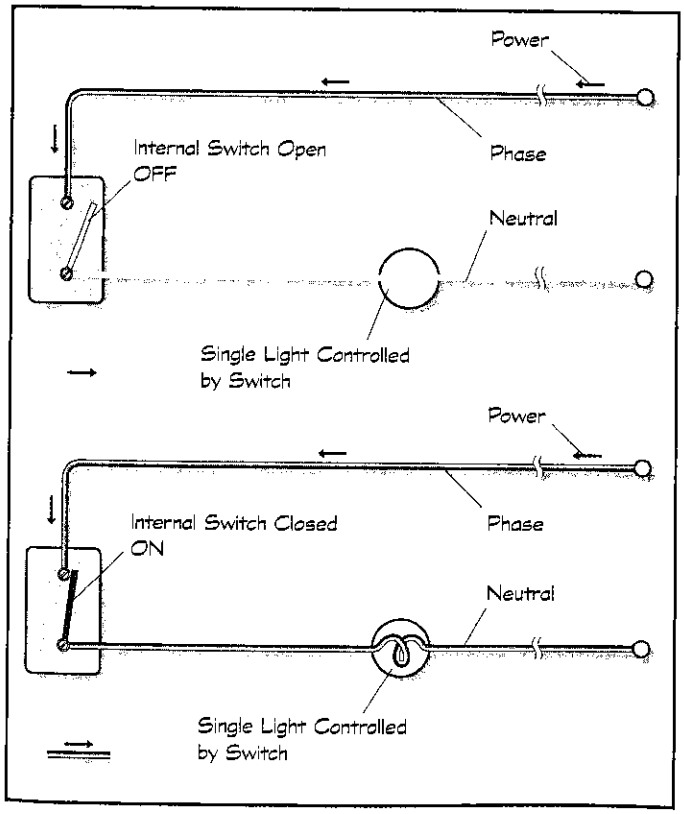
GFCI Breaker. To install the circuit breaker type of GFCI, simply insert the device into the panel box in the same way as a conventional circuit breaker; then connect the wires from the circuit you wish to protect. Connect the white corkscrew wire attached to the GFCI circuit breaker to the white neutral bus in the panel.



A GFCI circuit breaker *is easy to install—simply connect the black and white load wires to the appropriate screw terminals on the breaker; then connect the white "corkscrew" wire to the panel neutral bus.*



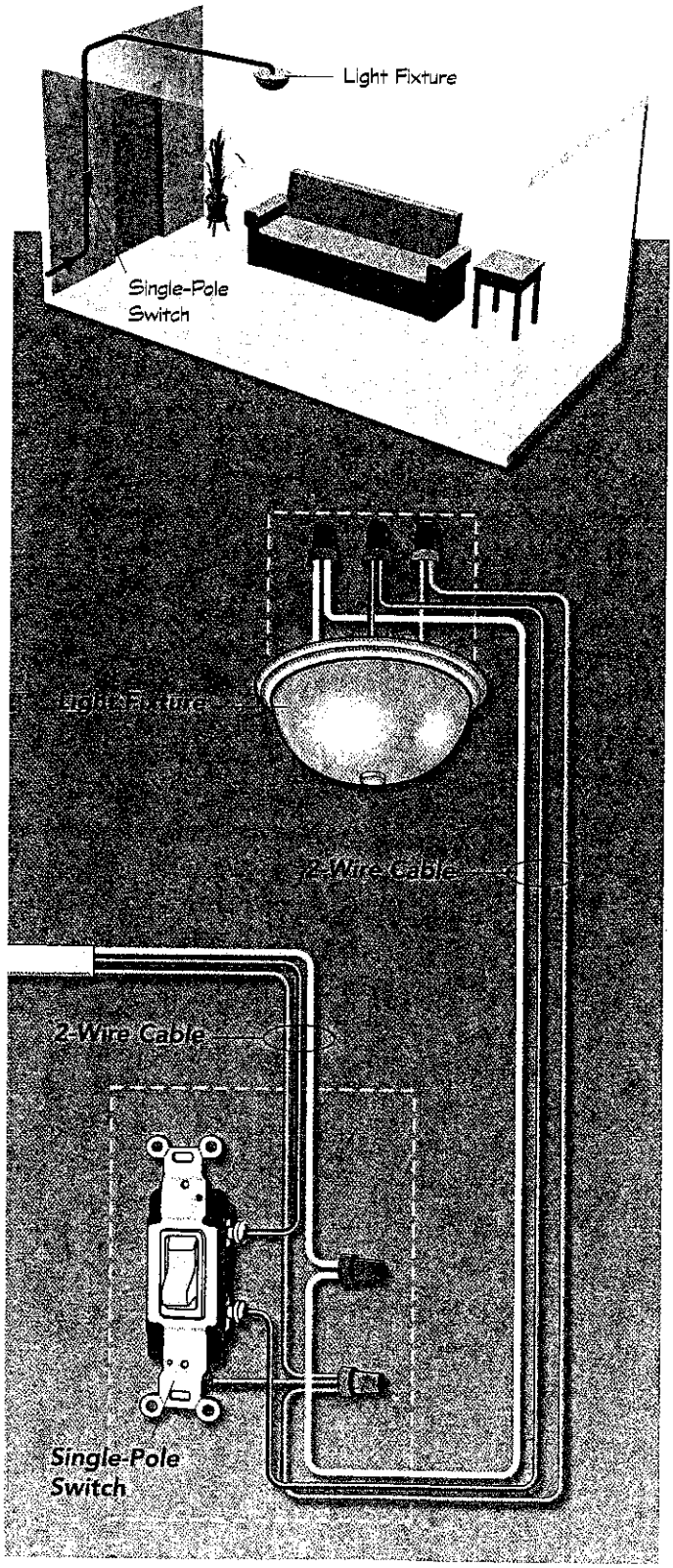
At the end of a circuit, *both the black and white wires connecting to a switch are hot. To indicate this, wrap the white wire with black tape.*



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.*

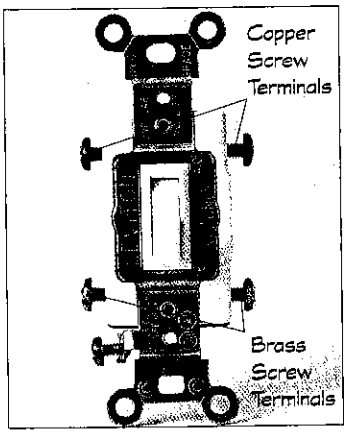
Single-Pole Switch to Light Fixture

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.

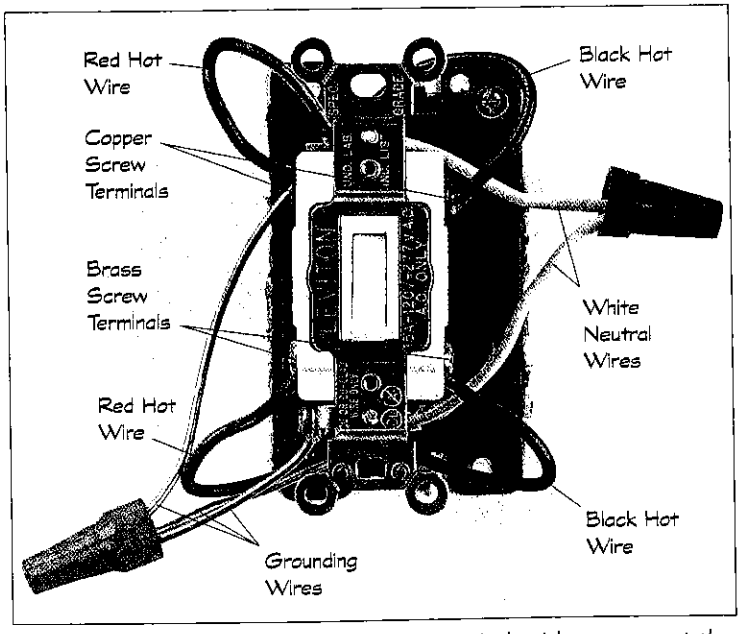


Four-Way Switches

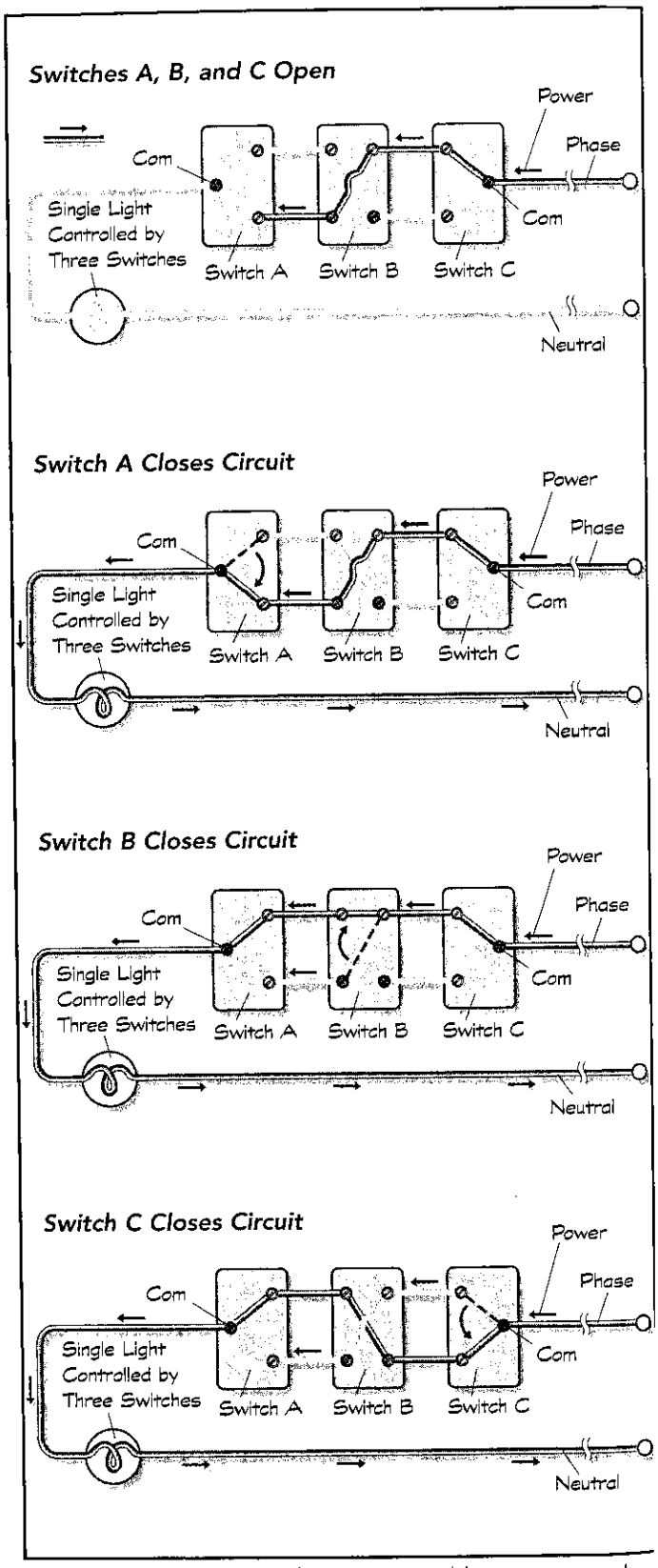
A four-way switch can be connected between two three-way switches to allow you to control a light from three different locations. A four-way switch is installed in line or "series" with the travelers between the two three-way switches. A three-wire cable should be run from the first three-way switch to the four-way switch and from the second three-way switch to the four-way switch. The red and black wires from the first switch connect to the brass-color screws, and the black and red wires from the second switch connect to the dark- or copper-color screws. The white neutral conductor is carried all the way through all switches. Pigtail the grounding wires to the green grounding screw inside the metal switch box.



A four-way switch *has four terminal screws. It looks similar to a double-pole switch, but does not have any dedicated* ON *or* OFF *position. A four-way switch controls an outlet or fixture from three separate locations, in tandem with two three-way switches; it must always be located between the other two switches on the circuit.*



The internal levers *in a four-way switch either connect the screw terminals in a straight vertical configuration or in a diagonal X pattern. In combination with the two three-way switches, this permits the circuit to be completed or broken by any one of the three switches.*

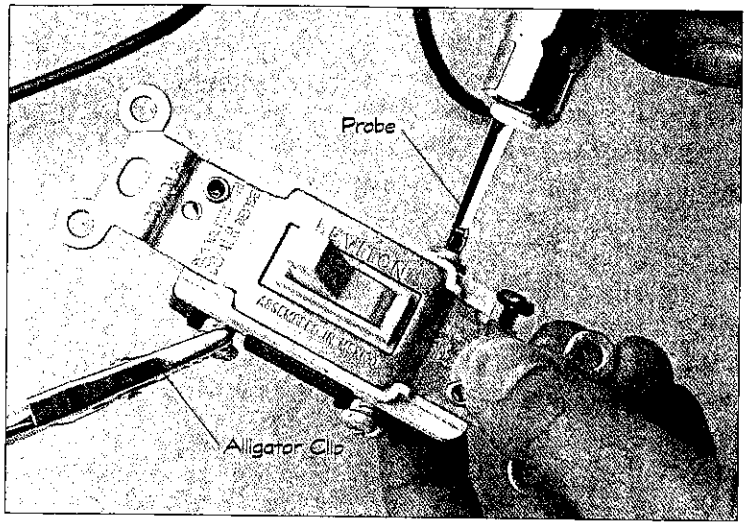


A four-way light switch *has two operable contacts and two fixed contacts. In the first position, the switch is open; in the second position, the circuit is completed to switch box A; in the switch is also closed but the circuit completed to switch box B; and in the fourth position, the circuit is closed to switch box C.*

CREATIVE HOMEOWNER® SMART TIP

Testing a Switch

When you flip on a switch and the switch circuit doesn't work, the problem may not be with the switch. It could be a blown fuse, a tripped circuit breaker, or a faulty fixture. First check the service panel; then test the switch. Begin by removing the fuse or setting the breaker on the switch circuit to the OFF position; then remove the switch coverplate. Apply the probes on a multi-tester to the black and white wire terminal screws to verify that the power is turned off; then turn on the switch. Next, touch the probe and clip of a battery-operated continuity tester to the wire terminals. If the switch is good, then the tester will either light up or buzz. Finally, turn off the switch. If it is good, then the tester should no longer light up or buzz. Replace the switch if it fails any of these tests. If the switch is good, the fault must be in the fixture.



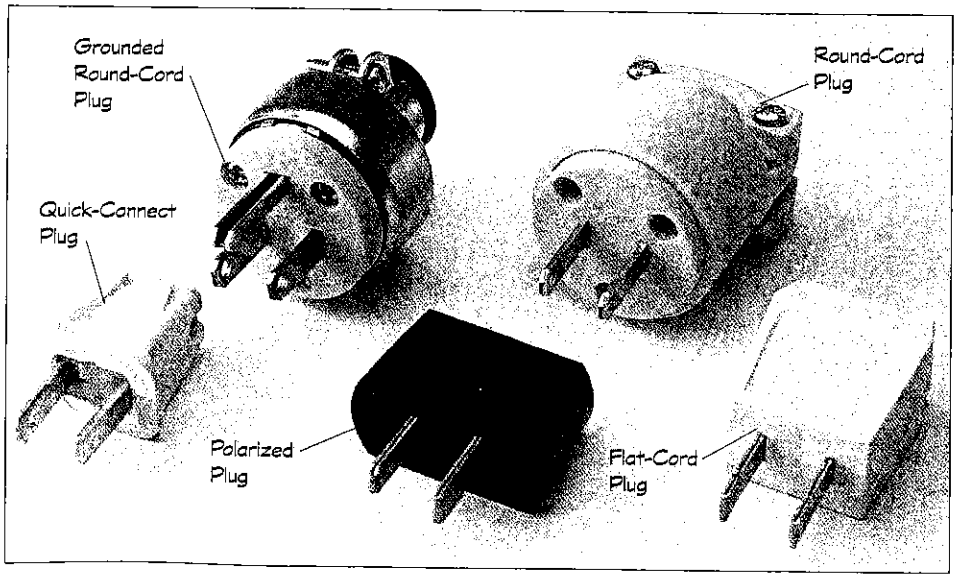
Use a continuity tester *to test the integrity of an unwired or disconnected switch. Attach the alligator clip to one terminal screw and touch the probe to the other. If the switch is good, the probe will light when you turn the switch on, but will not light when you turn it off.*

Plugs, Cords, and Sockets

Standard Plugs

Plugs come in a variety of different styles and shapes, including flat- or round-corded, grounded, polarized, and quick-connect. Round-corded plugs are typically used on larger appliances that require three-pronged, grounded plugs; smaller appliances commonly use flat-corded plugs. A polarized plug has one wide and one narrow prong and can only be inserted into a receptacle so that the neutral and hot cord wires properly align with the neutral and hot receptacle wires.

Some homeowners may still be using fixtures that have older-style, permanently attached cords and plugs. Because such cords and plugs no longer meet NEC standards, it is simply cheaper and safer for you to replace them, rather than attempting to repair them. When you do replace a plug or cord, be sure that the new device meets current code requirements (NEC Article 400). If your existing cord is in good condition, but the plug needs to be replaced, cut the cord just behind the plug, and strip the insulation off the end of the cut wires. Then properly reconnect them to the new plug.



Plugs come in various configurations *for different purposes; be sure that the replacement plugs you buy are appropriate for the appliances, receptacles, or wires to which they will be connected.*