

NONRESIDENT TRAINING COURSE

January 1998



Construction Electrician Basic

NAVEDTRA 14026

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Although the words "he," "him," and "his" are used sparingly in this course to enhance communication, they are not intended to be gender driven or to affront or discriminate against anyone.

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PREFACE

By enrolling in this self-study course, you have demonstrated a desire to improve yourself and the Navy. Remember, however, this selfstudy course is only one part of the total Navy training program. Practical experience, schools, selected reading, and your desire to succeed are also necessary to successfully round out a fully meaningful training program.

THE COURSE: This self-study course is organized into subject matter areas, each containing learning objectives to help you determine what you should learn along with text and illustrations to help you understand the information. The subject matter reflects day-to-day requirements and experiences of personnel in the rating or skill area. It also reflects guidance provided by Enlisted Community Managers (ECMs) and other senior personnel, technical references, instructions, etc., and either the occupational or naval standards, which are listed in the *Manual of Navy Enlisted Manpower Personnel Classifications and Occupational Standards*, NAVPERS 18068.

THE QUESTIONS: The questions that appear in this course are designed to help you understand the material in the text.

VALUE: In completing this course, you will improve your military and professional knowledge. Importantly, it can also help you study for the Navy-wide advancement in rate examination. If you are studying and discover a reference in the text to another publication for further information, look it up.

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Sailor's Creed

"I am a United States Sailor.

I will support and defend the Constitution of the United States of America and I will obey the orders of those appointed over me.

I represent the fighting spirit of the Navy and those who have gone before me to defend freedom and democracy around the world.

I proudly serve my country's Navy combat team with honor, courage and commitment.

I am committed to excellence and the fair treatment of all."

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SUMMARY OF THE CONSTRUCTION ELECTRICIAN TRAINING SERIES

CONSTRUCTION ELECTRICIAN BASIC

This training manual (TRAMAN) replaces *Construction Electrician 3* and should be studied by those seeking advancement to Construction Electrician Third Class.

CONSTRUCTION ELECTRICIAN INTERMEDIATE

This TRAMAN, when published (refer to NAVEDTRA 12061 for availability), will replace *Construction Electrician 3 & 2* and should be studied by those seeking advancement to Construction Electrician Second Class. Topics in this book will be a continuation of information covered in the *Construction Electrician Basic* TRAMAN.

CONSTRUCTION ELECTRICIAN ADVANCED

This TRAMAN, when published (refer to NAVEDTRA 12061 for availability), will replace *Construction Electrician 1* and should be studied by those seeking advancement to Construction Electrician First Class. Topics in this book will be a continuation of information covered in the *Construction Electrician Intermediate* TRAMAN.

INSTRUCTIONS FOR TAKING THE COURSE

ASSIGNMENTS

The text pages that you are to study are listed at the beginning of each assignment. Study these pages carefully before attempting to answer the questions. Pay close attention to tables and illustrations and read the learning objectives. The learning objectives state what you should be able to do after studying the material. Answering the questions correctly helps you accomplish the objectives.

SELECTING YOUR ANSWERS

Read each question carefully, then select the BEST answer. You may refer freely to the text. The answers must be the result of your own work and decisions. You are prohibited from referring to or copying the answers of others and from giving answers to anyone else taking the course.

SUBMITTING YOUR ASSIGNMENTS

To have your assignments graded, you must be enrolled in the course with the Nonresident Training Course Administration Branch at the Naval Education and Training Professional Development and Technology Center (NETPDTC). Following enrollment, there are two ways of having your assignments graded: (1) use the Internet to submit your assignments as you complete them, or (2) send all the assignments at one time by mail to NETPDTC.

Grading on the Internet: Advantages to Internet grading are:

- you may submit your answers as soon as you complete an assignment, and
- you get your results faster; usually by the next working day (approximately 24 hours).

In addition to receiving grade results for each assignment, you will receive course completion confirmation once you have completed all the assignments. To submit your assignment answers via the Internet, go to:

http://courses.cnet.navy.mil

Grading by Mail: When you submit answer sheets by mail, send all of your assignments at one time. Do NOT submit individual answer sheets for grading. Mail all of your assignments in an envelope, which you either provide yourself or obtain from your nearest Educational Services Officer (ESO). Submit answer sheets to:

COMMANDING OFFICER
NETPDTC N331
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32559-5000

Answer Sheets: All courses include one "scannable" answer sheet for each assignment. These answer sheets are preprinted with your SSN, name, assignment number, and course number. Explanations for completing the answer sheets are on the answer sheet.

Do not use answer sheet reproductions: Use only the original answer sheets that we provide— reproductions will not work with our scanning equipment and cannot be processed.

Follow the instructions for marking your answers on the answer sheet. Be sure that blocks 1, 2, and 3 are filled in correctly. This information is necessary for your course to be properly processed and for you to receive credit for your work.

COMPLETION TIME

Courses must be completed within 12 months from the date of enrollment. This includes time required to resubmit failed assignments.

PASS/FAIL ASSIGNMENT PROCEDURES

If your overall course score is 3.2 or higher, you will pass the course and will not be required to resubmit assignments. Once your assignments have been graded you will receive course completion confirmation.

If you receive less than a 3.2 on any assignment and your overall course score is below 3.2, you will be given the opportunity to resubmit failed assignments. **You may resubmit failed assignments only once.** Internet students will receive notification when they have failed an assignment--they may then resubmit failed assignments on the web site. Internet students may view and print results for failed assignments from the web site. Students who submit by mail will receive a failing result letter and a new answer sheet for resubmission of each failed assignment.

COMPLETION CONFIRMATION

After successfully completing this course, you will receive a letter of completion.

ERRATA

Errata are used to correct minor errors or delete obsolete information in a course. Errata may also be used to provide instructions to the student. If a course has an errata, it will be included as the first page(s) after the front cover. Errata for all courses can be accessed and viewed/downloaded at:

http://www.advancement.cnet.navy.mil

STUDENT FEEDBACK QUESTIONS

We value your suggestions, questions, and criticisms on our courses. If you would like to communicate with us regarding this course, we encourage you, if possible, to use e-mail. If you write or fax, please use a copy of the Student Comment form that follows this page.

For subject matter questions:

E-mail: n314.products@cnet.navy.mil
Phone: Comm: (850) 452-1001, Ext. 1826
DSN: 922-1001, Ext. 1826
FAX: (850) 452-1370
(Do not fax answer sheets.)
Address: COMMANDING OFFICER
NETPDTC (CODE 314)
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32509-5237

For enrollment, shipping, grading, or completion letter questions

E-mail: fleetservices@cnet.navy.mil
Phone: Toll Free: 877-264-8583
Comm: (850) 452-1511/1181/1859
DSN: 922-1511/1181/1859
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NAVAL RESERVE RETIREMENT CREDIT

If you are a member of the Naval Reserve, you will receive retirement points if you are authorized to receive them under current directives governing retirement of Naval Reserve personnel. For Naval Reserve retirement, this course is evaluated at 9 points. (Refer to *Administrative Procedures for Naval Reservists on Inactive Duty,* BUPERSINST 1001.39, for more information about retirement points.)

COURSE OBJECTIVES

In completing this nonresident training course, you will demonstrate a knowledge of the subject matter by correctly answering questions on the following subjects: Construction Support, Drawings and Specifications, Power Generation, Power Distribution, Interior Wiring, Communications and Lighting, and Electrical Appliances, Test Equipment, Motors, and Generators.

Student Comments

Course Title: *Construction Electrician Basic*

NAVEDTRA: 14026 **Date**: _____

We need some information about you:

Rate/Rank and Name: _____ SSN: _____ Command/Unit _____

Street Address: _____ City: _____ State/FPO: _____ Zip _____

Your comments, suggestions, etc.:

Privacy Act Statement: Under authority of Title 5, USC 301, information regarding your military status is requested in processing your comments and in preparing a reply. This informationwill not be divulged without written authorization to anyone other than those within DOD for official use in determining performance.

NETPDTC 1550/41 (Rev 4-00)

CHAPTER 1

CONSTRUCTION SUPPORT

As a Construction Electrician you will be involved in many aspects of construction work. This chapter touches on a few of these, such as rigging and hoisting, equipment movement, hazardous material, embarkation, and tool kits. Although this chapter does not deal with electrical work, you need to study and refer back to this chapter for your safety and the safety of your shipmates.

USING LINES AND SLINGS

The safety of personnel involved in rigging and hoisting operations largely depends upon care and common sense. Equally important is the proper selection of lines and slings for safe and stable lifts.

INSPECTIONS

The single most important operational check to be made on hoisting and rigging equipment is the line and rigging inspection. Such factors as abrasion, wear, fatigue, corrosion, and kinking are of great significance in determining usable life.

The only way to determine the safety of a line, its life expectancy, and its load-carrying ability is by regularly inspecting every foot of its length. The main points to watch for are external wear and cutting, internal wear between the strands, and deterioration of the fibers.

FIBER LINES

Fiber lines are made from either natural or synthetic fibers. The natural fibers come from plants and include manila, sisal, and hemp. The synthetic fibers include nylon, polypropylene, and the polyesters. The strength of these lines depends on their size, the fiber used, and the type of stranding.

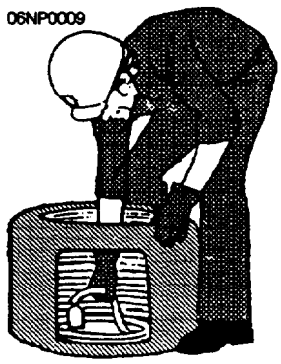


Figure 1-1.—Removing line from a shipping coil.

Uncoiling Line

New line is coiled, bound, and wrapped. The protective covering should not be removed until the line is to be used. This covering will protect the line during stowage and prevent tangling. To open, strip off the outer wrapping and look inside the coil for the end of the line. This should be at the bottom of the coil. If not, turn the coil over so that the end will be at the bottom, as shown in figure 1-1. Pull the end of the line up through the center of the coil. As the line comes up through the coil, it will unwind in a counterclockwise direction.

Whipping Line

The term *whipping* refers to the process of securing the ends of a line to prevent the strands from unraveling and the yarns from separating or fraying. Whippings are made from fine twine and will not increase the size of the line enough to prevent it from fitting the blocks or openings.

Figure 1-2 shows the steps to follow in applying a whipping. Make a loop in the end of the twine and place

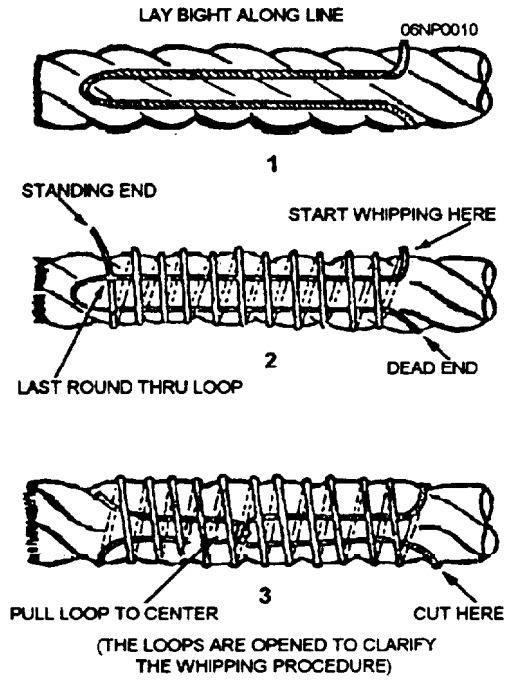


Figure 1-2.—Proper way to apply a line whipping.

the loop at the end of the line, as shown in the figure. Wind the standing part around the line covering the loop of the whipping. Leave a small loop uncovered, as shown. Pass the remainder of the standing end up through the small loop and pull the dead end of the twine, thus pulling the small loop and the standing end back towards the end of the line underneath the whipping. Pull the dead end of the twine until the loop with the standing end reaches a point midway underneath the whipping. Trim both ends of the twine close up against the loops of the whipping. Before cutting a line, place two whippings on the line 1 or 2 inches apart and make the cut between the whippings. This will prevent the ends from unraveling after they are cut.

Stowing Line

Before stowing a fiber line, you must take certain precautions to safeguard the line against deterioration. You should never stow a wet line. Always dry the line well before placing it in stowage.

After a line has been used, you should coil it down in a clockwise direction (assuming it is a right-hand lay). Should the line be kinked from excessive turns, remove the kinks by the procedure known as "thorough footing." You do this by coiling the line down counterclockwise and then pulling the bottom end of the coil up and out the middle of the coil. If the line is free of kinks as it leaves the coil, make it up in the correct manner. If it is still kinked, repeat the process before making up the line for stowage.

Choose your stowage space for line carefully. Line deteriorates rapidly if exposed to prolonged dampness. Furthermore, it is important for the stowage area to be dry, unheated, and well ventilated. To permit proper air circulation, you should either place the line in loose coils on a wood grating platform about 6 inches (15 cm) above the floor or hang the line in loose coils on a wooden peg.

You should NEVER expose a line to lime, acids, or other chemicals, or even stow it in a room containing chemicals. Even the vapors may severely damage line. As a final precaution, avoid continually exposing line to sunlight. Excessive sunlight will also damage the line.

Strength of Fiber Line

Overloading a line poses a serious threat to the safety of personnel, not to mention the heavy losses likely to result through damage to material. To avoid overloading, you must know the strength of the line you are working with. This involves three factors: breaking strength, safe working load, and safety factor.

BREAKING STRENGTH.—Refers to the tension at which the line will part when a load is applied. Line manufacturers have determined breaking strength through tests and have set up tables to provide this information

SAFE WORKING LOAD—Briefly defined, the "safe working load" (SWL) of a line is the load that can be applied without causing any kind of damage to the line. Note that the safe working load is considerably less than the breaking strength. A wide margin of difference between breaking strength and safe working load is necessary to allow for such factors as additional strain imposed on the line by jerky movements in hoisting or bending over sheaves in a pulley block.

SAFETY FACTOR.— safety factor of a line is the ratio between the breaking strength and the safe working load. Usually, a safety factor of 4 is acceptable, but this is not always the case. In other words, the safety factor will vary, depending on such things as the condition of the line and circumstances *under* which it is to be used. While the safety factor should NEVER be less than 3, it often should be well above 4 (possibly as high as 8 or 10). For best, average, or unfavorable conditions, the safety factor indicated below may often be suitable.

BEST conditions (new line): 4

AVERAGE conditions (line used but in good condition): 6

UNFAVORABLE conditions (frequently used line, such as running rigging): 8

Table 1-1 lists some of the properties of manila and sisal line, including strength. The table shows that the minimum breaking strength is considerably greater than the safe working capacity. The difference is caused by the application of a safety factor. The safe working load (SWL) of line is obtained by dividing the breaking strength (BS) by a factor of safety (FS). A new 1-inch-diameter No. 1 manila line has a breaking strength of 9,000 pounds, as indicated in table l-l. To determine the safe working load of the line, you would divide its breaking strength by a minimum standard safety factor

of 4. The result is an SWL of 2,250 pounds. A safety factor is always used because the breaking strength of line be comes reduced after use and exposure to weather conditions. In addition, a safety factor is required because of shock loading, knots, sharp bends, and other stresses that the line may encounter during its use.

If tables are not available, the SWL may be closely approximated by a rule of thumb. The rule of thumb for the SWL, in tons, for fiber line is equal to the square of the line diameter in inches (SWL = D^2). The SWL, in tons, of a 1/2-inch-diameter fiber line would be 1/2 inch squared or 1/4 ton. The rule of thumb allows a safety factor of approximately 4.

SYNTHETIC-FIBER LINES

Synthetic-fiber lines, such as nylon and polyester, have rapidly gamed wide use by the Navy. They are lighter in weight, more flexible, less bulky, and easier to handle and stow than manila lines. Also, they are highly resistant to mildew, rot, and fungus. Synthetic lines are stronger than natural-fiber line; for example, nylon is about three times stronger than manila. When nylon line is wet or frozen, the loss of strength is relatively small. Nylon line will hold a load, even though several strands may be frayed. Ordinarily, the line can be made reusable by cutting away the chafed or frayed section and splicing the good line together.

Table 1-1.—Properties of Manila and Sisal Line

Nominal diameter (inches)	Circum-ference (inches)	Lb per ft	No. 1 Manila		Sisal	
			Breaking strength (pounds)	Safe load (pounds) F.S. = 4	Breaking strength (pounds)	Safe load (pounds) F.S. = 4
1/4	3/4	.020	600	150	480	120
3/8	1 1/8	.040	1,350	325	1,080	260
1/2	1 1/2	.075	2,650	660	2,120	520
5/8	2	.133	4,400	1,100	3,520	880
3/4	2 1/4	.167	5,400	1,350	4,320	1,080
7/8	2 3/4	.186	7,700	1,920	6,160	1,540
1	3	.270	9,000	2,250	7,200	1,800
1 1/8	3 1/2	.360	12,000	3,000	9,600	2,400
1 1/4	3 3/4	.418	13,500	3,380	10,800	2,700
1 1/2	4 1/2	.600	18,500	4,620	14,800	3,700
1 3/4	5 1/2	.895	26,500	6,625	21,200	5,300
2	6	1.08	31,000	7,750	24,800	6,200
2 1/2	7 1/2	1.35	46,500	11,620	37,200	9,300
3	9	2.42	64,000	16,000	51,200	12,800

Tables 1-2 and 1-3 list the approximate safe working loads of new fiber lines with a safety factor of 5.

NOTE: These are for reference only. Check the manufacturer's ratings before determining the safe working loads, as they may differ from the tables.

You may not always have a chart available to tell you the safe working load for a particular size of line. There is a rule of thumb that will adequately serve your needs on such an occasion. The formulas below are examples of synthetic fiber lines used for rigging, not slings.

For **nylon** or **polyester** line, change the line diameter into eighths of an inch, square the numerator, and multiply by 60.

Example: 1/2-inch nylon line = 4/8-inch diameter

SWL = 4 x 4 x 60 = 960 lb

For polypropylene line, multiply the diameter by 40, and for polyethylene, by 35.

Remember that the strength of a line decreases with age, use, and exposure to excessive heat, boiling water, or sharp bends. Especially with used line, you should give these and other factors affecting strength careful consideration and make proper adjustment in the breaking strength and SWL of the line.

WIRE ROPE

During the course of a career, CEs often need to hoist or move heavy objects. Wire rope is used for heavy-duty work. In the following paragraphs, we will discuss the characteristics, construction, and usage of many types of wire rope as well as the safe working load, use of attachments and fittings, and procedures for the care and handling of wire rope.

Table 1-2.—Safe Working Load of Fiber Line

APPROXIMATE SAFE WORKING LOADS OF NEW FIBER LINES — POUNDS Three-Strand Line Safety Factor = 5					
Nominal Line Diameter (inches)	Manila	Nylon	Polypropylene	Polyester	Polyethylene
3/16	100	200	150	200	150
1/4	120	300	250	300	250
5/16	200	500	400	500	350
3/8	270	700	500	700	500
1/2	530	1,250	830	1,200	800
5/8	880	2,000	1,300	1,900	1,050
3/4	1,080	2,800	1,700	2,400	1,500
7/8	1,540	3,800	2,200	3,400	2,100
1	1,800	4,800	2,900	4,200	2,500
1 1/8	2,400	6,300	3,750	5,600	3,300
1 1/4	2,700	7,200	4,200	6,300	3,700
1 1/2	3,700	10,200	6,000	8,900	5,300
1 5/8	4,500	12,400	7,300	10,800	6,500
1 3/4	5,300	15,000	8,700	12,900	7,900
2	6,200	17,900	10,400	15,200	9,500

Table 1-3.—Safe Working Load of Braided Synthetic Fiber Line

APPROXIMATE SAFE WORKING LOADS OF NEW BRAIDED SYNTHETIC FIBER LINES (LB) SAFETY FACTOR = 5			
Nominal Line Diameter (inches)	Nylon Cover Nylon Core	Nylon Cover Polypropylene Core	Polyester Cover Polypropylene Core
1/4	420	—	380
5/16	640	—	540
3/8	880	680	740
7/16	1,200	1,000	1,060
1/2	1,500	1,480	1,380
9/16	2,100	1,720	—
5/8	2,400	2,100	2,400
3/4	3,500	3,200	2,860
7/8	4,800	4,150	3,800
1	5,700	4,800	5,600
1 1/8	8,000	7,000	—
1 1/14	8,800	8,000	—
1 1/2	12,800	12,400	—
1 5/8	16,000	14,000	—
1 3/4	19,400	18,000	—
2	23,600	20,000	—

Construction

Wiie rope consists of three parts: wires, strands, and core (fig. 1-3). In the manufacture of wire rope, a number of WIRES are laid together to form the STRAND. Then a number of STRANDS are laid together around a CORE to form the wire ROPE.

The basic unit of wire-rope construction is the individual wire, which may be made of steel, iron, or other metal in various sixes. The number of wires to a strand will vary, dependingonthepurpose for which the wire rope is intended. Wiie rope is designated by the number of strands per rope and the number of wires per strand. Thus a 1/2-inch, 6 by 19 wire rope will have six strands with 19 wires per strand; but it will have the same outside diameter as a 1/2-inch, 6 by 37 wire rope, which will have six strands with 37 wires of much smaller size per strand.

Wire rope that is made up of a large number of small wires is flexible. The small wires are, however, easily broken, so the wire rope does not resist external abrasion. Wire rope that is made up of a smaller number

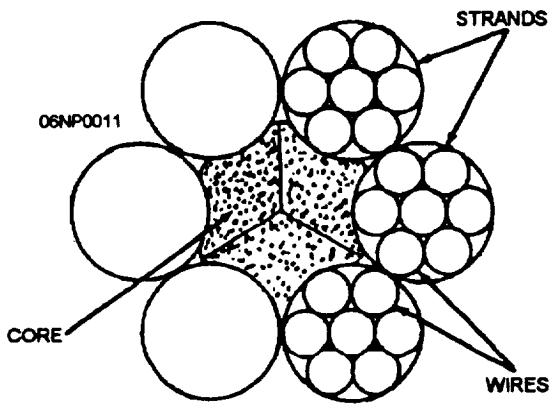


Figure 1-3.—Parts of a wire rope.

of larger wires is more resistant to external abrasion but is less flexible.

The CORE, the element around which the strands are laid to form the wire rope, may be of hard fiber, such as manila, hemp, plastic, paper, or sisal. Also, a wire-strand core may be used. Each type of core serves the same basic purpose—to support the strands laid around it.

A FIBER CORE offers the advantage of increased flexibility. Also, it serves as a cushion to reduce the effects of sudden strain and acts as a reservoir for the oil to lubricate the wires and strands to reduce friction between them. Wire rope with a fiber core is used in places where flexibility of the wire rope is important.

A WIRE-STRAND CORE not only resists heat better than a fiber core but it also adds about 15 percent to the strength of the wire rope. On the other hand, the wire strand makes the wire rope less flexible than a fiber core would.

An INDEPENDENT WIRE-ROPE CORE is a separate wire rope over which the main strands of the wire rope are laid. It usually consists of six seven-wire strands laid around either a fiber core or a wire-strand core. This core strengthens the wire rope more, provides support against crushing, and supplies maximum resistance to heat.

Wire rope may be made by either of two methods. If the strands or wires are shaped to conform to the curvature of the finished wire rope before laying up, the *wire* rope is termed *preformed.* If they are not shaped before fabrication, the wire rope is termed *nonpreformed.* When cut, preformed wire rope tends not to unlay, and it is more flexible than nonpreformed wire rope. With nonpreformed wire rope, twisting produces a stress in the wires; and, when it is cut or broken, the stress causes the strands to unlay. In nonpreformed wire rope, unlaying is rapid and almost instantaneous, which could cause serious injury to someone not familiar with it.

The main types of wire rope used by the Navy have 6, 7, 12, 19, 24, or 37 wires in each strand. Usually, the wire rope has six strands laid around a fiber or steel center.

Two common types of wire rope, 6 by 19 and 6 by 37 wire rope, are shown in figure 1-4. The 6 by 19 type of wire rope, having six strands with 19 wires in each strand, is commonly used for rough hoisting and skidding work where abrasion is likely to occur. The 6 by 37 wire rope, having six strands with 37 wires in each strand, is the most flexible of the standard six-strand wire ropes. For that reason, it is particularly suitable when you are going to use small sheaves and drums, such as are used on cranes and similar machinery.

Grades of Wire Rope

Wire rope is made in a number of different grades, three of which are mild-plow steel, plow steel, and improved-plow steel.

MILD-PLOW STEEL wire rope is tough and pliable. It can stand up under repeated strain and stress, and it has a tensile strength of 200,000 to 220,000 pounds per square inch (psi).

PLOW STEEL wire rope is unusually tough and strong. This steel has a tensile strength (resistance to lengthwise stress) of 220,000 to 240,000 psi. This wire rope is suitable for hauling, hoisting, and logging.

IMPROVED-PLOW STEEL wire rope is one of the best grades of wire rope available, and most, if not all, of the wire rope you will use in your work will probably be made of this material. It is stronger, tougher, and more resistant to wear than either plow steel or mild-plow steel. Each square inch of improved-plow steel can stand a strain of 240,000 to 260,000 psi.

Measuring Wire Rope

The size of wire rope is designated by its diameter. The true diameter of a wire rope is considered as being the diameter of the circle that will just enclose all of its strands. Both the correct and incorrect methods of measuring wire rope are shown in figure 1-5. Note, in particular, that the CORRECT WAY is to measure from the top of one strand to the top of the strand directly opposite it. Use calipers to take the measurement; if calipers are not available, an adjustable wrench will do.

To ensure an accurate measurement of the diameter of a wire rope, always measure the wire rope at three

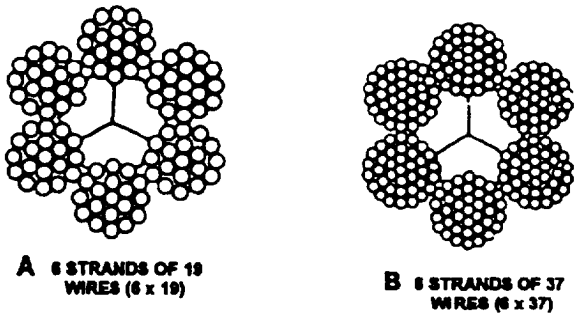


Figure 1-4.—Two types of wire rope.

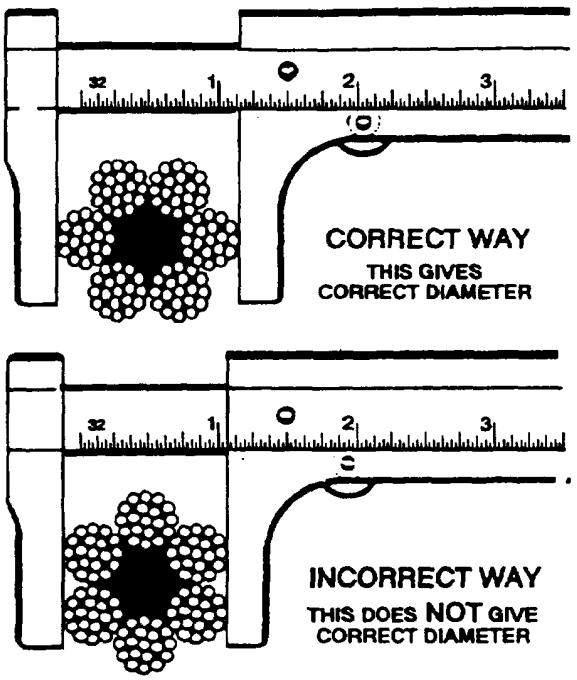


Figure 1-5.—Correct and incorrect methods of measuring wire rope.

places on a six-stranded, and four places on an eight-stranded wire rope. Use the average of the three measurements as the diameter of the wire rope.

Safe Working Load

The term *safe working load* (SWL), as used in reference to wire rope, means the load that you can apply and still obtain the most efficient service and also prolong the life of the wire rope. Most manufacturers provide tables that show the safe working load for their wire rope under various conditions. In the absence of these tables, you may apply the following rule-of-thumb formula to obtain the SWL:

$$SWL \text{ (in tons)} = D^2 \times 8$$

This particular formula provides an ample margin of safety to account for such variables as the number, size, and location of sheaves and drums on which the wire rope runs and such dynamic stresses as the speed of operation and the acceleration and deceleration of the load, all of which can affect the endurance and breaking strength of the wire rope. Remember this formula is a **general computation,** and you should also consider the overall condition of the wire rope.

In the above formula, D represents the diameter of the rope in inches. Suppose you want to find the SWL of a 1/2-inch-diameter wire rope. Using the formula above, you would solve the problem as follows:

$$SWL = (1/2)^2 \times 8$$

$$SWL = 2 \text{ tons}$$

WIRE-ROPE ATTACHMENTS

Wire rope can be attached to other wire ropes, chains, pad eyes, or equipment by splicing, which is permanent, or by any of a number of wire-rope attachments. These include sockets and wire-rope clips. In general, these attachments permit the wire rope to be used with greater flexibility than would be possible with a more permanent splice. The attachments allow the same wire rope to be made up in a variety of different arrangements.

Clips

A temporary eye splice may be put in wire rope by using clips. A single clip (fig. 1-6) consists of three parts: U-bolt, saddle, and nuts. The correct and incorrect methods of applying these clips to wire rope are shown in figure 1-6; the second incorrect method shown is the most common. Notice that the correct way is to apply the clips so that the U-bolts bear against the bitter end; that is, the short end of the wire rope. If the clips are attached incorrectly, the result will be distortion or mashed spots on the live end of the wire rope. After a wire rope is under strain, tighten the clips again. On operating wire ropes, tighten the clips daily and inspect the wire ropes carefully at points where

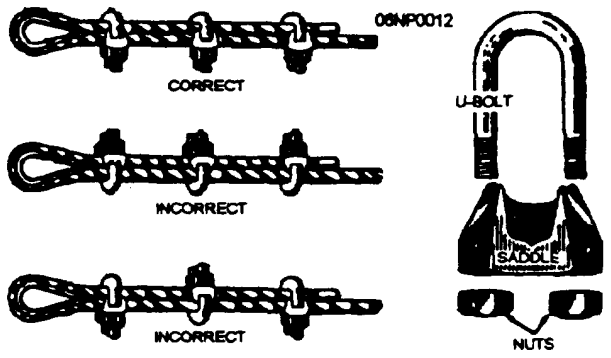


Figure 1-6.—Use of wire-rope clips.

there are clips. Pay particular attention to the wire at the clip farthest from the eye, as vibration and whipping are heaviest here and fatigue breaks are likely to occur.

To obtain maximum strength in the temporary eye splice, use the correct size and number of wire clips. The size is stamped on the saddle between the two holes. A rule of thumb for determining the number of clips required for various sizes of wire rope is to multiply the diameter of the wire rope by 3 and add 1. Stated as a formula, this means

3D + 1 = number of clips.

For example, if the wire rope has a diameter of 1 inch, determine the number of clips as follows:

(3 x 1) + 1 = 4 clips

In case the answer contains a fraction, then use the next largest whole number. For example, suppose you want to find the number of clips for a wire rope 1/2 inch in diameter. Using the formula, the answer would be 2 1/2 clips. You simply use the next whole number to get the correct answer.

You should space the clips properly to provide a good hold on the wire rope. You can determine the correct distance between the clips by multiplying 6 times the diameter of the wire rope. Where D is equal to

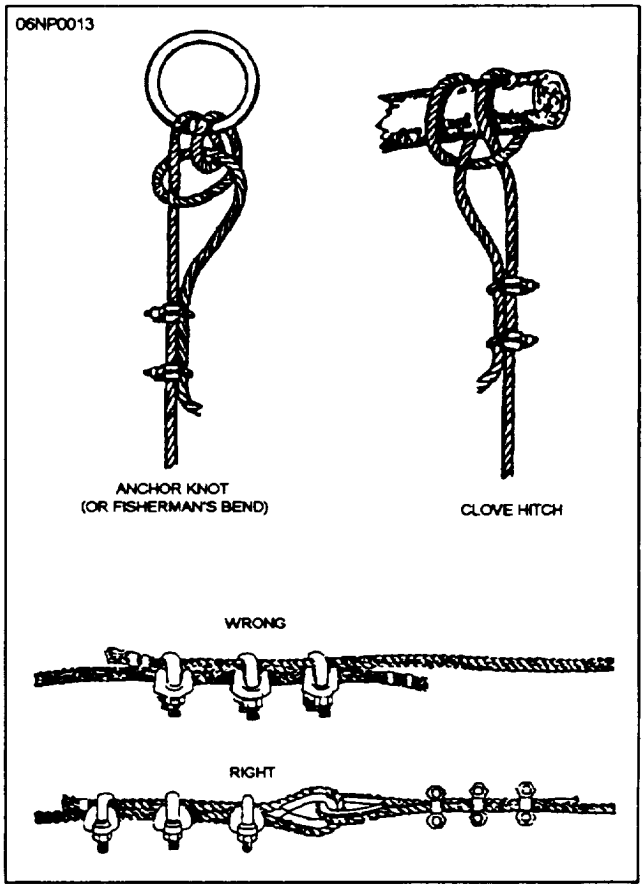


Figure 1-7.—Wire-rope bends and couplings.

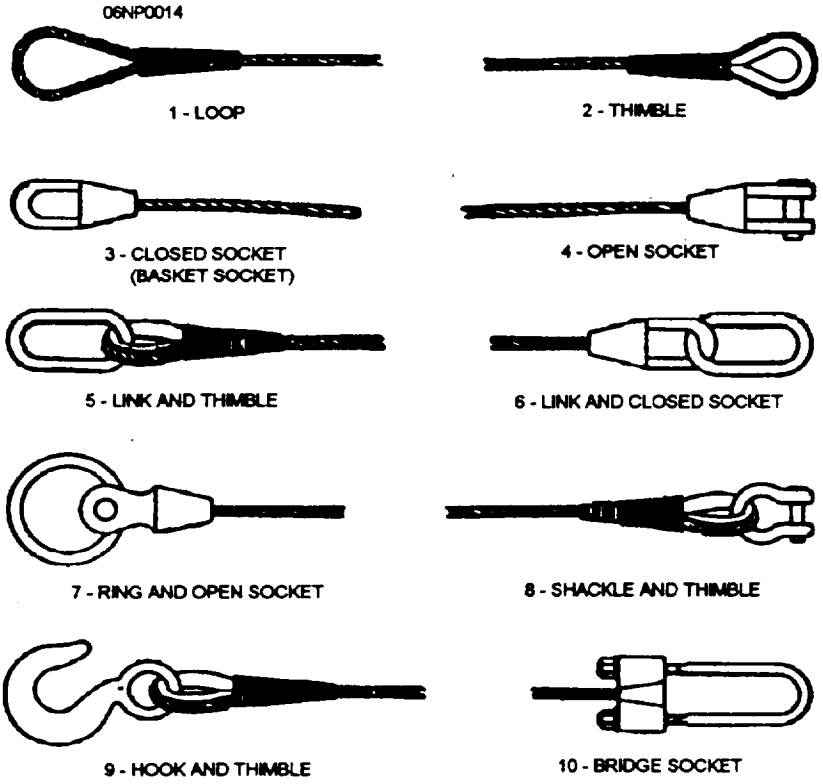


Figure 1-8.—Wire-rope fittings.

the diameter, 6 x D = DISTANCE BETWEEN CLIPS. Here, as in determining the number of clips, if the answer contains a fraction, use the next whole number.

You should inspect and tighten wire-rope clips at regular intervals. Also, after comparatively long use, remove the clips and examine the wire rope for broken wires. If any are present, remove the damaged part and make a new attachment.

Knots

Although wire-rope fittings are stronger and safer and make wire rope last longer, you may have to use knots in emergencies. Use knots secured with clips (fig. 1-7). Figure 1-7 also shows the proper way to join two wire ropes.

Fittings

fittings are attached to the ends of wire rope so that the wire rope can be easily connected to other wire ropes, chains, pad eyes, or heavy equipment. Figure 1-8 shows some standard fittings. The type of fitting used depends on the job. For instance, to hoist a bundle of conduit from ground level, use two wire rope slings made using a thimble in the wire rope and then attaching a shackle to the thimble. A thimble in an eye splice reduces abrasive wear on the wire rope (fig. 1-8, view 2).

Hooks and Shackles

Hooks and shackles (fig. 1-9) provide a useful means of hauling the lifting loads without tying directly to the object with a line, wire rope, or chain. They can be attached to wire rope, fiber line, blocks, or chains. Shackles should be used for loads too heavy for hooks to handle.

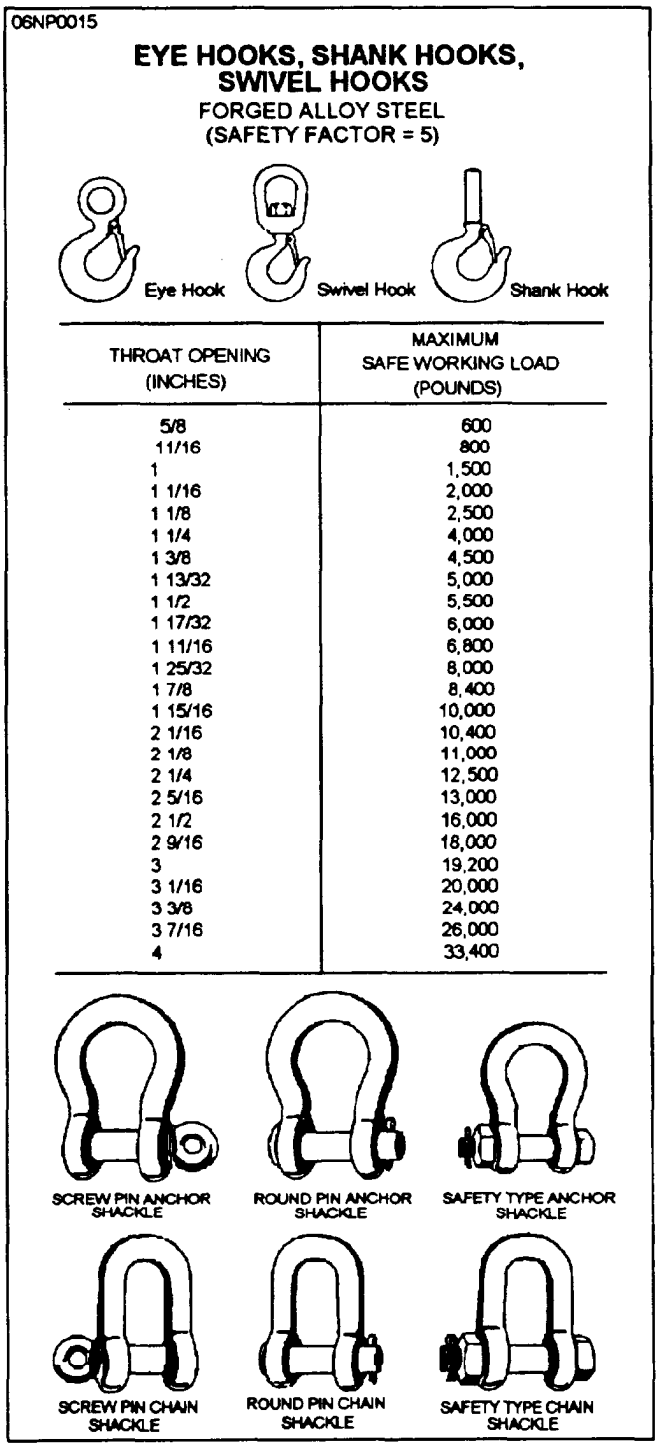
When hooks fail because of overloading, they usually straighten out and lose or drop their load. When a hook has been bent by overloading, do NOT straighten it and put it back into service.Cut it in half with a cutting torch and discard it.

Hooks should be given a visual inspection at the beginning of each workday and before lifting a full-rated load. If you are not sure whether a hook is strong enough to lift the load, use a shackle.

You should use hooks that close and lock where there is danger of catching on an obstruction. This applies particularly to hoisting buckets, or cages, and especially in shaft work. Hooks and rings used with chain should have about the same strength as the chain.

SLINGS

Slings are widely used in the moving and hoisting of heavy loads. You can obtain some types of slings already made up, but frequently you may have to make



THROAT OPENING (INCHES)	MAXIMUM SAFE WORKING LOAD (POUNDS)
5/8	600
11/16	800
1	1,500
1 1/16	2,000
1 1/8	2,500
1 1/4	4,000
1 3/8	4,500
1 13/32	5,000
1 1/2	5,500
1 17/32	6,000
1 11/16	6,800
1 25/32	8,000
1 7/8	8,400
1 15/16	10,000
2 1/16	10,400
2 1/8	11,000
2 1/4	12,500
2 5/16	13,000
2 1/2	16,000
2 9/16	18,000
3	19,200
3 1/16	20,000
3 3/8	24,000
3 7/16	26,000
4	33,400

Figure 1-9.—Hooks and shackles.

your own. Slings may be constructed of fiber line, wire rope, or chain.

Fiber-Line and Wire-Rope Slings

FIBER-LINE slings offer the advantage of flexibility and protection of finished material. At the same time, fiber-line slings are not as strong as wire-rope or chain slings. In addition, fiber-line slings are more likely to be damaged in the event of sharp edges on the material being hoisted than are wire-rope or chain slings.

Three types of fiber-line and wire-rope slings commonly used for lifting a load are the endless, single-leg, and bridle slings.

An ENDLESS SLING, usually referred to as a SLING, can be made by splicing together the ends of a piece of fiber line or wire rope to form an endless loop.

An endless sling is easy to handle, and you can use it in several different ways to lift loads. Frequently, it is used as a choker hitch (fig. 1-10). To form a choker hitch, cast the sling under the load to be lifted and insert one loop through the other and over the hoisting hook.

A SINGLE-LEG SLING, commonly referred to as a STRAP, can be constructed by forming a spliced eye in each end of a piece of fiber line or wire rope. Sometimes the ends of a piece of wire rope are spliced into eyes around thimbles, and one eye is fastened to a hook with a shackle. With this arrangement, the shackle and hook are removable.

A single-leg sling may be used as a choker hitch (fig. 1-11) in hoisting by passing one eye through the other eye and over the hoisting hook.

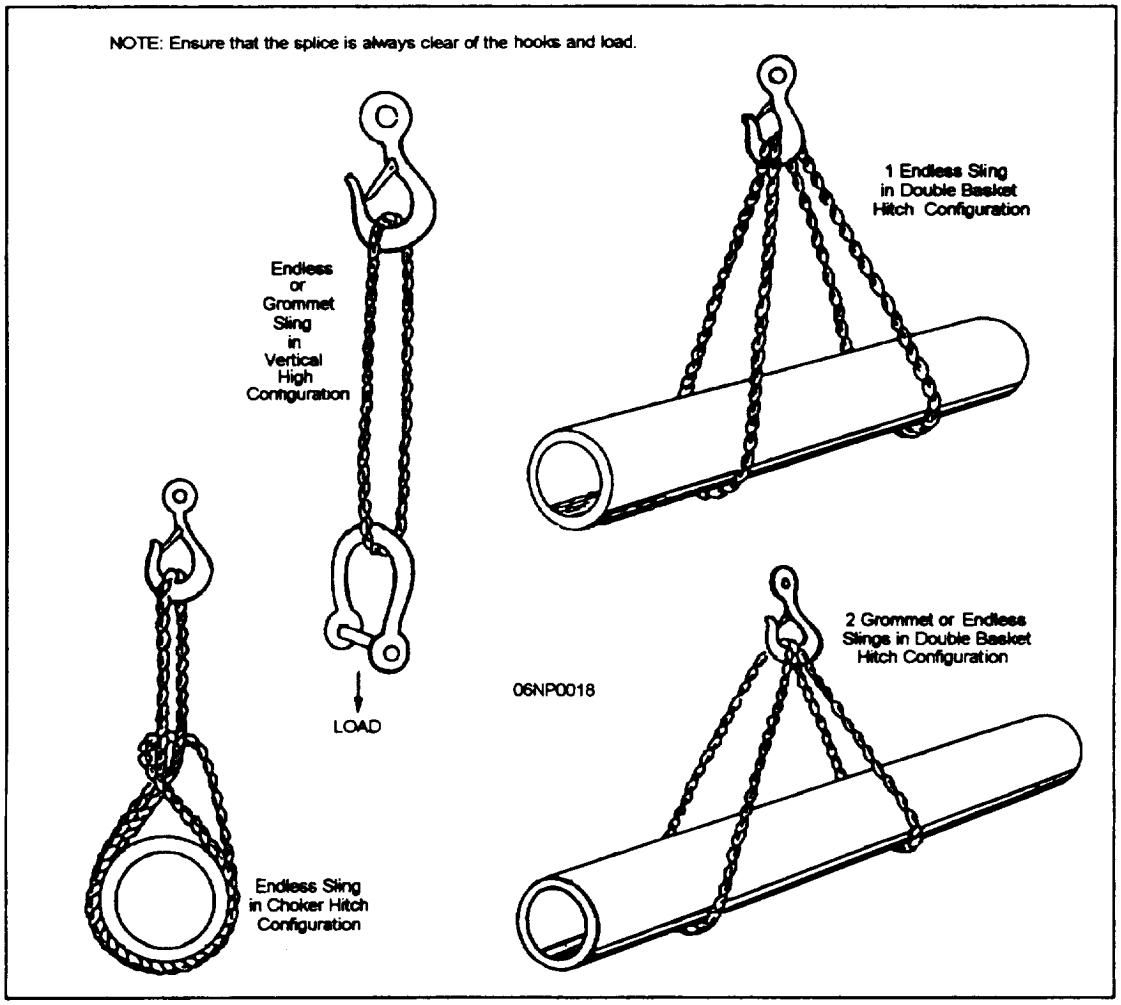


Figure 1-10.—Choker hitch formed from an endless sling.

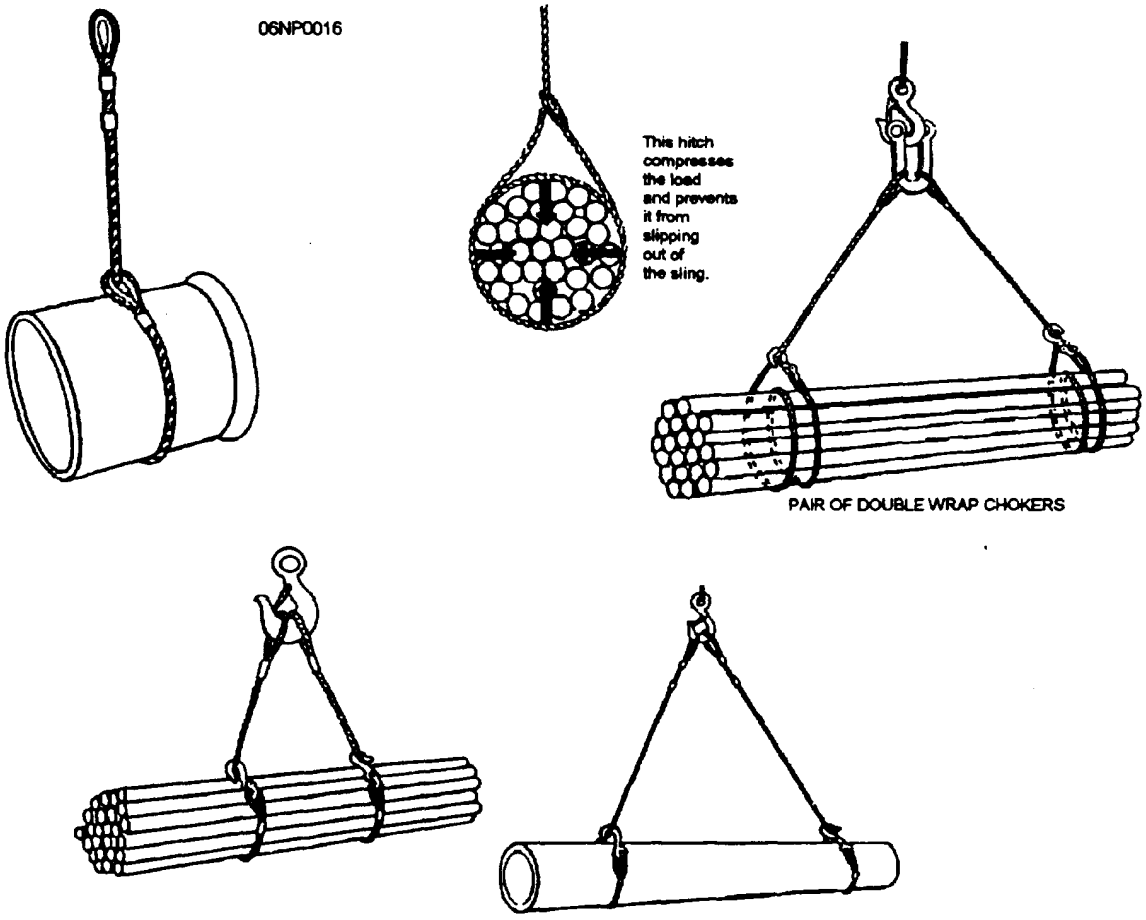


Figure 1-11.—Choker hitch formed by a single-leg sling.

You can use single-leg slings to make various types of BRIDLES. Two types are shown in figure 1-12. You can use two or more single slings for a given combination. Also, if an individual sling is not long enough for the job at hand, you can combine two of the single slings to form a longer single sling.

It is advantageous to have matched sets of slings (that is, two or more of equal length) so that when it is necessary to use more than one to hoist a load, the strain will be equal and the load will come up evenly. You should mark slings that are of equal length for ease of identification. Painting the eyes of equal-length slings the same color is one way of doing this.

In lifting heavy loads, always make a special effort to ensure that the bottoms of the sling legs are fastened to the load in a manner that will prevent damage to the load. Many pieces of equipment have eyes fastened to them during the process of manufacture to aid in lifting. With some loads, though, fastening a hook to the eye on one end of each sling leg provides an adequate means for securing the sling to the load.

Chafing gear (protective pads) must be used when a sling is exposed to sharp edges at the comers of a load. Pieces of round wood, heavy bagging, or old rubber tires are excellent materials to use as padding.

Chain Slings

Chain slings are frequently used in hoisting and moving heavy steel items, such as rails, pipes, wide-flange beams, and angles. They are also desirable for slinging hot loads and in handling loads with sharp edges that might cut wire rope.

Steel-length CHAIN SLINGS are available with variable type ends and lengths. Types include a 1/2-inch (12.7-mm) size sling, obtainable in either 12- or 20-foot (3.6-m or 6-m) lengths. This is a one-leg type of sling with a center swivel, equipped with a grab hook

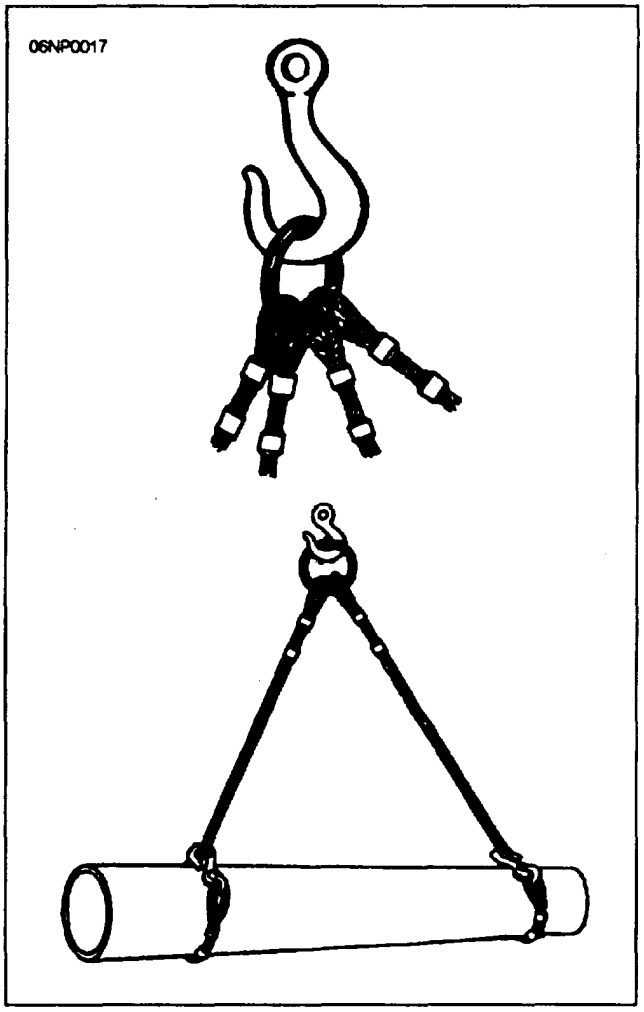


Figure 1-12.—Bridles.

on one end and a pelican hook on the other. There is also available a 3/4-inch (19.05-mm) chain sling, 22 feet (6.6 m) long, with a grab hook on one end and a Cinch (100-mm) link on the other.

Before doing any lifting with a chain sling, first place dunnage between the chain and the load to provide a gripping surface. In handling rails or a number of lengths of pipe, make a round turn and place the hook around the chain as shown in figure 1-13.

In using chain slings, you must exercise care to avoid twisting or kinking the chain while it is under stress. This condition might cause failure of the chain, even in handling a light load. Before lifting, make sure that the chain is free from twists and kinks. Make sure, also, that the load is properly seated in the hook (not on the point) and that the chain is free from nicks or other damage. Avoid sudden jerks in lifting or lowering the load, and always consider the angle of lift when using a sling chain bridle.

Store chains in a clean, dry place where they will not be exposed to the weather. Before storage, it is a good idea to apply a light coat of lubricant to prevent rust.

Makeshift repairs, such as fastening links of a chain together with bolts or wire, should never be permitted. When links become worn or damaged cut them out of the chain; then fasten the two adjacent links together with a connecting link. After the connecting link is closed and welded, it will be as strong as the other links. For cutting small-size chain links, use bolt cutters. For cutting large-size links, use a hacksaw or oxyacetylene torch.

Inspection of Slings

Slings must be inspected frequently and removed from service whenever defects are detected. Bear in mind that a defective sling may cause serious injury to personnel or extensive damage to equipment in case of failure under load.

You should check FIBER-LINE slings carefully for signs of deterioration caused by exposure to the weather. You should also check closely to determine whether any of the fibers have been broken or cut by sharp-edged objects.

Broken wires are a major defect to look for when inspecting WIRE-ROPE SLINGS. When four percent of the total number of wires in the rope are found to have nicks, or cuts, they should be replaced. However, if a chain shows evidence of stretching or distortion of more than five percent in any five-link section, make sure the entire chain is discarded.

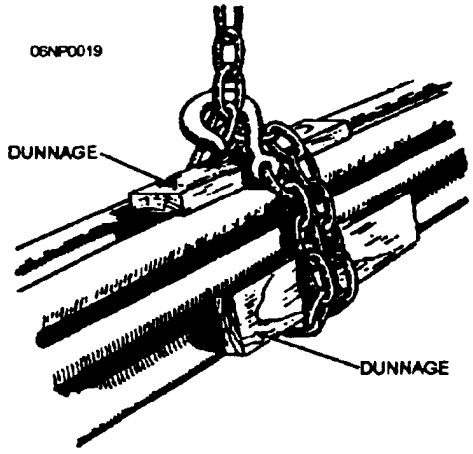


Figure 1-13.—Chain sling.

The least sign of binding at the juncture points of links indicates collapse in the sides of the link caused by stretching. Such a condition is dangerous, and the chain should be removed from service.

Spreaders and Pallets

When hoisting with slings, you may often need to use spreader bars to prevent crushing and damaging the load. Spreader bars are short bars or pipes that have eyes fastened to each end. By setting spreader bars in the sling legs above the top of the load (fig. 1-14), you change the angle of the sling leg and avoid crushing the load, particularly the upper portion.

The use of cargo PALLETS in combination with slings is a big advantage on jobs that involve the hoisting and moving of small-lot items (fig. 1-15). You may need to use spreader bars when hoisting pallets to avoid damaging the pallets and load. The pallet provides a small platform or board on which a number of items can be placed and moved as a unit rather than piece by piece. Palletizing obviously is quicker and easier than moving each individual item separately.

MOVING MATERIALS AND EQUIPMENT

The safe movement of equipment and materials does not just happen. It takes knowledgeable people to communicate, control, and rig movements. Personnel safety, undamaged materials/ equipment, and operational efficiency are the responsibility of all personnel involved.

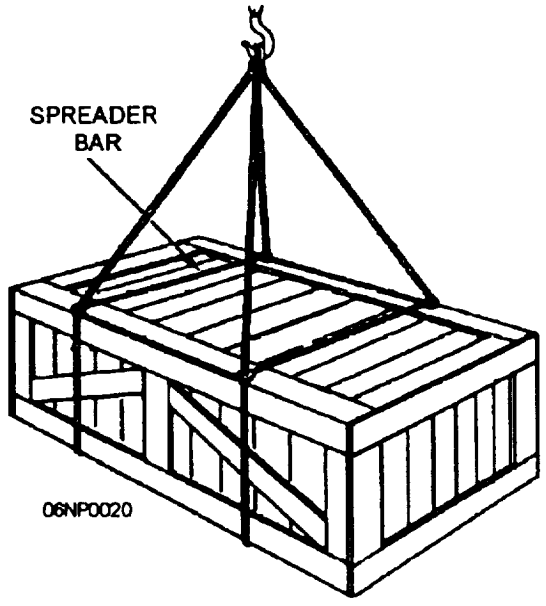


Figure 1-14.—Use of spreader bars in a sling.

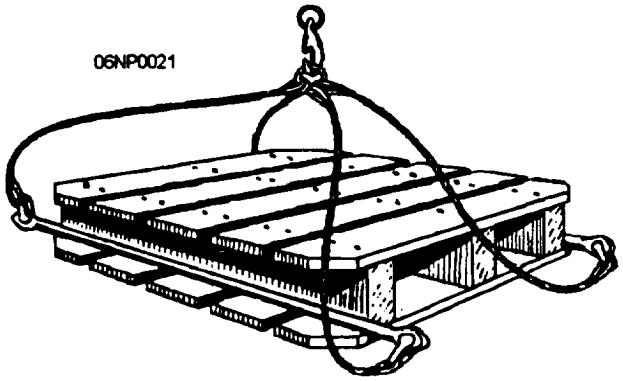


Figure 1-15.—Cargo pallets in combination with slings.

SIGNALLING

CEs are frequently required to act as signalmen for crane or hoist operators and for the positioning of equipment. There are a number of precautions and procedures that should be observed in these operations.

Whenever the operator's view is obstructed so that he cannot see the path of travel of any part of the equipment, load, or components, a competent signalman is required to be stationed in such a position that he or she can be easily seen by the operator and where the signalman has a full view of the intended path of travel of the equipment, load, or components, yet where he or she will be clear of the intended path of travel. The signalman should assist the operator by watching the load when it is out of view of the operator and communicating with the operator by the use of prearranged visual signals (app. III) or a suitable communication system.

The signalman must

- be fully qualified by experience with the operation.
- wear high-visibility gloves.
- use hand signals only when conditions are such that the signals are clearly visible to the operator.
- be made responsible for keeping the public and all unauthorized personnel outside the operating radius of the crane or the path of the equipment.
- direct the load so that it never passes over anyone.

When the signalman desires to give the operator any instructions other than those provided by the established signal system, the operator should be instructed to stop all motion FIRST.

Hand signals can be used effectively when the distance between the operator and the signalman is not great, but two-way radios should be used when the distance or atmospheric conditions prevent clear visibility. Adequate lighting and signalling arrangements must be available during night work, and the equipment must not be operated when either is inadequate.

PROCEDURES AND PRECAUTIONS FOR LIFTING OPERATIONS

The most important rigging precaution is to determine the weight of all loads before attempting to lift them, to make ample allowances for unknown factors, and to determine the available capacity of the equipment being used. In cases where the assessment of load weight is difficult, safe load indicators or weighing devices should be fitted. This chapter also includes a section dealing with the estimation of load weights.

It is equally important to rig the load so that it is stable. Unless the center of gravity of the load is below the hook, the load will shift.

The safety of personnel involved in rigging and hoisting operations largely depends upon care and common sense. Remember these safe practices.

- Know the safe working load of the equipment and tackle being used. Never exceed this limit.
- Determine the load weight before rigging it.
- Examine all hardware, equipment, tackle, and slings before using them and **survey** defective components. Discarded equipment may be used by someone not aware of the hazards or defects.
- Never can-y out any rigging or hoisting operation when the weather conditions are such that hazards to personnel, property, or the public are created. You must carefully examine the size and shape of the loads being lifted to determine if a hazard exists during high wind speeds. Avoid handling loads that have large wind-catching surfaces that could cause loss of control of the load during high or gusty winds. The wind can critically affect the loading and load-landing operation and the safety of the personnel involved (fig. 1-16).

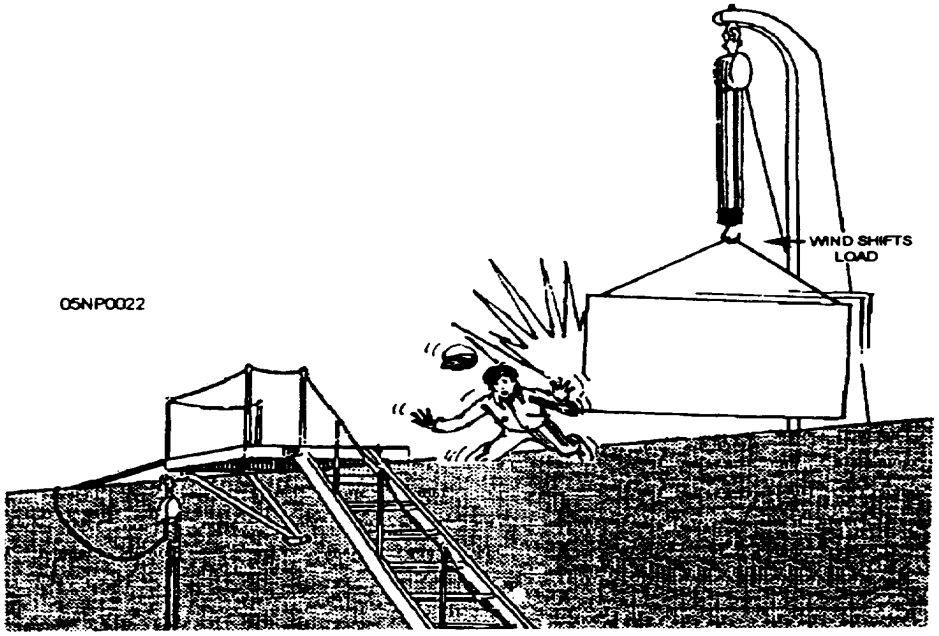


Figure 1-16.—Wind effects on load.

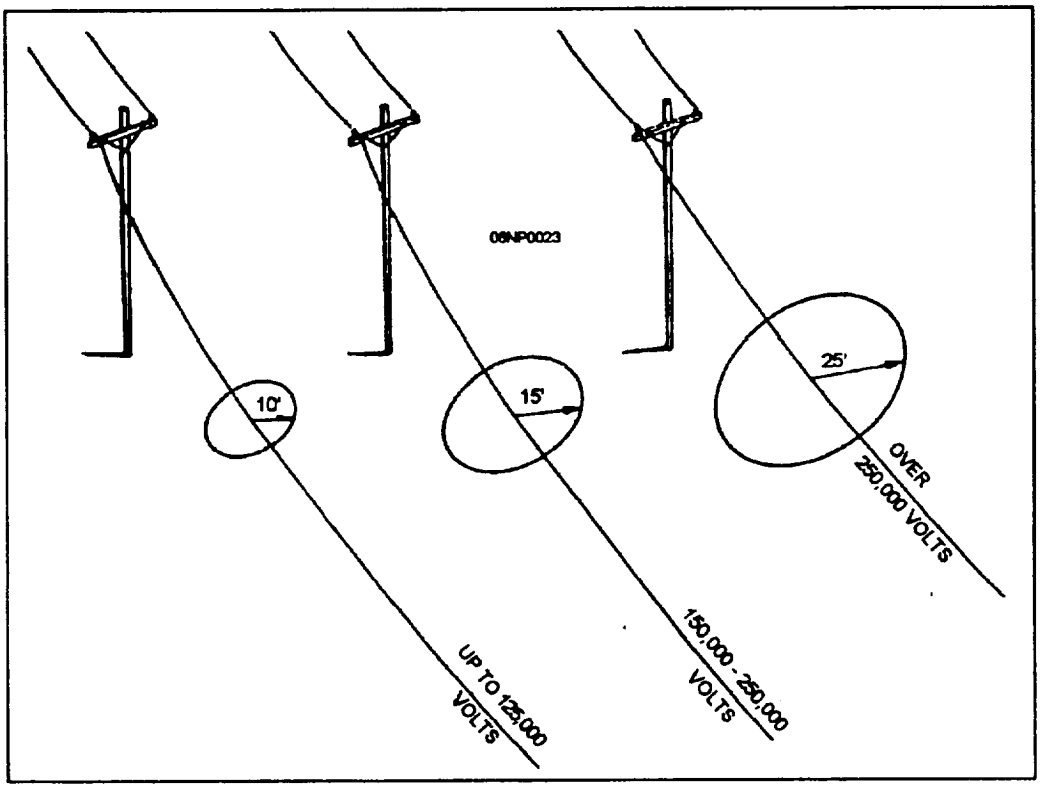


Figure 1-17.—Minimum safe distance for working around energized conductors.

• **The primary killer of riggers and those persons handling loads is electrocution caused by the contact of the boom, load line, or load of a crane with electric power lines.** When working with or around cranes that are within a boom's length of any power line, you must ensure that the power to that section of line is secured. If for some reason this cannot be accomplished, a competent signalman must be stationed at all times within view of the operator to warn him when any part of the machine or its load is approaching the minimum safe distance from the power line (fig. 1-17). You must also exercise caution when working near overhead lines that have long spans, as they tend to swing laterally because of the wind, and accidental contact could occur.

• The safe working loads of hoisting equipment apply only to freely suspended loads on plumb hoist lines. If the hoist line is not plumb at all times when handling loads, then additional side loads will endanger the stability of the equipment. In circumstances such as this, structural failures can result without any warning (fig. 1-18).

• Never use kinked or damaged slings or hoist wire ropes. To provide maximum operating efficiency and safety, you should give all slings and fittings thorough periodic inspections as well as daily inspections for signs of wear and abrasion, broken wires, worn or cracked fittings, loose seizing and splices, kinking, crushing, flattening, and corrosion. Special care should be taken in inspecting the areas around thimbles and fittings.

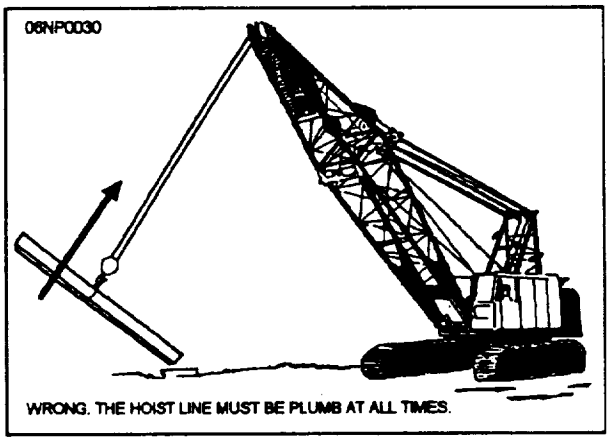


Figure 1-18.—Incorrect lifting procedures.

- When using choker hitches, do not force the eye down towards the load once tension is applied. Wire rope damage is the invariable result (fig. 1-19).

- Whenever two or more wire rope eyes must be placed over a hook, install a shackle on the hook with the shackle pin resting in the hook and hook the wire rope eyes to the shackle. This will prevent the spread of the sling legs from opening up the hook and also prevent the eyes from damaging each other when under load (fig. 1-20).

The following procedures and precautions should be observed whenever loads are to be handled:

- Rig all loads to prevent the dislodgement of any part Suspended loads should be securely slung and properly balanced before they are set in motion.

- Keep the load under control at all times. Where necessary by the rotation, use one or more guide wire ropes or tag lines to prevent the rotation or uncontrolled motion (fig. 1-21).

- Land all loads safely and block them properly before unhooking and unslinging them (fig. 1-22).

- Never wrap the hoist wire rope around the load Attach the load to the hook by slings or other rigging devices that are adequate for the load being lifted.

- Bring the load line over the center of gravity of load before starting the lift.

- Load and secure materials and equipment being hoisted to prevent any movement that could create a hazard in transit.

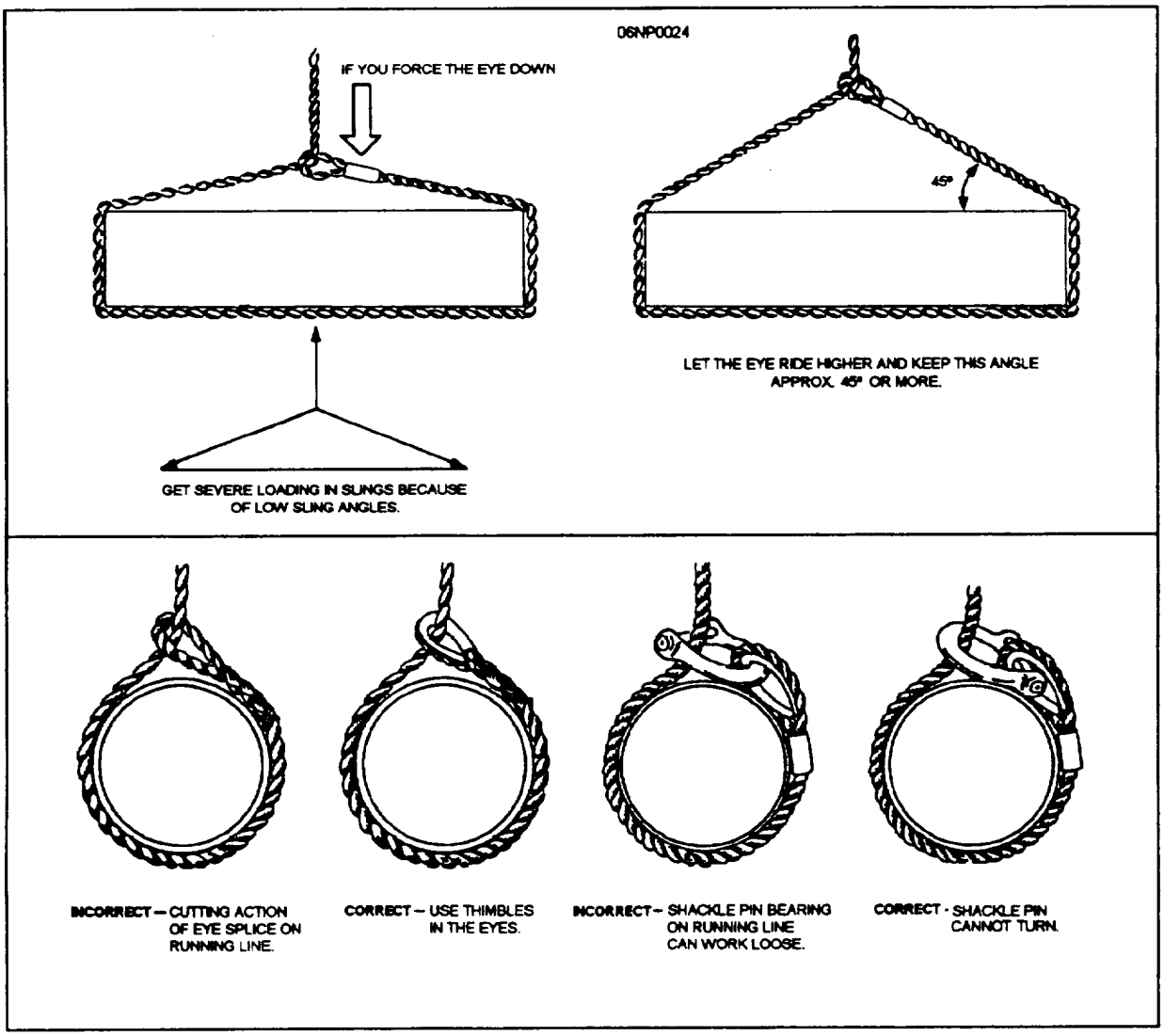


Figure 1-19.—Proper position of choker hitches for lifting.

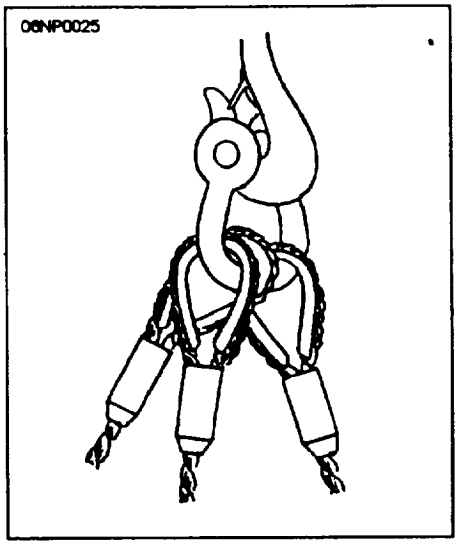


Figure 1-20.—Shackle use with two or more wire ropes.

- Keep hands away from pinch points as the slack is being taken up.

- Wear gloves when handling wire rope.

- Make sure that all personnel stand clear while loads are being lifted and lowered or while the slings are being drawn from beneath the load The hooks may catch under the load and suddenly fly free.

- Before making a lift, check to see that the sling is properly attached to the load

- Never, under any circumstances, ride on a load that is being lifted.

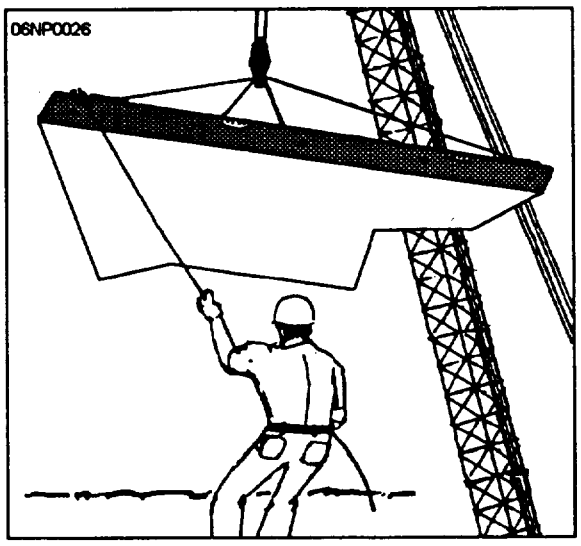


Figure 1-21.—Using tag lines to control load.

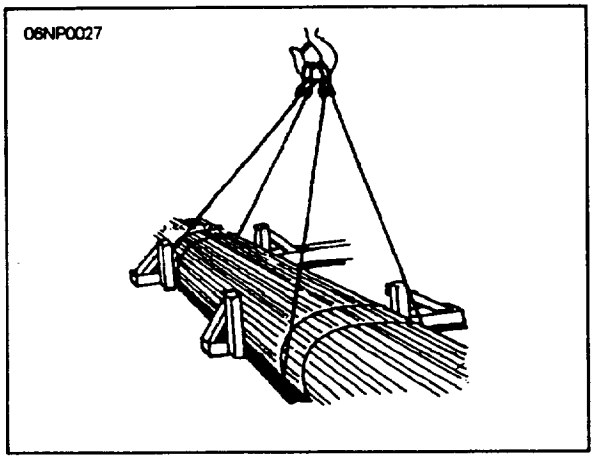


Figure 1-22.—Before loads are unhooked, they must be properly blocked.

- Never allow the load to be carried over the heads of any personnel.

- Never make temporary repairs to a sling. Procedures for proper repairs to a damaged sling should be established and followed

- Remove or secure all loose pieces of material from the load before it is moved.

- Make sure that the load is free before lifting and that all sling legs are taking the load.

HAZARDOUS MATERIAL

Read OPNAVINST 4110.2 dated 20 June 1989, subject: *Hazardous Material Control and Management* (HMC&M). This instruction establishes uniform policy, guidance, and requirements for the life-cycle control and total quality leadership (TQL) of hazardous material acquired and used by the Navy.

This instruction, unless otherwise specified applies to all Navy organizations and shore activities involved in the planning, procurement, acquisition, stowage, distribution, requisition, use, or other disposition of hazardous material (including disposal of used hazardous materials and hazardous wastes in the United States and its territories). Navy shore activity requirements in foreign countries are to comply with the requirements of host nation Status of Forces agreements if they are more restrictive than U.S. regulations. Where host national requirements are less stringent, conform to U.S. OSHA and EPA laws and regulations to the extent feasible.

The Department of Defense (DoD) established the Hazardous Material Information System (HMIS) to acquire, stow, and disseminate manufacturer's data on hazardous material (HM). The system provides a means to share and communicate information on HM procured by a single DoD activity with all other commands, activities, and units within DoD.

HAZARDOUS WASTE AND THE SEABEE

As you read the above paragraphs, you may have been inclined to think that the message and warnings could not possibly apply to you at your level. If this is what you thought, you were definitely wrong. It is true that the above instructions, along with a few others, give us the rules and regulations we must follow in regard to hazardous material, but they were also written for your protection. You, as a DoD employee, are ensured that the information on hazardous materials you may come in contact with will be available to you. This information is to be made available by means of comprehensive hazard communication programs, which are to include container labeling and other forms of warning, Material Safety Data Sheets (MSDS), and training.

As a member of today's Navy, you must be aware of the importance of hazardous material, used hazardous material and hazardous waste. You also must recognize the hazards of hazardous material, used hazardous material and hazardous waste to personnel and the environment. You must pay particular attention to OPNAVINST 4110.2 and OPNAVINST 5100.23C on the use, stowage, and disposal of hazardous material in your workplace.

MATERIAL SAFETY DATA SHEETS (MSDS)

To comply with the OSHA Hazard Communication Standard, 29 CFR 1910.1200, manufacturers of chemical products must use an MSDS, OSHA Form 174, or an equivalent form containing the identical data elements to inform the users of the chemical, physical, and hazardous properties of their product. The completed form identifies key information about the product; name, address, and emergency contact for the manufacture; the identity of hazardous ingredients; physical/chemical characteristics; fire and explosion hazard data; reactivity data; health hazard data; precautions for safe handling and use; and control measures (fig. 1-23). All data submitted must comply with the provisions of FED-STD 313C (NOTAL).

You must be aware of any chemical hazards that are used in your work spaces or on the jobsite. An MSDS must be available in the workplace or posted conspicuously on all hazardous materials. The MSDS must be provided by the supply department and also by suppliers of any hazardous material issued or purchased. The MSDS must contain all the information you will need to work, stow, and dispose of hazardous material safely. In addition, the MSDS will identify any personnel protective clothing or equipment needed, as well as first aid or medical treatment required in case of exposure.

LABELED HAZARDOUS MATERIAL AND HAZARDOUS WASTE CONTAINERS

Each container of material possessing hazardous ingredients should be properly labeled by the manufacturer, importer, and or shipper(s) to warn personnel of the potential dangers of the material. In the event warning labels are inadvertently removed or damaged in shipping before receipt by shore activities, commercial suppliers should be required to provide OSHA Hazard Communication (HAZCOM) compliant replacement labels. Activities are not required to put DoD or other hazardous material warning labels on new stocks because the manufacturer is responsible for placing a warning label on it that conforms with the HAZCOM standard.

OSHA labeling requirements are provided in reference 29 CFR 1910.1200 for workplace use of hazardous material. This OSHA standard requires that containers of hazardous material be labeled, tagged, or marked with the identity of the hazardous chemical(s); appropriate hazard warnings; and the name and address of the chemical manufacturer, importer, or other responsible party. Further information on hazardous material labeling can be found in DODINST 6050.5.

HAZARDOUS MATERIAL LABEL

Labeling and marking of hazardous material containers is a function of the manufacturer, importer, or distributor. Your supply department should not accept improperly or incompletely labeled hazardous material. They should refuse to accept it and return it. However, if you need to relabel a container because the original label becomes damaged, unreadable, or is missing, use the DoD Hazardous Chemical Warning

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard, 29 CFR 1910.1200. Standard must be consulted for specific requirements.

U.S. Department of Labor

Occupational Safety and Health Administration
(Non - Mandatory Form)
Form Approved
OMB No. 1218 - 0072

IDENTITY *(As Used on Label and List)*

Note : Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name	Emergency Telephone Number
Address *(Number, Street, City, State, and Zip Code)*	Telephone Number for Information
	Date Prepared
	Signature of Preparer *(Optional)*

Section II — Hazardous Ingredients / Identity Information

Hazardous Components (Specific Chemical Identity ; Common Name(s)	OSHA PEL	ACGIH TLV	Other Limits Recommended	% *(Optional)*

Section III — Physical / Chemical Characteristics

Boiling Point		Specific Gravity ($H_2O = 1$)	
Vapor Pressure (mm Hg)		Melting Point	
Vapor Density (Air = 1)		Evaporation Rate (Butyl Acetate = 1)	

Solubility in Water

Appearance and Color

Section IV — Fire and Explosion Hazard Data

Flash Point (Method Used)	Flammable Limits	LEL	UEL

Extinguishing Media

Special Fire Fighting Procedures

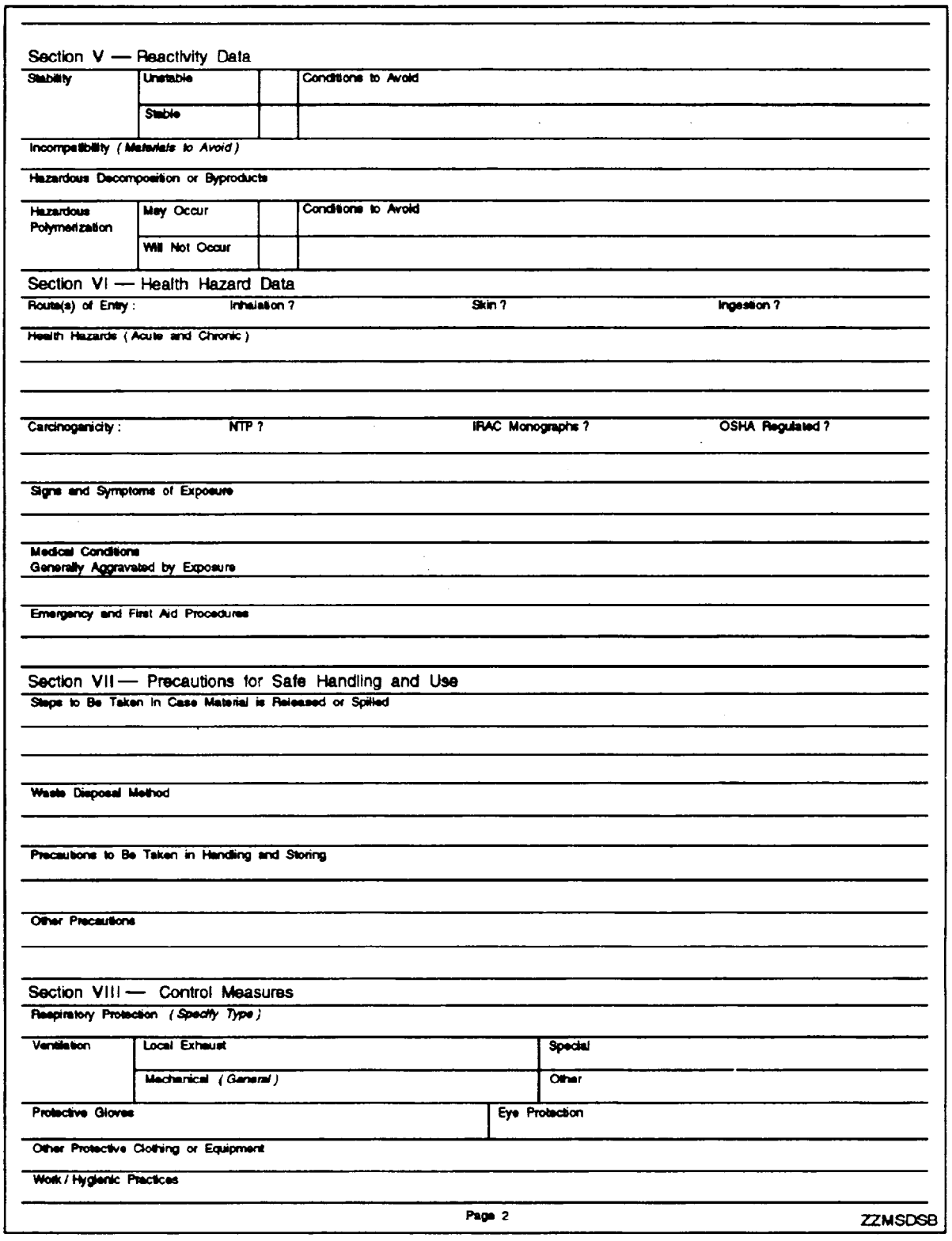
Unusual Fire and Explosion Hazards

(Reproduce Locally)

OSHA 174 , Sept. 1985

ZZMSDSF

Figure 1-23A.—Material Safety Data Sheet (front).



Section V — Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable		

Incompatibility (Materials to Avoid)

Hazardous Decomposition or Byproducts

Hazardous Polymerization	May Occur		Conditions to Avoid
	Will Not Occur		

Section VI — Health Hazard Data

Route(s) of Entry: Inhalation ? Skin ? Ingestion ?

Health Hazards (Acute and Chronic)

Carcinogenicity: NTP ? IRAC Monographs ? OSHA Regulated ?

Signs and Symptoms of Exposure

Medical Conditions
Generally Aggravated by Exposure

Emergency and First Aid Procedures

Section VII — Precautions for Safe Handling and Use

Steps to Be Taken In Case Material is Released or Spilled

Waste Disposal Method

Precautions to Be Taken in Handling and Storing

Other Precautions

Section VIII — Control Measures

Respiratory Protection (Specify Type)

Ventilation	Local Exhaust	Special
	Mechanical (General)	Other

Protective Gloves	Eye Protection

Other Protective Clothing or Equipment

Work / Hygienic Practices

Page 2

ZZMSDSB

Figure 1-23B.—Material Safety Data Sheet (back).

Label in figure 1-24. These are the only approved labels to be used to identify hazardous material (according to DODINST 6050.5) and can be filled in using the DoD HMIS CD-ROM.

EMBARKATION

The movement of equipment/material done at a battalion level will involve personnel throughout the command. While Alpha company has the bulk of the

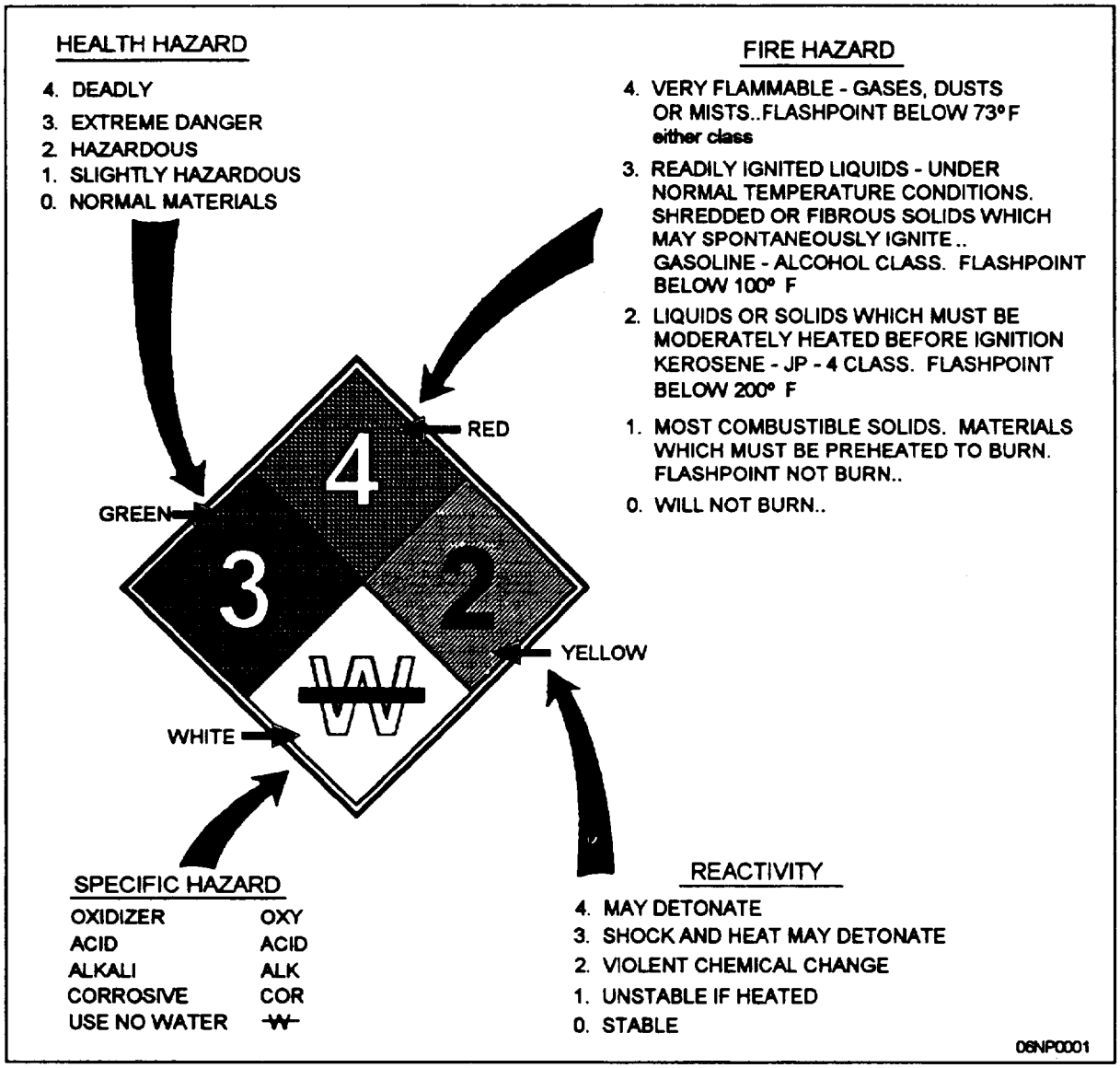


Figure 1-24.—Hazardous chemical warning label.

responsibility, you, as a CE, can and will become involved.

AIR DETACHMENT

The Air Detachment (Air Det), as stated in U.S. *Naval Mobile Construction Battalion (NMCB) Doctrine and Policy Governing,* OPNAVINST 5450.46, is part of a Naval Mobile Construction Battalion (NMCB) organization and is capable of deploying within 48 hours of notification. The mission of the Air Det is to provide contingency support for the Navy, Marine Corps, and other forces, and perform and participate in disaster recovery operations and field exercises (FEX). The Air Det has approximately 90 personnel assigned and contains air-liftable supplies, tools, and Civil Engineer Support Equipment (CESE) to perform both horizontal and vertical construction. The Air Det is self-sufficient for 30 days (600 construction hours), except for ammunition, rations, and fuel. The Air Det can operate independently of an NMCB for an indefinite period when provided logistic support.

Personnel are assigned to the Air Det by the Battalion Operations Department using the basic

guidelines provided in the *NCF Embarkation Manual,* COMCBPAC/COMCBLANTINST 3120.1. The ratings and number of personnel assigned to the Air Det are governed by the tasking of the mission.

The Air Det is organized into three platoons: an equipment platoon, a support platoon, and a construction platoon. The equipment platoon supervisor organizes the platoon into a military formation and assigns military and job-related responsibilities.

TABLE OF ALLOWANCE (TOA)

The Table of Allowance (TOA) outfits the Naval Mobile Construction Battalion with the capability to perform construction operations under contingency conditions for 90 days (1800 construction hours) without resupply. However, fuel and subsistence are limited to 15 days support, and construction materials that support construction operations are not part of the TOA. The area commander/project sponsor requiring the use of Seabees is responsible for the procurement and shipment of construction materials.

The Civil Engineer Support Office (CESO), Port Hueneme, California, is the system manager responsible for maintaining NCF TOAs. CESO develops new allowances as directed by COMNAVFACENGCOM and collects field recommendations for revisions to existing TOAs. The TOA represents the best selection of tools and supplies needed to provide general construction capabilities; however, the TOA is not capable of meeting every conceivable operational requirement. When an assigned project requires tools or equipment in excess of the unit's capability, the allowance is supplemented by augmentation.

CESE REQUIREMENTS

The amount of CESE and supplies required for a mission is controlled by the availability of airlift, sealift, or over-the-road support. This requires the Air Det to preplan and prioritize all tasking and request only the amount of resources needed to accomplish the mission successfully. The knowledge and expertise of the equipment platoon supervisor enhances the Air Det's ability to identify and request the required CESE, supplies, and POL for the Air Det mission. This allows the embarkation office to prepare aircraft load plans to meet the Air Det's needs.

OPERATOR ASSIGNMENTS

Once the CESE list has been established, the equipment platoon supervisor must assign operators and co-drivers. Operators are required to accompany the CESE throughout the transport to the mission site and also must stand by their assigned CESE that has been prepared and staged at the marshalling area for the joint inspection (JI). The staging and marshalling area is where equipment and materials are received. CESE is inspected for cleanliness and fluid leaks, mobile loads are completed, vehicles are weighed and marked for center of balance, cargo is palletized on the Air Force 463L cargo pallets (fig. 1-25), and cargo and CESE are placed into a configuration for each aircraft A pre-JI is held and performed by the battalion embarkation officer and the regiment embarkation staff from Port Hueneme, California, or Gulfport, Mississippi, during the home-port period. When the battalion is deployed overseas, COMCBPAC/COMCBLANT embarkation representatives perform the pre-JI. The pre-JI allows the battalion time to correct any discrepancies before the main JI.

CESE AND MATERIAL PREPARATION

Upon notification of the Air Det to mount-out. the battalion reorganizes and sets up a mount-out control center (MOCC). The MOCC is under the direction of the battalion executive officer. The MOCC controls, coordinates, and monitors the movement of all personnel, supplies, and equipment to the marshalling area. The MOCC and the embarkation staff control all aspects of an NMCB mount-out and serves as the coordinating center for all the companies and battalion staff.

PALLETIZED CARGO

The 463L pallet is the Air Force standard equipment for the movement of concentrated cargo. Military aircraft installed with a dual-rail system that consists of rows of rollers allow the 463L pallets loaded with cargo to move easily into the aircraft. The 463L pallet is made of corrosion-resistant aluminum and has a softwood core. The pallet has an outside dimension of 108 inches by 88 inches and is 2 1/4 inches thick. The cargo area space is 104 inches by 84 inches, which allows for 2 inches around the pallet to attach straps, nets, or other restraint devices. The pallet weighs 290 pounds empty and has a maximum load capacity of 10,000 pounds.

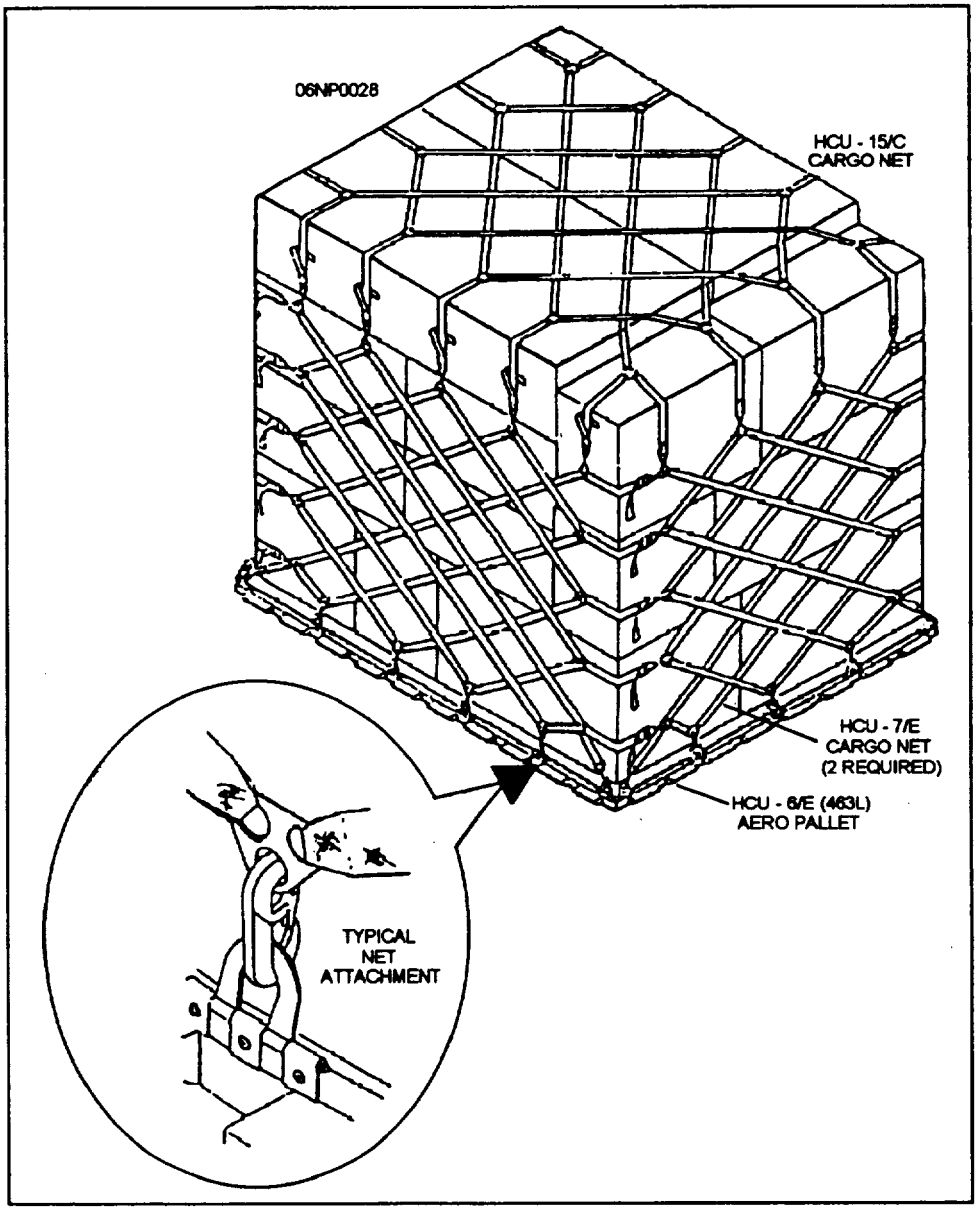


Figure 1-25.—463L pallet with cargo and net.

PROJECTS

The primary purpose of the construction platoon is to perform construction operations for the Air Det with the support of the equipment and support platoons. Construction tasking covers a broad scope of activities: disaster recovery operations, war damage repairs, rapid runway repairs, humanitarian relief, constructing advance base functional components, and so forth. The assignment of ratings assigned to the Air Det depends on the extent of tasking, such as horizontal or vertical construction. The amount of time allotted to plan construction projects depends on the urgency for the Air Det to embark to the mission site.

TOOL KITS

Some tool kits are groups of tools assembled for specific purposes, like bending conduit or pulling wire or cable. Other kits include tools for general electrical construction work. The kits for general work include toolboxes. Enough toolboxes are supplied in the kit for one crew of Construction Electricians.

The Civil Engineer Support Office (CESO) determines the contents of the kits. CESO is located at the Construction Battalion Center (CBC), Port Hueneme, California. Kit contents may change as new tools become available and as the need for a particular assembly is pointed out to CESO by Construction Electricians in the field

TOOL KIT INVENTORIES

The requirements associated with tool kit accountability sometimes vary from one activity to another. You are responsible for tools checked out to you from the central toolroom (CTR). Tools are not only expensive but are essential equipment for those who use them in constructing a quality project. The proper tools must be available when and where they are needed. The only way to be certain the right tools are available when needed is to keep track of them at all times.

Kits from CTR should be maintained at 100 percent of kit assembly allowance. Damaged and worn tools should be returned to CTR for replacement in kind. Tools requiring routine maintenance, such as power tools, should be turned in for repair and reissue. You will be required to submit NAVSUP Form 1250-1s (fig. 1-26) signed by a designated officer for tools and/or consumables needed to replace consumed, lost, or missing items in the kits. Normally, these NAVSUP Forms 1250-1s will be attached to the biweekly inventory sheets (fig. 1-27). EXCESSIVE SHORTAGES BETWEEN INVENTORIES ARE TO BE INVESTIGATED.

TOOL STOWAGE AND SECURITY

The crew leader must plan ahead for tool stowage and security. When there is no secure place to stow tools at the jobsite, you may need to make arrangements to haul them back to the camp each day. “Gang” boxes are sometimes used to secure all the tools of a crew at a jobsite. These are large lockable boxes constructed of wood or steel and are sometimes equipped with wheels. Even though these boxes may have sloped roofs and be waterproofed, they should be placed on high ground in case of local flooding. Once you have considered storage and security of tools, you need to decide how to keep up with them through the workday.

You are responsible for the security and safe operation of your tools. Crew members may want to carry their toolboxes to the jobsite or leave them in the gang box or secure area. Toolboxes are best kept locked. Tools used daily may be kept in a pouch. For safety and tool-security reasons, you should be especially careful not to leave small hand tools lying around.

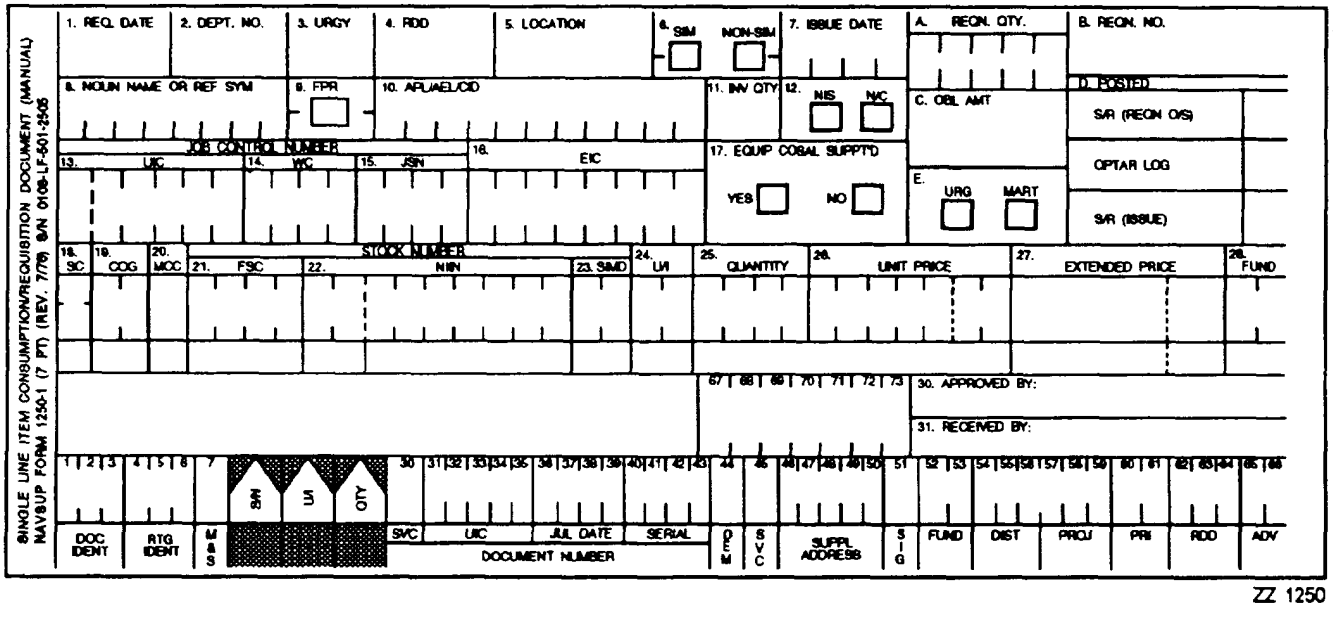


Figure 1-26.—Single-Line Item Consumption Document (Manual), NAVSUP Form 1250-1.

FACSO RPT SYM/NO. 04440/B356IRQ1 I N V E N T O R Y M A N A G E M E N T S Y S T E M 06NP0029 89JUN06

42 PROJECT NO. AEG94 KIT INVENTORY LIST TA31 PAGE 211

80007 SEQ. NO. G SEQUENCE = KIT, SEQ. NO. ALPHA

COG	STOCK NUMBER	QTY	UI	UNIT PRICE	EXT. PRICE	(JULIAN DATE OF INVENTORY/ NAVSUP FORM 1250 DEPT NO AND QUANTITY SHORT) (J/D DEPT#(QTY)) (J/D DEPT#(QTY)) (J/D DEPT#(QTY)) (J/D DEPT#(QTY)) (J/D DEPT#(QTY)) (J/D DEPT#(QTY)) (J/D DEPT#(QTY))
9G	4240-01-100-9016	2	EA	23.96	47.92	
	STRAP SAFETY IMPREGNATED NYLON W/NEOPRENE 1 3/4 X 72 KLEIN-KORD P/N 5295-6 W/STD SNAPS					
9Q	4240-00-844-8035	2	PR	5.42	10.84	
	STRAP SET CALF F/CLIMBERS TREE AND POLE,USE W/NSN 4240-01-158-0553 AND 4240-00-893-3326					
9G	5970-00-419-4291	2	RO	.91	1.82	
	TAPE ELEC 0.75NX108FT (BLK) PLSTC					
9Q	5210-00-926-1772	1	EA	12.46	12.46	
	TAPE MEASURE CHROME CLAD 100FT LONG W/HAND CRANK, GRADUATED IN FEET,INCHES AND 8THS OF AN INCH					
9Q	5120-00-277-4248,	2	EA	16.00	32.00	
	WRENCH LINEMAN DBL					
9Q	5120-00-264-3796	2	EA	8.33	16.66	
	WRENCH OE ADJ 12N					
9Q	5120-00-240-5328	2	EA	5.77	11.81	
	WRENCH OE ADJ 8N					
9Q	5120-00-935-7340	1	SE	17.41	17.41	
	WRENCH SET HEX KEY T HANDLE 10PCS 3/32 THRU 3/8N					
	KIT 80007 TOTAL			1,683.01		

SUBTOTAL, SUPPLEMENTAL SHEET SHORTAGES THIS PERIOD ( ) ( ) ( ) ( ) ( ) ( ) ( )
SUBTOTAL, DOLLAR VALUE OF SHORTAGES THIS PERIOD ( ) ( ) ( ) ( ) ( ) ( ) ( )
CUMULATIVE SHORTAGES TO DATE, THIS CUSTODIAN (8FS) ( ) ( ) ( ) ( ) ( ) ( )

I ACKNOWLEDGE CUSTODY AND PERSONAL ACCOUNTABILITY FOR THE MATERIAL IN THIS KIT. (CUSTODIAN . DEPT/CO DATE)

Figure 1-27.—Tool kit inventory list.

CHAPTER 2

DRAWINGS AND SPECIFICATIONS

The Naval bases, advance bases, Seabee camps, and equipment of the Navy were built from plans drawn on blueprints. They are operated, checked, and maintained according to information found on these same blueprints. When the equipment fails in service or is damaged in battle, blueprints are used to aid the repairman. When new parts are to be made or a facility is expanded, blueprints provide the necessary information Planning, scheduling, and manpower and material estimating are based on the information contained in these blueprints. This chapter discusses the function and care of blueprints and the importance of being able to read and work from them.

This chapter will also discuss electrical diagrams and schematics. Diagrams and schematics are maps that indicate the configuration of circuits and circuit connections and components of electrical equipment. When properly used, they are an invaluable aid in installation, troubleshooting, and repair of an electrical component. Understanding and being able to use blueprints and schematics will be some of the most important work assignments you will have as a Construction Electrician.

BLUEPRINTS

Blueprints are reproduced copies of mechanical or other types of technical drawings. The term *blueprint reading* means interpreting the ideas expressed by others on drawings whether the drawings are actually blueprints or not.

Drawing or sketching is the universal language used by engineers, technicians, and skilled craftsmen. Whether this drawing is made freehand or with drawing instruments, it is used to convey all the necessary information to the individual who will then fabricate and assemble the mechanical device.

PARTS OF A BLUEPRINT

Military blueprints are prepared as to size, format, location, and information included in the various blocks according to the Military Standards (ML-STD-100) (latest revision) Engineering Drawing Practices. American National Standard Institute (ANSI) is the mandatory publication used by the Navy for the graphic symbols (ANSI Y32.2—1975) and electrical wiring symbols (ANSI Y32.91—1972). These standards are used on electrical diagrams and electrical drawings. The various parts of a blueprint are described briefly in the following paragraphs.

Title Block

The requirements that determine what information must be included in a title block (fig. 2-1) vary. The title block, however, will contain the title of the drawing, the signature of the approving authority, the drawing number, the sheet number (when the drawing is one of a set of several sheets), and the number of sheets in the project set.

The Naval Facility Engineering Command (NAVFACENGCOM) also requires the following information in title blocks: the name and location of the activity; the specifications and contract numbers (if any); the preparing activity, including the architect-engineer (A-E) firm, if applicable; and the surnames of the personnel concerned in the preparation of the drawings. The code identification number 80091 is to appear in the title block of all NAVFACENGCOM drawings as well as a sheet designation letter (I—Index, C—Civil, A—Architectural, S—Structural, M—Mechanical, P—Plumbing, E—Electrical, and W—Waterfront).

Drawing Number

All blueprints are identified by a drawing number that appears in a block in the lower right-hand comer of the title block. The drawing number is especially important, both for purposes of filing the blueprint and for locating the correct drawing when it is specified on another blueprint.

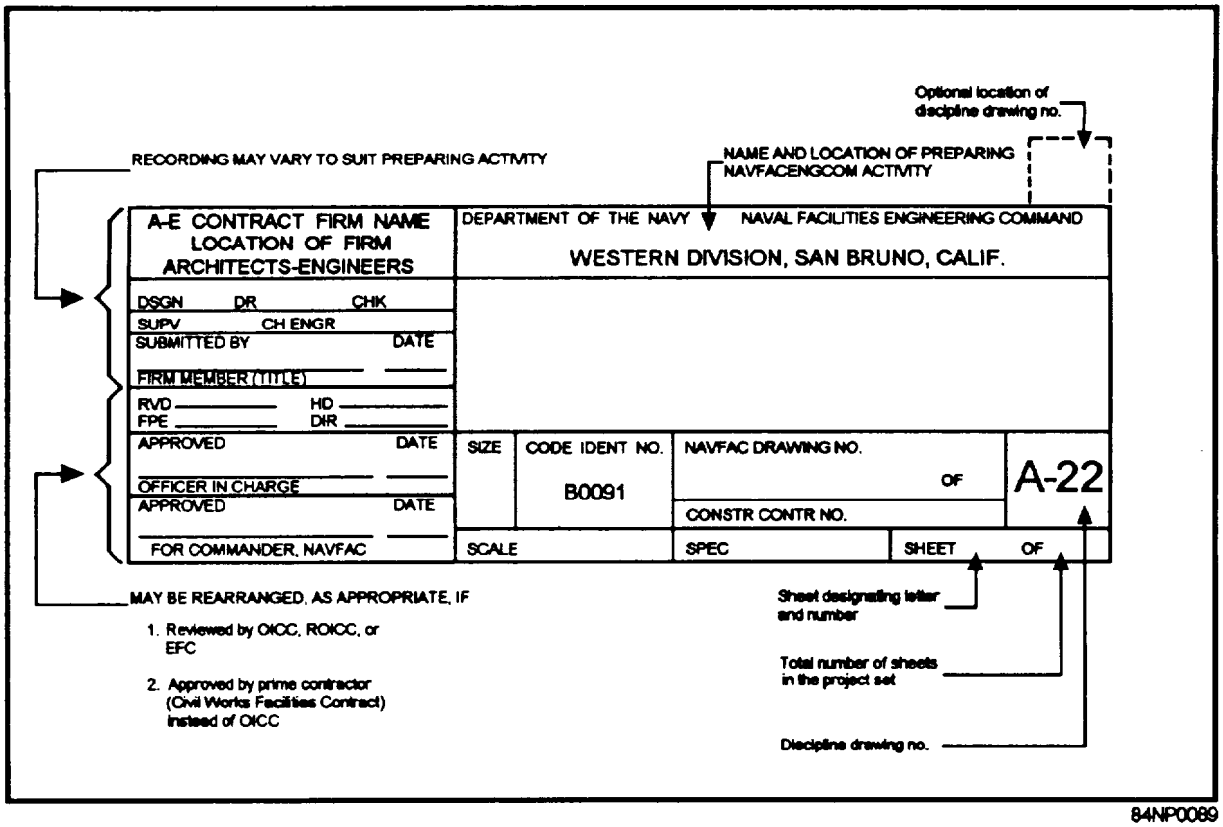


Figure 2-1.—Title block.

Revision Block

The revision block is usually located in the upper right-hand comer of the blueprint and is used for recording of changes (revisions) to the print. All revisions are noted in this block and are dated and identified by a letter and a brief description of the revision (fig. 2-2).

Scale

The graphic representation of the project is drawn to some proportion of the actual size of the project. One-eighth inch on such a drawing is equal to a foot of the actual size of the project. Although the original drawing is scaled accurately, your drawing will be a copy of that original and will not likely be the same size as the original drawing. The copy may have been reduced slightly. The paper size is also affected by temperature and humidity. The paper may stretch or shrink. Because of these factors, do not rely on measurements taken by laying a rule on the drawing. For example, do not assume that a number of units (as 1/8-inch increments) on the drawing is equal to that same number of feet on the project. This may or may

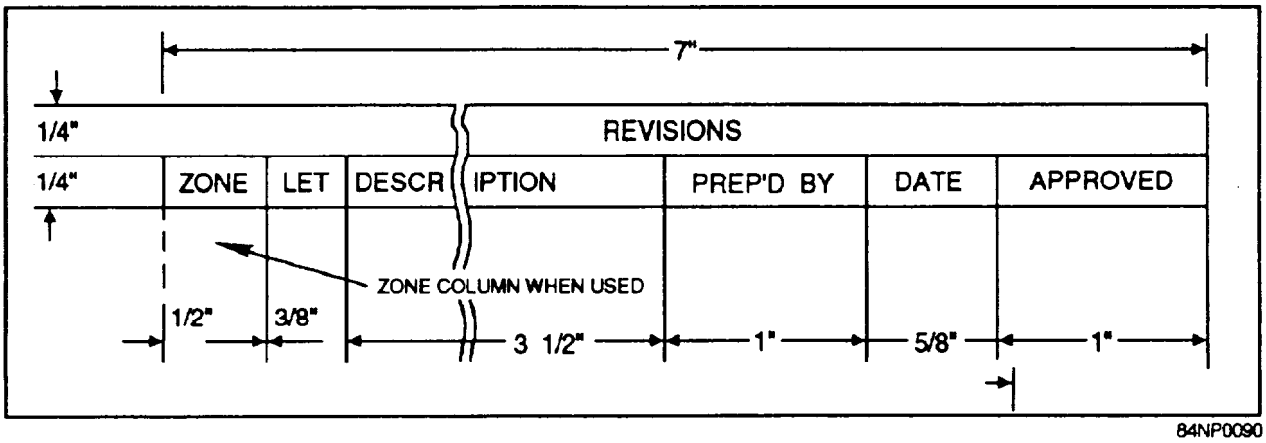


Figure 2-2.—Revision block.

not be true. The assumption can result in expensive and time-consuming rework. Play it safe and read the dimensions shown on the drawing.

Legend or Symbols

The legend, if used, is generally placed in the upper right-hand comer of a blueprint below the revision block. The legend is used to explain or define a symbol or special mark placed on a blueprint. A symbol may have more than one meaning. It should be noted that all symbols used are not from a single standard. The important thing is that you understand the meaning of the symbols on the drawing on which you are working. The legend will give you that meaning. The legend in figure 2-3 shows the symbols and their meanings from the partial floor plan below it.

Bill of Material

On a blueprint, the bill of material block contains a list of the parts and material used on or required by the print concerned. The block identifies parts and materials by stock number or other appropriate number and also lists the quantity used or required.

The bill of material often contains a list of standard parts, known as a parts list or schedule. Many commonly used items, such as machine bolts, screws, fittings, and valves, have been standardized by the

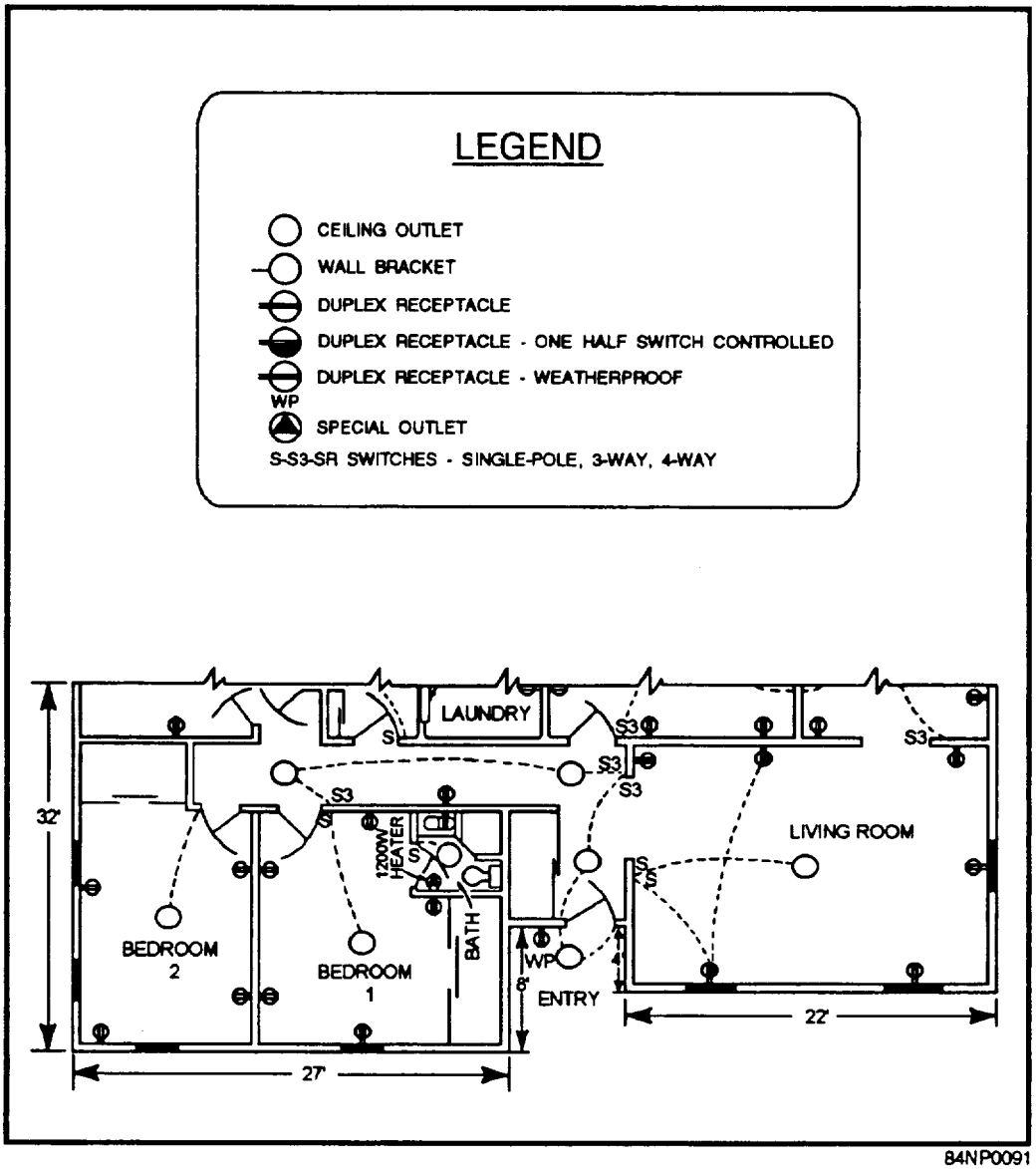


Figure 2-3.—A legend with partial floor plan.

military. A bill of material for an electrical plan is shown in figure 2-4.

SPECIFICATIONS

Even well-drawn construction drawings cannot adequately reveal all the aspects of a construction project. There are many features that cannot be shown graphically. For instance, how can anybody show on a drawing the quality of workmanship required for the installation of electrical equipment or who is responsible for supplying the materials, except by extensive hand-lettered notes. The standard procedure then is to supplement construction drawings with written descriptions. These detailed written instructions, commonly called specifications (specs), define and limit the materials and fabrication according to the intent of the engineer or the designer. The specifications are an important part of the project because they eliminate possible misinterpretation and ensure positive control of the construction.

There are many different types of specifications. A few of those common to the Naval Construction Force (NCF) will be discussed here.

NAVFACENGCOM SPECIFICATIONS

NAVFACENGCOM specifications are prepared by the Naval Facilities Engineering Command, which sets forth the standards of construction for the NCF and all work performed under the jurisdiction of the Naval Facilities Engineering Command.

Several types of specifications influence the preparation of NCF project specifications. These include NAVFACENGCOM guide specifications and type specifications; commercial specifications and standards; technical society and association standards, such as American National Standards Institute (ANSI) and Underwriters Laboratories (UL); and manufacturers' standards.

BILL OF MATERIALS

ITEM NO.	DESCRIPTION	UNIT	ASSEMBLY OR FSN NO.	QUANTITIES	
				TROP	NORTH
3-1	LIGHTING CIRCUIT - NAVFAC DWG. NO. 203414	EA	3016	3	3
3-2	POWER BUS, 100A - NAVFAC DWG. NO. 304131	EA	3047	1	1
3-3	RECEPTACLE CKT - NAVFAC DWG. NO. 303660	EA	3019	2	2
3-4	BOX, RECEPTACLE W/CLAMP FOR NONMETALLIC SHEATH WIRE	EA	5325-102-604	3	3
3-5	LAMP ELECTRIC, MED. BASE, INSIDE FROSTED, 200W, 120V	EA	6240-180-314	60	60
3-6	PLUG: ATTACHMENT, 3 WIRE, 15 AMP, 125 V	EA	5935-102-309	10	10
3-7	PLATE: BRASS, DUPLEX RECEPTACLE	EA	3325-800-101	5	5
3-8	RECEPTACLE, DUPLEX, 3 WIRE, 15 AMP, 125 V	EA	5325-100-102	5	5
3-9	ROD, GROUND, 3/4" X 10'-0"	EA	5306-200-180	12	12
3-10	WIRE, NO. 2 1/C STRANDED, HARD DRAWN, BARE	LB	6143-134-200	52	52
3-11	SWITCH, SAFETY, 2 P, ST 30 AMP, 250 V, PLUS FUSE	EA	5930-142-401	2	2
3-12	CLAMP, GROUND ROD	EA	5209-100-101	13	13
3-13	SWITCH, SAFETY, 200 AMP, 250 V, 3 P	EA	5930-201-903	1	1
3-14	FUSE, RENEWABLE, 200 AMP, 250 V	EA	5920-100-000	6	6
3-15	LINK, FUSE, 200 AMP, 250 V	EA	5920-100-001	6	6
	FUSE PLUG, 30 AMP, 125 V	EA	5920-100-102	12	12

ZZ84M004

Figure 2-4.—Bill of material.

FEDERAL AND MILITARY SPECIFICATIONS

Federal specifications cover the characteristics of materials and supplies used jointly by the Navy and other government agencies. Federal specifications do not cover installation or workmanship for a particular project but specify the technical requirements and tests for materials, products, and services. Federal specifications dictate the minimum requirements acceptable for use of all federal agencies. The engineering technical library should contain all of the commonly used federal specifications pertinent to Seabee construction.

Military specifications are those specifications that have been developed by the Department of Defense. Like federal specifications, they also cover the characteristics of materials. They are identified by MIL preceding the first letter and serial number, such as MIL-L-19140C (lumber and plywood, fire-retardant treated).

Your main concern will be with project specifications. Even if you do not see them, you should know that they exist and what kind of information they include.

PROJECT SPECIFICATIONS

Construction drawings are supplemented by written project specifications. Project specifications give detailed information regarding materials and methods of work for a particular construction project. They cover various factors relating to the project, such as general conditions, scope of work, quality of materials, standards of workmanship, and protection of finished work. The drawings, together with the project specifications, define the project in detail and show exactly how it is to be constructed. Usually, any set of drawings for an important project is accompanied by a set of project specifications. The drawings and project specifications are inseparable. The drawings indicate what the project specifications do not cover; and the project specifications indicate what the drawings do not portray, or they clarify further details that are not covered or amplified by the drawings and notes on the drawings. Whenever there is conflicting information on the drawings and project specifications, the project specifications take precedence over the drawings.

The general requirements are usually the first specifications listed for the structure, stating the type of foundation, character of load-bearing members (wood frame, steel frame, or concrete), type or types of doors and windows, types of mechanical and electrical installations, and the principal function of the building.

Next follows the specific conditions that must be carried out by the constructors. These are grouped in divisions under headings applying to each major phase of construction, such as the following typical list of divisions:

1. GENERAL REQUIREMENTS
2. SITE WORK
3. CONCRETE
4. MASONRY
5. METALS
6. CARPENTRY
7. MOISTURE CONTROL
8. DOORS, WINDOWS, AND GLASS
9. FINISHES
10. SPECIALTIES
11. EQUIPMENT
12. FURNISHINGS
13. SPECIAL CONSTRUCTION
14. CONVEYING SYSTEMS
15. MECHANICAL
16. ELECTRICAL
17. EXPEDITIONARY STRUCTURES

Sections under one of these general categories sometimes begin with general requirements for that category. For example: under DIVISION 16.—ELECTRICAL, the first section might read as follows:

> 16.—0l.—General Requirements.—Electrical installation must conform to the requirements of the National Electrical Code©. This includes all temporary work and the complete installation. The service entrance equipment must conform to the requirements of the local electric utility company if it is the source of electric power for the building or facility.

Subsequent sections under DIVISION 16.—ELECTRICAL would specify various quality criteria and standards of workmanship for the different types of electrical installation work; for example:

16.—05.—Installation of Wires and Cables. Installation of wire in conduit is made with the use of pull lines or fish tapes and an approved wire-pulling lubricant. Suitable equipment should be provided to prevent cutting or abrasion of conductor insulation during the pulling of the wires. Lubricating compound must not have a harmful effect on the conductor insulating materials. All wires in a conduit are bundled and pulled at one time. Pulling lines are attached by direct connection to the conductors or by the use of a cable grip. Slack is provided at attachment of devices or splicing. In outlet boxes, for future installation of wiring devices, the ends of wires are insulated with tape or a suitable wire connector. All conductors of each circuit in a junction box containing multiple circuits must be permanently identified with suitable labels.

Nonmetallic-sheathed cable may be installed exposed on walls and ceilings in protected areas or concealed in hollow walls, under floors, or above ceilings. Provisions for outlets and switches are made by running the cable into outlet boxes. All splices are enclosed in outlet or junction boxes; this requirement applies to both exposed and concealed installation.

The moment your battalion or unit receives orders to undertake a major construction project, watch for the arrival of sets of drawings and specifications, which are usually provided well in advance of the deployment period. These drawings and specifications will also be the basis for the P&E and scheduling. Take a look at the specifications. After you advance in rate, especially if you are concerned with P&E, it will be your responsibility to study the applicable specifications thoroughly.

NAVFACENGCOM has prepared specifications that cover practically every subject on naval construction. These specifications are the standards followed by the NCF—above all other specifications that may be available.

DRAWINGS AND SKETCHES

As a Construction Electrician you will be required to read and interpret drawings and specifications, sketches, and electrical diagrams. Before you can work with drawings effectively, you must know how to interpret electrical symbols correctly. Knowing how to draw and interpret freehand sketches is also important. You will see how the different parts of a drawing relate to the overall plan the drawing represents. You will also learn to recognize the different types of drawings and their uses.

SYMBOLS

One of the most important symbols to use right at the beginning of a new job is the directional symbol. This symbol, which is usually an arrow labeled "N" for north, enables the reader of a construction drawing to orient it. A drawing is properly oriented when it is held so that the north arrow shown on the drawing is pointing toward north. Construction Electricians sometimes find themselves standing in open ground with only a drawing and an area staked off by the Engineering Aid who tells them where to start shoveling for an underground conduit run. The drawing must be properly oriented so the reader can relate the information on it to the surrounding area. Understanding common standard symbols, such as the north arrow mentioned above, is a must for some one who expects to do well inelectrical construction work.

Some of the most common symbols you will see in building construction work are listed in figure 2-5. These symbols were selected from ANSI Y32.9—1972. Study these symbols carefully. A good way to memorize them is to copy each symbol several times while thinking of the electrical component or device it represents. Learn to relate each symbol mentally to the component it represents whenever you see the component. For example, as you pull the wire through a conduit in a floor slab, you might try to recall the symbol mentally for "wiring concealed in floor." When you walk into the company office and see a duplex receptacle outlet, you should think about its symbol. This practice will enable you to associate symbols to actual electrical devices. This type of training will help you become a better CE.

Although figure 2-5 shows some of the most common standard symbols, these are by no means the only ones you will see in your work. Sometimes a symbol for a particular component or device may have been created by the architect or engineer who developed the drawing. For various reasons, some of the symbols on a drawing may not be standard. Many times you will figure out what a symbol means by analyzing it and thinking about what it looks like. The legend on a drawing should show any nonstandard symbols and their meanings.

Lighting Outlets

Ceiling *Wall*

Surface or Pendant Incandescent, Mercury-Vapor, or Similar Lamp Fixture

Surface or Pendant Individual Fluorescent Fixture

Surface or Pendant Continuous-Row Fluorescent Fixture

Bare-Lamp Fluorescent Strip

Surface or Pendant Exit Light

Junction Box

Receptacle Outlets

Grounded *Ungrounded*

Single Receptacle Outlet

Duplex Receptacle Outlet

Duplex Receptacle Outlet–Split Wired

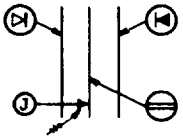
Single Special-Purpose Receptacle Outlet

Range Outlet (typical)

Floor Duplex Receptacle Outlet

Floor Telephone Outlet

Application: example of the use of various symbols to identify location of different types of outlets or connections for underfloor duct or cellular floor systems



Switch Outlets

Single-Pole Switch

S

Double-Pole Switch

S2

Three-Way Switch

S3

Four-Way Switch

S4

Key-Operated Switch

SK

Switch and Pilot Lamp

SP

Switch for Low-Voltage Switching System

SL

Switch and Single Receptacle

S

Switch and Double Receptacle

S

Door Switch

SD

Time Switch

ST

Residential Occupancies

Signaling system symbols for use in identifying standardized residential type signal system items on residential drawings where a descriptive symbol list is not included on the drawing.

Push button

Buzzer

Bell

Annunciator

Interconnection Box

Bell-Ringing Transformer

BT

Interconnecting Telephone

Radio Outlet

R

Television Outlet

TV

Panelboards, Switchboards, and Related Equipment

Flush-Mounted Panelboard and Cabinet

NOTE: Identify by notation or schedule.

Surface-Mounted Panelboard and Cabinet

Switchboard, Power Control Center, Unit Substations (should be drawn to scale)

Flush-Mounted Terminal Cabinet

NOTE: In small-scale drawings the TC may be indicated alongside the symbol.

TC

Surface-Mounted Terminal Cabinet

TC

Motor or Other Power Controller

MC

Externally Operated Disconnection Switch

Combination Controller and Disconnection Means

84NP0092

Figure 2-5.—Graphic symbols used in building construction.

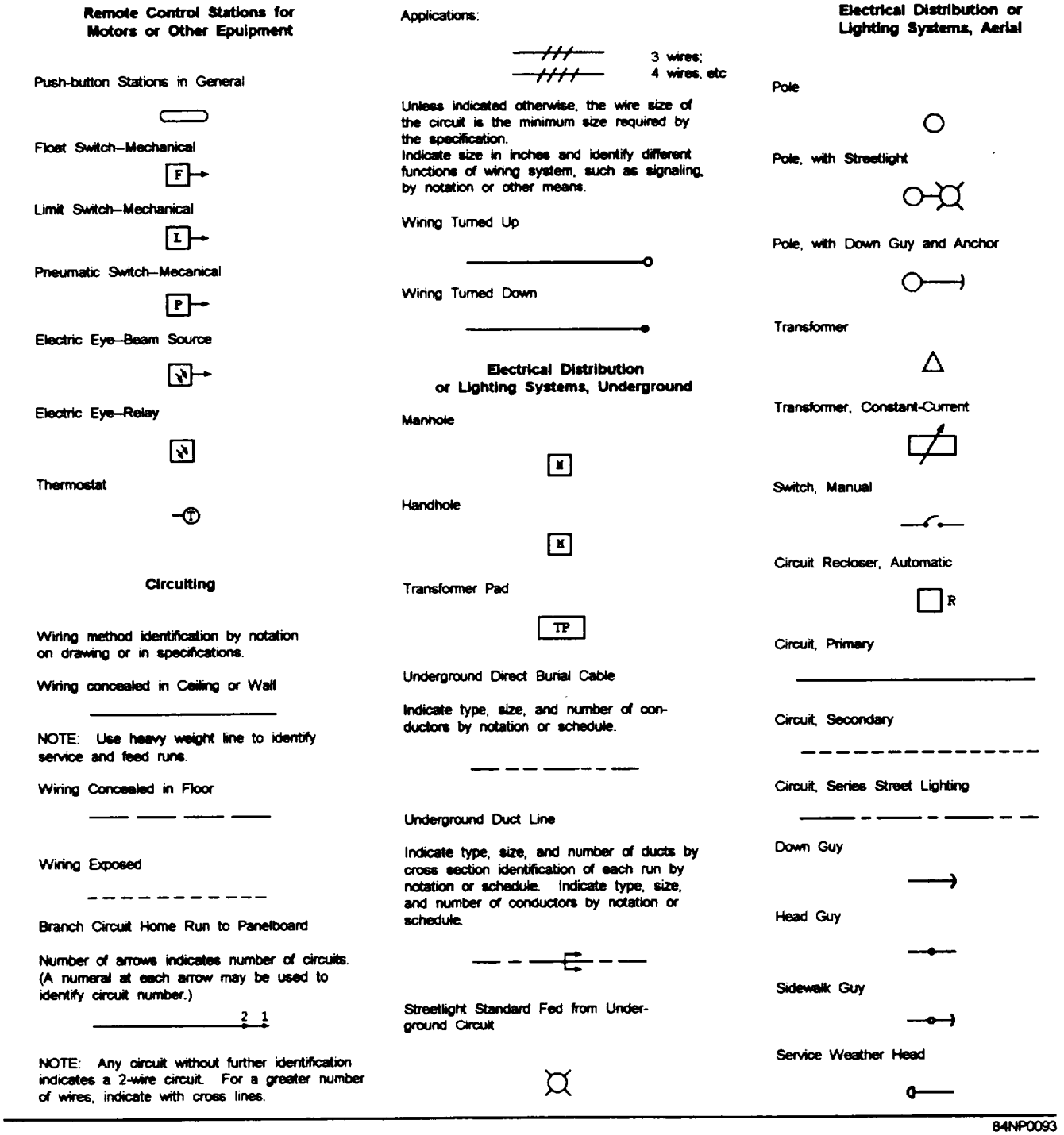


Figure 2-5.—Graphic symbols used in building construction—Continued.

Figure 2-6 shows some more standard electrical symbols. They may also be used in construction drawings but will most often be seen in other types of drawings, such as schematic diagrams. The symbols in figure 2-6 were selected from ANSI Y32.2-1975. This standard gives the following information about the symbols that may help you understand them better:

- Graphic symbols are used to show the functioning or interconnections of a circuit graphically.

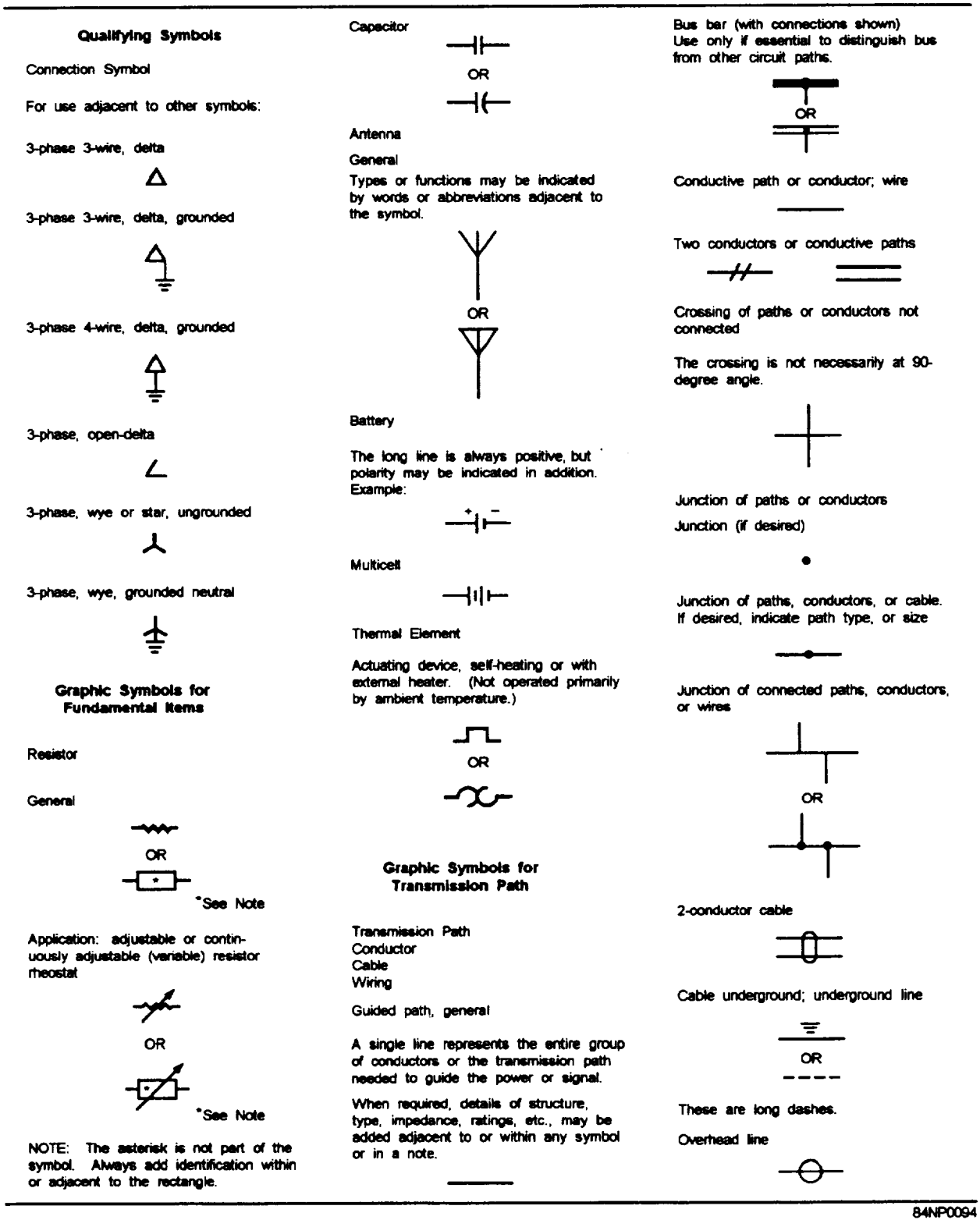


Figure 2-6.—Graphic symbols used in electrical and electronic diagrams.

Circuit Return

Ground general symbol

NOTE: Supplementary information may be added to define the status or purpose of the earth if this is not readily apparent.

(1) A direct conducting connection to the earth or body of water that is a part thereof.
(2) A conducting connect to a structure that serves a function similar to that of an earth ground (that is, a structure such as a frame of an air, space, or land vehicle that is not conductively connected to earth).



Chassis or frame connection; equivalent chassis connection (of printed-wiring boards)

A conducting connection to a chassis or frame, or equivalent chassis connection of a printed-wiring board. The chassis or frame (or equivalent chassis connection of a printed-wiring board) may be at substantial potential with respect to the earth or structure in which this chassis or frame (or printed-wiring board) is mounted.



Graphic Symbols for Contacts, Switches, Contacts, and Relays

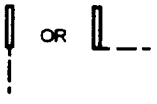
Electrical Contact

Fixed contact for jack, key, relay, switch, etc





‡ Sleeve



‡ The broken line - — - indicates where line connection to a symbol is made and is not part of the symbol

Moving Contact

Adjustable or sliding contact for resistor, inductor, etc



Locking



Nonlocking

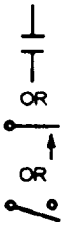
Basic Contact Assemblies

The standard method of shown a contact is by a symbol indicating the circuit condition it produces when the actuating device is in the de-energized or nonoperated position. The actuating device may be of a mechanical, electrical, or other nature, and a clarifying note may be necessary with the symbol to explain the proper point at which the contact functions; for example, the point where a contact closes or opens as a function of changing pressure, level, flow, voltage, current, etc. In cases where it is desirable to show contacts in the energized or operated condition and where confusion may result, a clarifying note shall be added to the drawing.

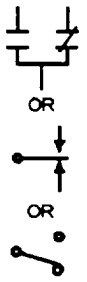
Closed contact (break)



Open contact (make)



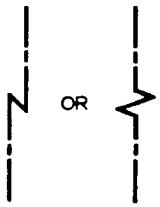
Transfer



Make-before-break



Magnetic Blowout Coil



Operating Coil
Relay Coil



Switch

Fundamental symbols for contacts, mechanical connections, etc, may be used for switch symbols.

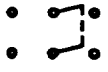
Single-throw, general



Double-throw, general



2-pole double-throw switch with terminals shown



NOTE: The asterisk is not part of the symbol. Always replace the asterisk by a device designation.

84NP0095

Figure 2-6.—Graphic symbols used in electrical and electronic diagrams—Continued.

Push button, Momentary or Spring-Return

Circuit closing (make)



Circuit opening (break)



Two-circuit

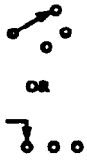


Selector or Multiposition Switch

The position in which the switch is shown may be indicated by a note or designation of switch postion.

General (for power and control diagrams)

Any number of transmission paths may be shown.



Limit Switch
Sensitive Switch

NOTE: Identify by LS or other suitable note.

Track-type, circuit-closing contact



Track-type, circuit-opening contact



Flow-Actuated Switch

Closes on increase in flow



Opens on increase in flow



Liquid-Level-Actuated Switch

Closes on rising level



Opens on rising level



Pressure-or Vacuum-Actuated Switch

Closes on rising pressure



Opens on rising pressure



Temperature-Actuated Switch

Closes on rising temperature



Opens on rising temperature



Thermostat

Closes on rising temperature



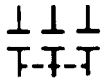
*See Note

Contactor

See also CIRCUIT BREAKER

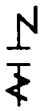
Fundamental symbols for contacts, coils, mechanical connections, etc, are the basis of contactor symbols and should be used to represent contactors on complete diagrams. Complete diagrams of contactors consist of combinations of fundamental symbols for control coils, mechanical connections, etc, in such configurations as to represent the actual device. Mechanical interlocking should be indicated by notes.

Manually operated 3-pole contactor



NOTE: The t° symbol shall be shown or be replaced by data giving the nominal or specific operating temperature of the device.

Electrically operated 1-pole contactor with series blowout coil



Electrically operated 3-pole contactor with series blowout coils; 2 open and 1 closed auxiliary contacts (shown smaller than the main contacts)



Relay

Fundamental symbols for contacts, mechanical connections, coils, etc, are the basis or relay symbols and should be used to represent relays on complete diagrams.

The following letter combinations or symbol elements may be used with relay symbols. The requisite number of these letters or symbol elements may be used to show what special features a relay possesses.



AC Alternating-current or ringing relay
D Differential
DB Double-biased (biased in both directions)
DP Dashpot
EP Electrically polarized
FO Fast-operate
FR Fast-release
L Latching
MG Marginal
ML Magnetic-latching (remanent
NB No bias
NR Nonreactive



P Magnetically polarized using biasing spring, or having magnet bias
SA Slow-operate and slow-release



SO Slow-operate
SR Slow-release
SW Sandwich-wound to improve blance to longitudinal currents

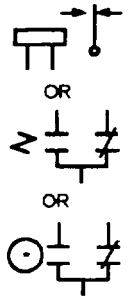
The proper poling for a polarized relay shall be shown by the use of + and – designations applied to the winding leads. The interpretation of this shall be that a voltage applied with the polarity as indicated shall cause the armature to move toward the contact shown nearer the coil on the diagram. If the relay is equipped with numbered terminals, the proper terminal numbers shall also be shown.

Basic

84NP0096

Figure 2-6.—Graphic symbols used in electrical and electronic diagrams—Continued.

Relay with transfer contacts



Graphic Symbols for Terminals and Connectors

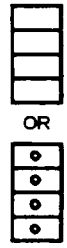
Terminals

Circuit terminal

Terminal board or terminal strip, with 4 terminals shown; group of 4 terminals

Number and arrangement as convenient.

NOTE: Internal lines and terminals may be omitted if terminal identifications are shown within the symbol.



Cable Termination

Line shown on left of symbol indicates cable.



Connector
Disconnecting Device
Jack
Plug

The contact symbol is not an arrowhead. It is larger and the lines are drawn at a 90-degree angle.

Female contact 

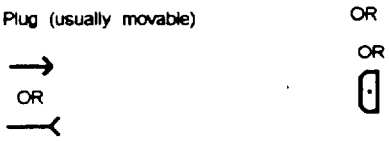
Male contact 

Receptacle or jack (usually stationary)

NOTE: The asterisk is not part of the symbol. If desired, indicate the type of contacts: male (—►) or female (►—).



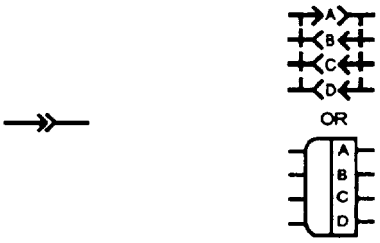
Plug (usually movable)



Separable connectors (engaged)



Engaged 4-conductor connectors; the plug has 1 male and 3 female contacts with individual contact designations shown in the complete-symbol column



Communication switchboard-type connector

2-conductor (jack) 

2-conductor (plug) 

Graphic Symbols for Transformers, Inductors, and Windings

Core

General or air core

If it is necessary to identify an air core, a note should appear adjacent to the symbol of the inductor or transformer

NO SYMBOL

Magnetic core of inductor or transformer

Not to be used unless it is necessary to identify a magnetic core.



Inductor
Winding (machine or transformer)
Reactor
Radio-Frequency Coil
Telephone Retardation Coil

See also OPERATING COIL

General



Magnetic-core inductor
Telephone loading coil

If necessary to show a magnetic core.



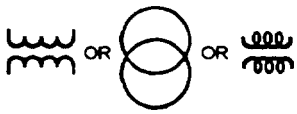
Tapped



Adjustable inductor



Transformer
General

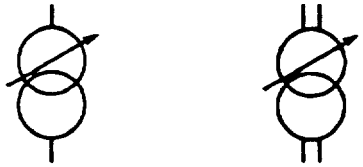


Shielded transformer with magnetic core shown



One winding with adjustable inductance

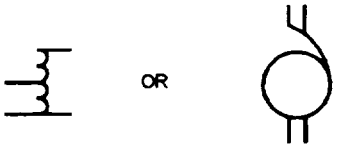




Adjustable mutual inductor; constant-current transformer



Autotransformer, 1-phase



84NP0097

Figure 2-6.—Graphic symbols used in electrical and electronic diagrams—Continued.

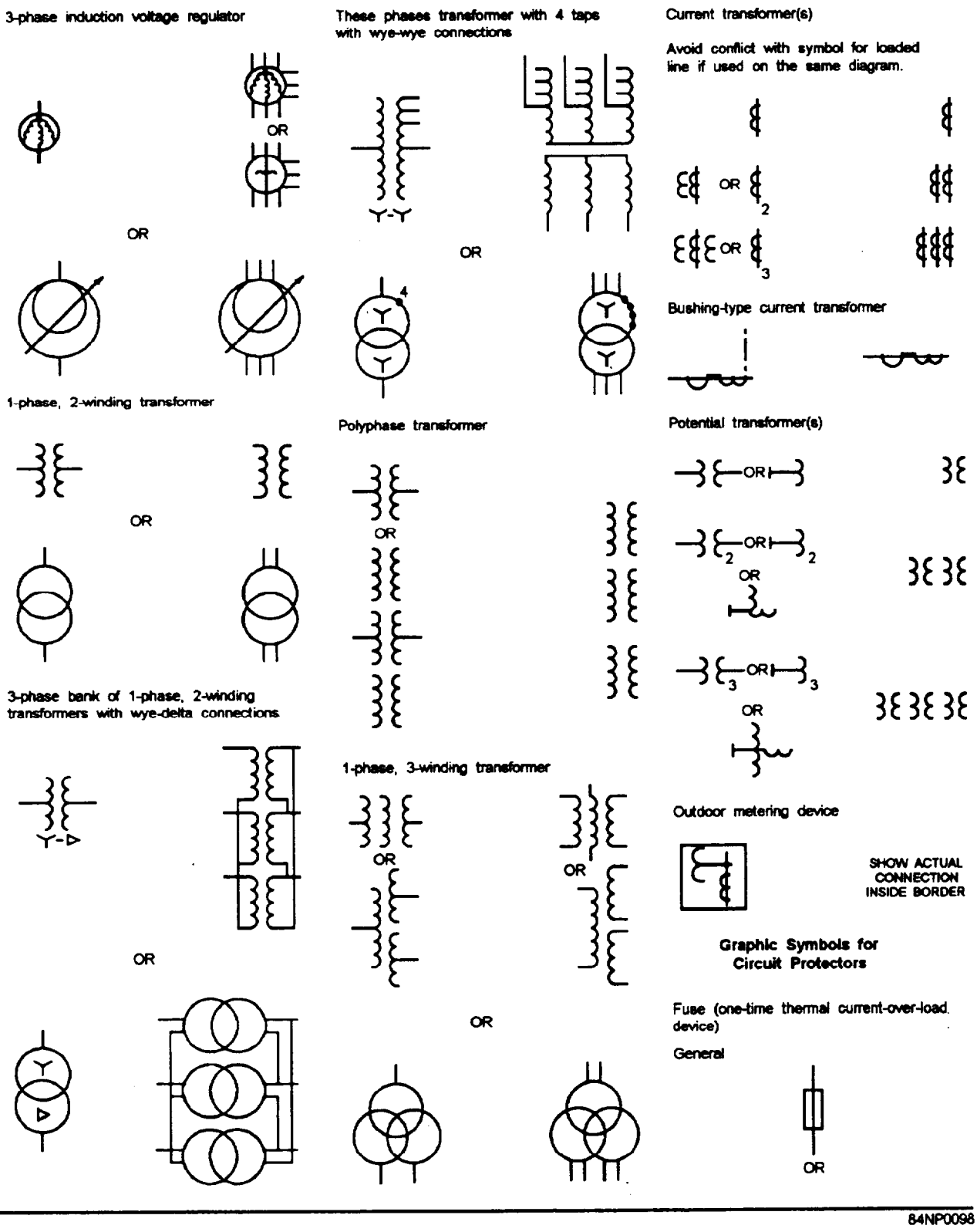


Figure 2-6.—Graphic symbols used in electrical and electronic diagrams—Continued

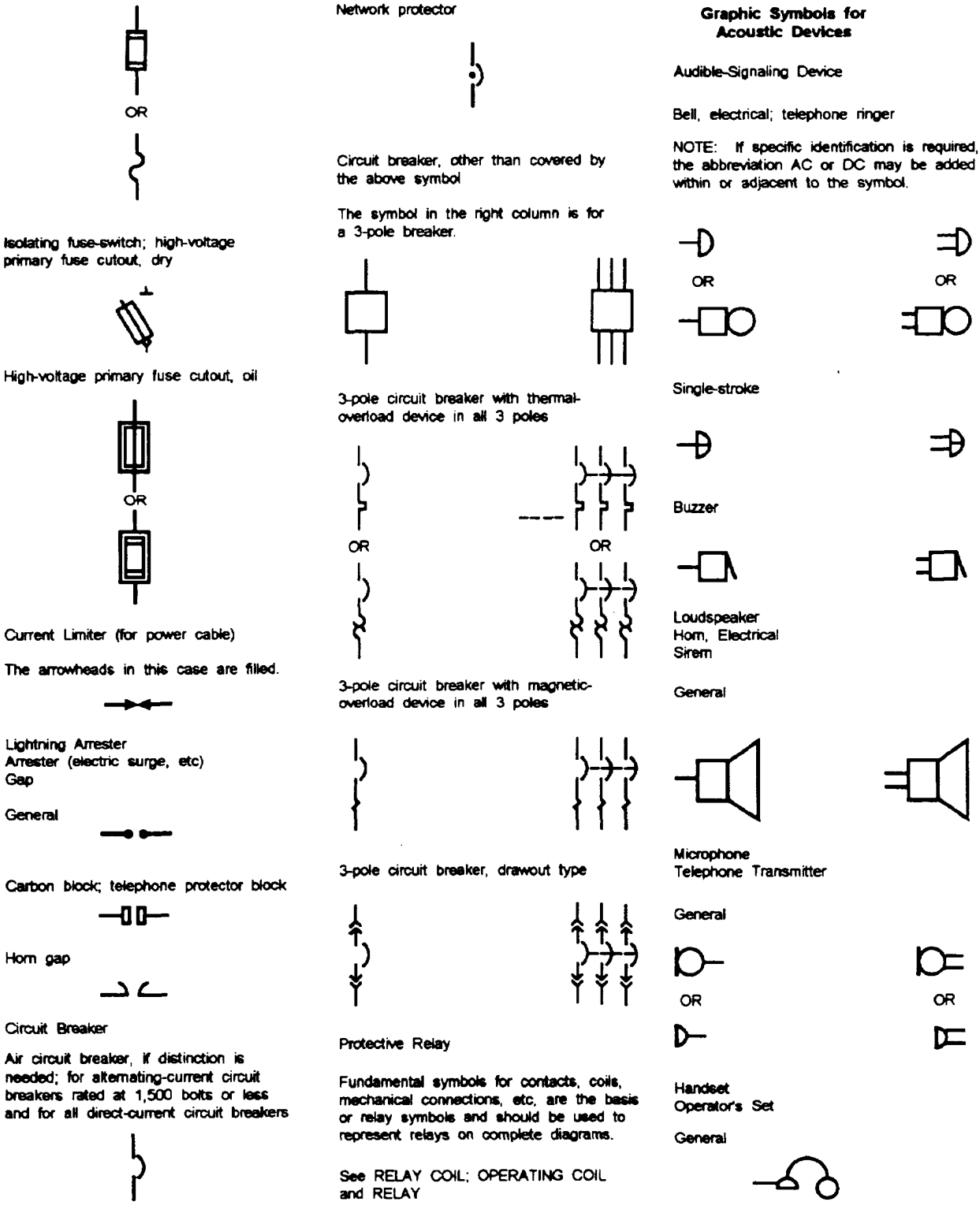


Figure 2-6.—Graphic symbols used in electrical and electronic diagrams—Continued.

Telephone Receiver
Earphone

General



Headset, double



Headset, single



Graphic Symbols for Lamps and Visual-Signaling Devices

Lamp

Lamp, general; light source, general



NOTE: This symbol may be used to represent one or more lamps with or without operating auxiliaries.

NOTE: If it is essential to indicate the following characteristics, the specified letter or letters may be inserted within or placed adjacent to the symbol.

A	Amber
B	Blue
C	Clear
G	Green
O	Orange
OP	Opalescent
P	Purple
R	Red
W	White
Y	Yellow
ARC	Arc
EL	Electroluminescent
FL	Fluorescent
HG	Mercury vapor
IN	Incandescent
IR	Infrared
NA	Solium vapor
NE	Neon
UV	Ultraviolet
XE	Xenon
LED	Light-emitting diode

Fluorescent lamp

2-terminal



4-terminal



Incandescent lamp (incandescent-filament illuminating lamp



Ballast lamp; ballast tube

The primary characteristic of the element within the circle is designed to vary non-linearly with the temperature of the element.



Visual-Signaling Device

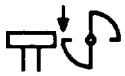
Annunciator (general)



Annunciator drop or signal, shutter or grid type



Annunciator drop or signal, ball type



Manually restored drop



Electrically restored drop



Communication switchgoard-type lamp; indicating lamp

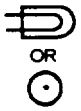


Indicating, pilot, signaling, or switch-board light; indicator light signal light

If confusion with other circular symbols may occur, the D-shaped symbol should be used.



OR



Jeweled signal light



Graphic Symbols for Readout Devices

Meter Instrument

NOTE: The asterisk is not part of the symbol. Always replace the asterisk by one of the following letter combinations, depending on the function of the meter or instrument, unless some other identification is provided in the circle and explained on the diagram.

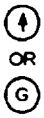


A	Ammeter
AH	Ampere-hour meter
C	Coulombmeter
CMA	Contact-making (or breaking) ammeter
CMC	Contact-making (or breaking) clock
CMV	Contact-making (or breaking) voltmeter
CRO	Oscilloscope Cathode-ray oscillograph
DB	DB (decibel) meter Audio level/meter
DBM	DBM (decibels referred to 1 milliwatt) meter
DM	Demand meter
DTR	Demand-totalizing relay
F	Frequency meter
GD	Ground detector
I	Indicating meter
μA or UA	Microammeter
MA	Milliammeter
NM	Noise meter
OHM	Ohmmeter
OP	Oil pressure meter
OSCG	Oscillograph, string
PF	Power factor meter
PH	Phasemeter
PI	Position indicator
RD	Recording demand meter
REC	Recording meter
RF	Reactive factor meter
SY	Synchroscope
t°	Temperature meter
THC	Thermal converter
TLM	Telemter
TT	Total time meter Elapsed time meter
V	Voltmeter
VA	Volt-ammeter
VAR	Varmeter
VARH	Varhour meter
VI	Volume indicator Audio-level meter
VU	Standard volume indicator Audio-level meter
W	Wattmeter
WH	Watthour meter

84NP0100

Figure 2-6.—Graphic symbols used in electrical and electronic diagrams—Continued.

Galvanometer



Graphic Symbols for Rotating Machinery

Rotating Machine

Basic



Generator (general)

Avoid conflict with symbols for galvanometer if used on the same diagram.

OR



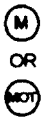
Generator, direct-current



Generator, alternating-current



Motor (general)



Motor, direct-current



Motor, alternating-current



Winding Connection Symbols

Motor and generator winding connection symbols may be shown in the basic circle using the following representations.

1-phase



2-phase



3-phase wye (ungrounded)



3-phase wye (grounded)



3-phase delta



Alternating-Current Machines

Squirrel-cage induction motor or generator, split-phase induction motor or generator, rotary phase converter, or repulsion motor



Wound-rotor induction motor, synchronous induction motor, induction generator, or induction frequency converter



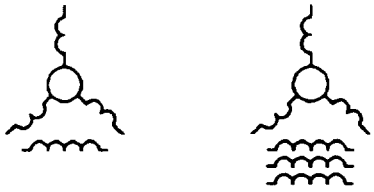
1-phase shaded-pole motor



1-phase repulsion-start induction motor



3-phase regulating machine



Alternating-Current Machines with Direct-Current Field Excitation

Synchronous motor, generator, or condenser



Graphic Symbols for Mechanical Functions

Mechanical Connection
Mechanical Interlock

Mechanical connection

The top symbol consists of short dashes.

NOTE: The short parallel lines should be used only where there is insufficient space for the short dashes in series.



Mechanical Motion

Translation, one direction

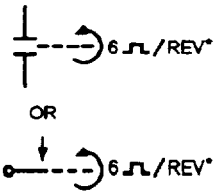
Translation, both directions

Rotation, one direction



Application: angular motion, applied to open contact (make), symbol

NOTE: The asterisk is not part of the symbol. Explanatory information (similar to type shown) may be added if necessary to explain circuit operation.



Rotation, both directions



Alternating or reciprocating



Rotation designation (applied to a resistor)

CW indicates position of adjustable contact at the limit of clockwise travel viewed from knob or actuator end unless otherwise indicated.

84NP0101

Figure 2-6.—Graphic symbols used in electrical and electronic diagrams—Continued.

NOTE: The asterisk is not part of the symbol. Always add identification within or adjacent to the rectangle.



OR



Manual Control

General



Operated by pushing



Operated by pushing and pulling (push-pull)



Graphic Symbols for Composite Assemblies

Circuit Assembly
Circuit Subassembly
Circuit Element

NOTE: The asterisk is not part of the symbol. Always indicate the type of apparatus by appropriate words or letters

NOTE: The use of a general circuit-element symbol is restricted to the following:

a. Diagrams drawn in block form.
b. A substitute for complex circuit elements when the internal operation of the circuit element is not important of the purpose of the diagram.

General



Accepted abbreviations from ANSI Z32.13-1950 may be used in the rectangle.

The following letter combinations may be used in the rectangle:

CLK	Clock
EQ	Equalizer
FAX	Facsimile set
FL	Filter
IND	Indicator
PS	Power supply
RG	Recording unit
RU	Reproducing unit
DIAL	Telephone dial
TEL	Telephone station
TPR	Teleprinter
TTY	Teletypewriter

Amplifier

General

The triangle is pointed in the direction of transmission.

The symbol represents any method of amplification (electron tube, solid-state device, magnetic device, etc).

NOTE: If identification, electrical values, location data, and similar information must be noted within symbol, the size or aspect ratio the original symbol may be altered providing its distinctive shape is retained.

Amplifier use may be indicated in the triangle by words, standard abbreviations, or a letter combination from the following list:

BDG	Bridging
BST	Booster
CMP	Compression
EXP	Direct-current
LIM	Limiting
MON	Monitoring
PGM	Program
PRE	Preliminary
PWR	Power
TRQ	Torque



Application: amplifier with associated power supply



General

NOTE: Triangle points in direction of forward (easy) current as indicated by a direct-current ammeter, unless otherwise noted adjacent to the symbol. Electron flow is in the opposite direction.

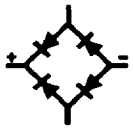
NOTE: This symbol represents any method of rectification (electron tube, solid-state device, electrochemical device, etc).



Controlled



Bridge-type rectifier



On connection or wiring diagrams, rectifier may be shown with terminals and polarity marking. Heavy line may be used to indicate nameplate or positive-polarity end.



For connection or wiring diagram

84NP0102

Figure 2-6.—Graphic symbols used in electrical and electronic diagrams—Continued.

A graphic symbol represents the function of a part in the circuit.

- Qualifying symbols may be added to symbols when the special characteristic is important to the function of the device and aids in the understanding of the overall function performed. For example, connection symbols shown in column 1 of figure 2-6 are headed "Qualifying Symbols." They are combined with transformer symbols shown further on in the figure.

- Some symbols may be similar or identical to other symbols but have different meanings. Only one meaning will apply to a specific symbol used on a diagram. Notes, asterisks, and flagging techniques may be used with symbols having multiple meanings. A tabulation listing the intended meanings should be provided.

Except where noted, the orientation of a symbol on a drawing does not alter the meaning of the symbol.

FREEHAND SKETCHES

When installing electrical systems and circuits, you will sometimes have to exchange information about your job with others. A freehand sketch can be an accurate and a concise way to communicate this information.

This type of drawing is informal in character, may or may not be drawn to scale, and need not follow any particular format. A sketch can be used in many ways. One example of where to use a sketch is to show a field change that must be made. Nomatterhowwellaproject is planned, occasionally field changes have to be made. You may see that a field change is necessary because a conduit run cannot practically be routed according to the approved drawing or plan. You can make a freehand sketch showing only what has to be changed. The sketch may include dimensions, symbols, and other information needed to convey your idea of the required change to someone else (like the project supervisor or project chief).

TYPES OF DRAWINGS AND DIAGRAMS

The types of drawings to be discussed here include working drawings, architectural drawings, mechanical drawings, shop drawings, and electrical diagrams.

CONSTRUCTION DRAWINGS

A construction drawing is any drawing that furnishes the information required by the craftsmen to rough in equipment or erect a structure. The terms **working drawings** and **construction drawings** are sometimes used interchangeably. Information presented in a set of working drawings, along with the specifications, should be complete so the craftsman who uses them will require no further information.

Working drawings show the size, quantity, location, and relationship of the building parts. Generally, working drawings may be divided into three main categories: architectural, mechanical, and electrical.

- Regardless of the category, working drawings serve several functions:

- They provide a basis for making material, labor, and equipment estimates before construction starts.

- They give instructions for construction, showing the sixes and location of the various parts.

- They provide a means of coordination between the different ratings.

- They complement the specifications; one source of information is incomplete without the other when drawings are used for construction work.

Architectural Drawings

Architectural drawings consist of all the drawings that describe the structural members of the building and their relationship to each other. This includes foundation plans, floor plans, framing plans, elevations, sections, details, schedules, and bills of materials.

Plans

A plan is actually a part of the architectural drawing that represents a view of the project from above. Two types of plans will be discussed here: plot plans and floor plans.

PLOT PLANS.—A plot plan (also called a site plan) includes not only the project but also the surrounding area. The project may be represented only by an outline, such as the Director's Quarters project on the plot plan in figure 2-7. The grades at fixed points are shown throughout the area. This is done to show how the land slopes before construction is started and the finished grade after construction is completed. The north arrow symbol, used for orientation of the drawing, is shown. The Construction Electrician may have to have a plot plan to construct a pole line to the project site at or near the earliest phase of construction. Another example is when the slope and grade of the surrounding area is to be changed and you have to bury cable or conduit. You must know what the finished grade is and how deep to dig. This type of work requires close coordination between you, the Engineering Aids, Equipment Operators, and Builders. By looking over the plot plan, you will know what to do to prepare for the job.

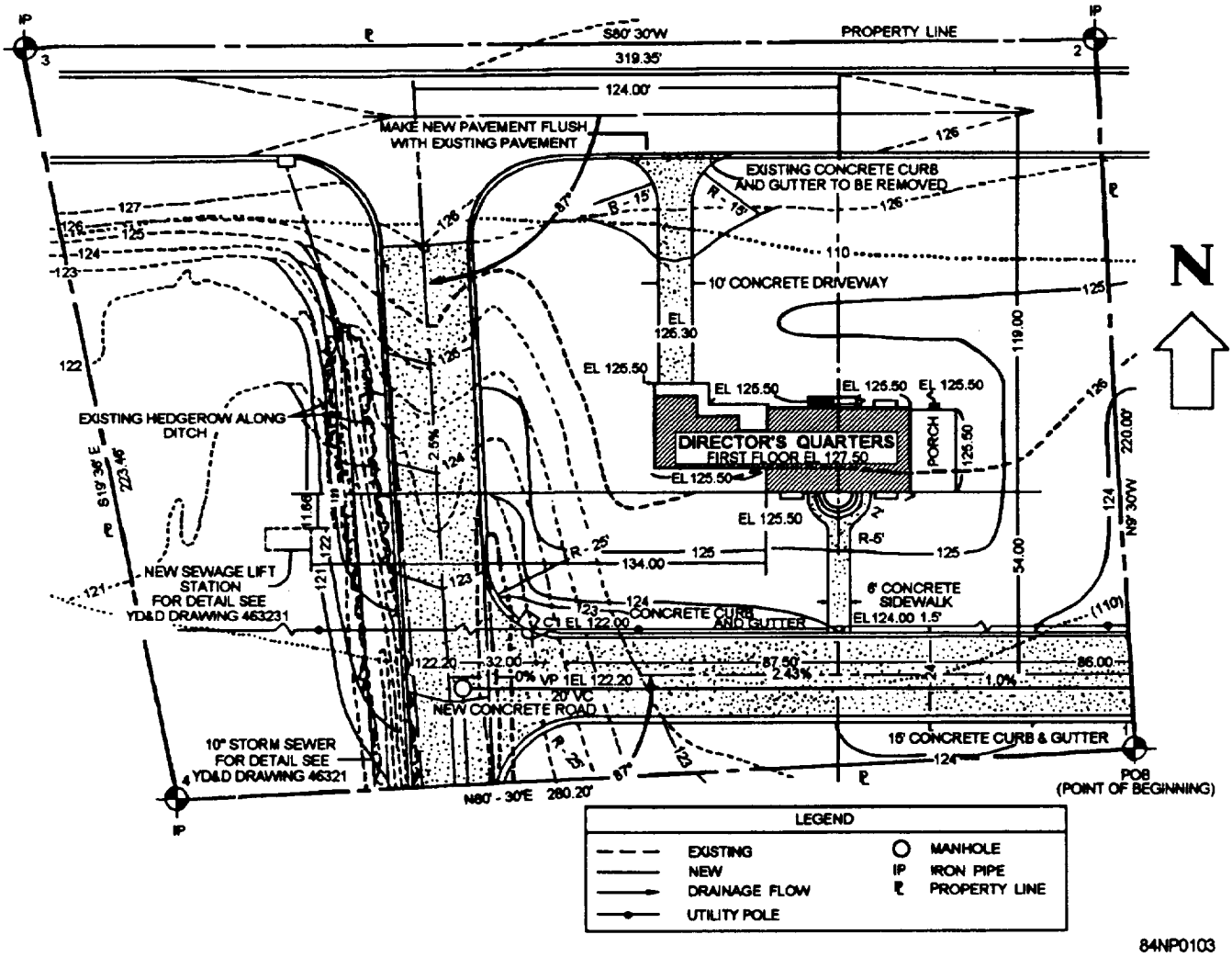


Figure 2-7.—Plot plan including "Director's Quarters" project.

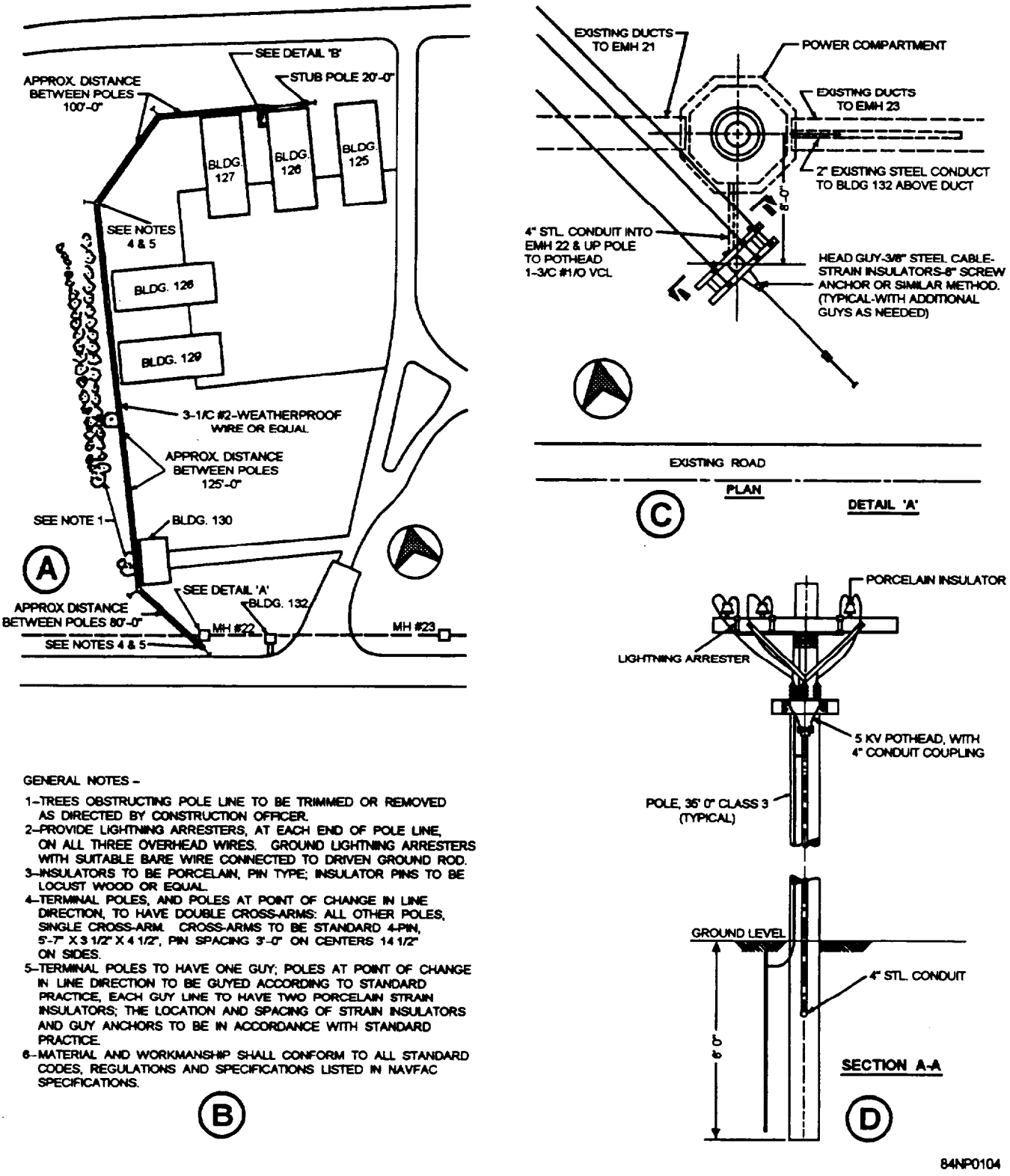


Figure 2-8.—Plot plan with electrical layout, general notes, detail, and section drawings.

Another type of plot plan can be seen in figure 2-8. Figure 2-8, view A, shows five buildings that are to be supplied with electricity for power and lighting. An electrical layout has been superimposed on the plot plan General notes (fig. 2-8, view B), one detail (fig. 2-8, view C), and section A-A (fig. 2-8, view D) of that detail are shown The dotted line at the bottom of the page indicates underground ducts containing previously laid cable.

The design engineer has decided to tap the cable at manhole 22 and run lines overhead to dead-end at the rear of building 126. Figure 2-8, view C, shows that lines are to be run underground from manhole 22 to the first pole crossarms. At building 126, lines are to be carried down the pole, regathered through a pothead into the conduit again, and run underground to a concrete slab, and out through another pothead to a transformer bank. Where do you get this information? Refer to figure 2-9.

Figure 2-9 shows detail B is indicated in figure 2-8, view A. This represents the installation behind building 126 where the overhead line terminates. The last pole in the system is shown in the lower left comer. From the pole to the transformer bank, the underground conduit is indicated by dotted lines. The conduit runs underground to the concrete slab on which the transformers rest. Section A-A gives construction details of the slab.

FLOOR PLANS.—Imagine that you want to know the outline of a building, including each partition.

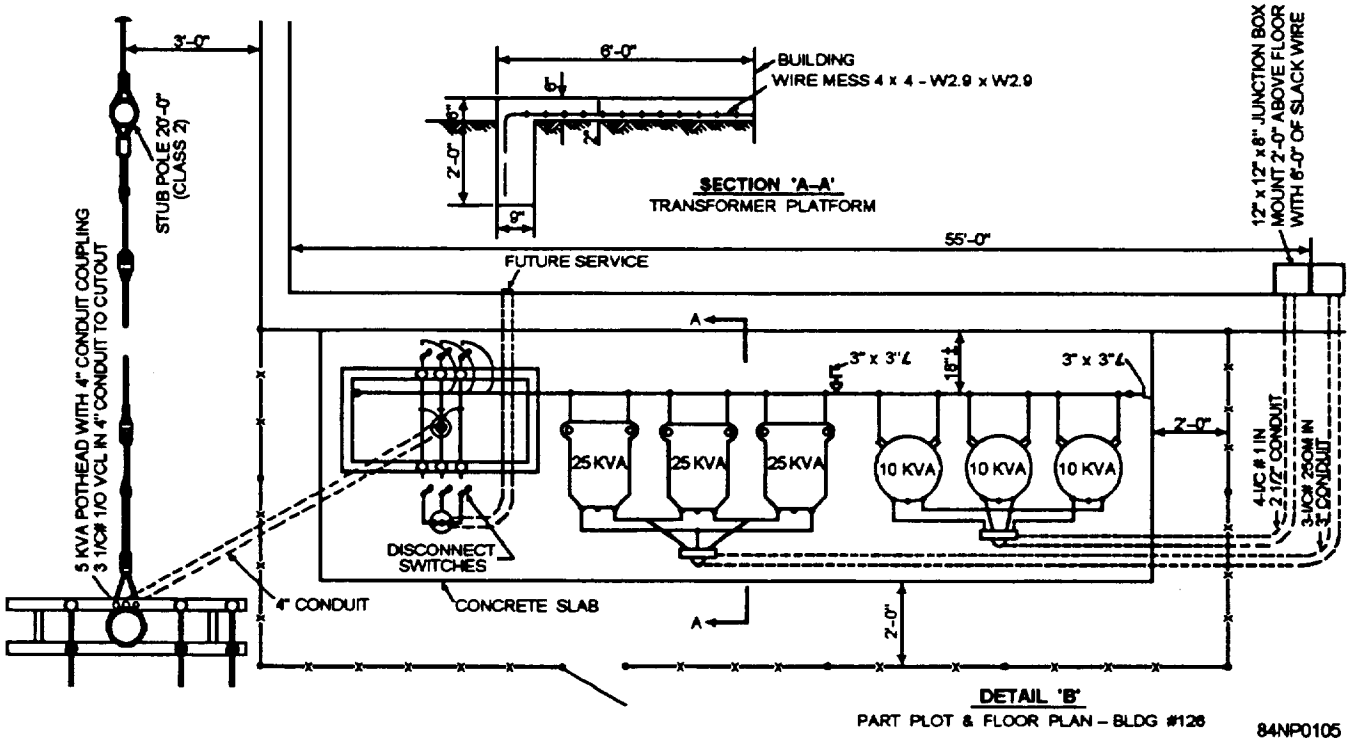


Figure 2-9.—Detail B indicated in figure 2-8.

This building is shown in figure 2-10, view A, and you areequippedwithahugesaw. Ifyousawedthe building in half horizontally and looked down on it from above, you would see the complete outline of the building (view B). This particular view directly above would be called a floor plan (view C). Architects and engineers project their thoughts of a building, not yet built, onto a piece of paper and call it a floor plan. It does not matter that the heights of the outlets, appliances, or building parts are different. These heights will be indicated by figures in inches or feet, next to the symbols that represent them. Electrical construction drawings are floor plans modified by the inclusion of electrical symbols.

Figure 2-11 shows an electrical layout superimposed on an outline taken from an architectural floor plan The service line that brings power into the house is a three-wire line in 1 1/4-inch conduit. The service line feeds power by way of a service switch to a lighting panel, from which three branch circuits run to the lighting fixtures and convenience outlets in the rooms. The symbols for these fixtures and outlets and the service switch are shown at the bottom of figure 2-11.

Elevations

An elevation is a drawing that represents a view of the finished structure as you would see it from the front, back, left, or right. There are interior elevations, such as a view of a fireplace, as well as exterior elevations, as shown in the elevations of a small building shown in figure 2-12.

Doors, windows, shapes of roof, chimneys, and exterior materials are shown. These views provide the viewer with a finished appearance.

Few dimensions are given on elevations. Only those vertical dimensions that cannot be shown on the plan are generally included on an elevation view. A Construction Electrician can quickly see from any one of the elevations in figure 2-12 that there is an attic where easy access would be provided to electrical wiring. This is important where there is a requirement for junction boxes that must be accessible. The electrician can also see a foundation wall where, if a service lateral is required, a conduit or sleeve must be placed (for a later run of conduit). This knowledge will allow the electrician to plan ahead to work with the

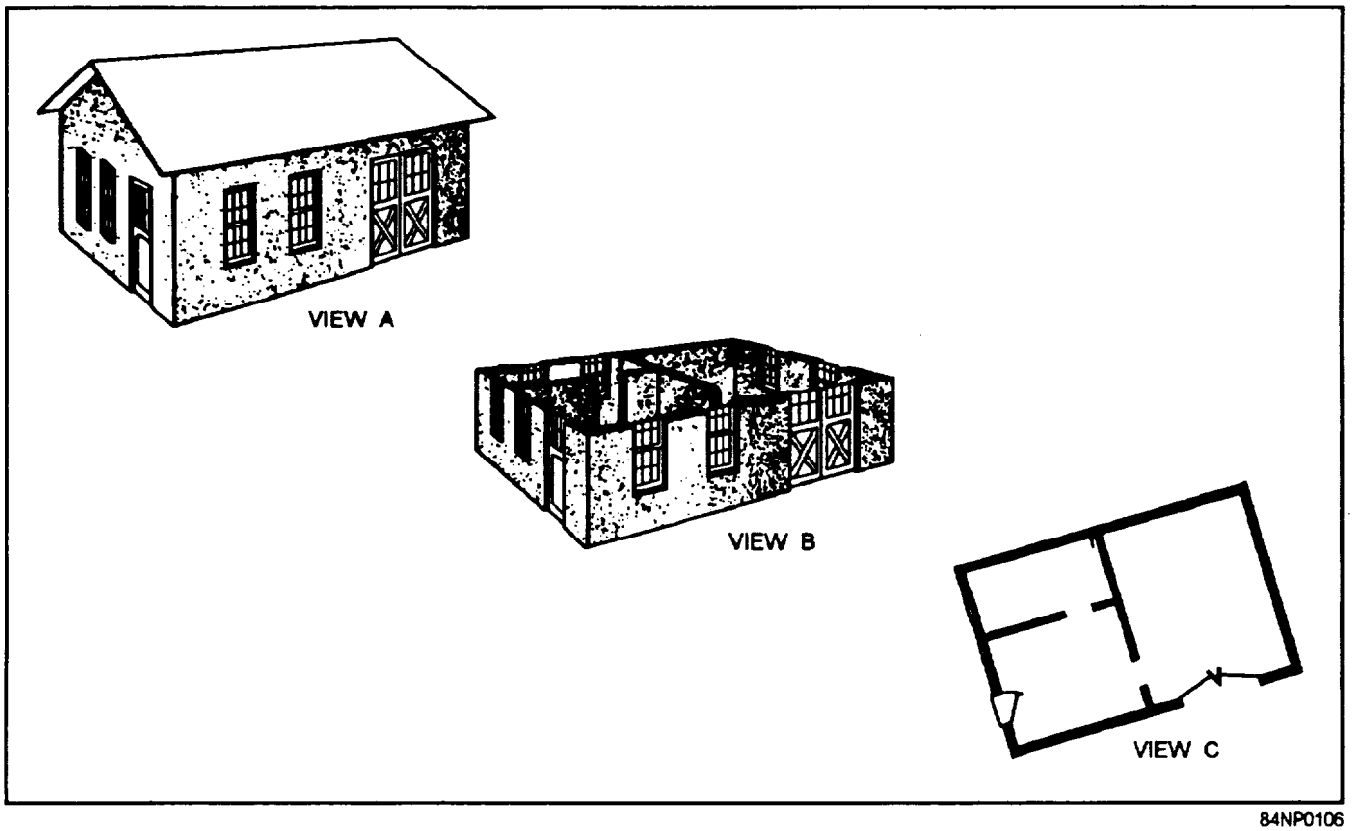


Figure 2-10.—Floor plan development.

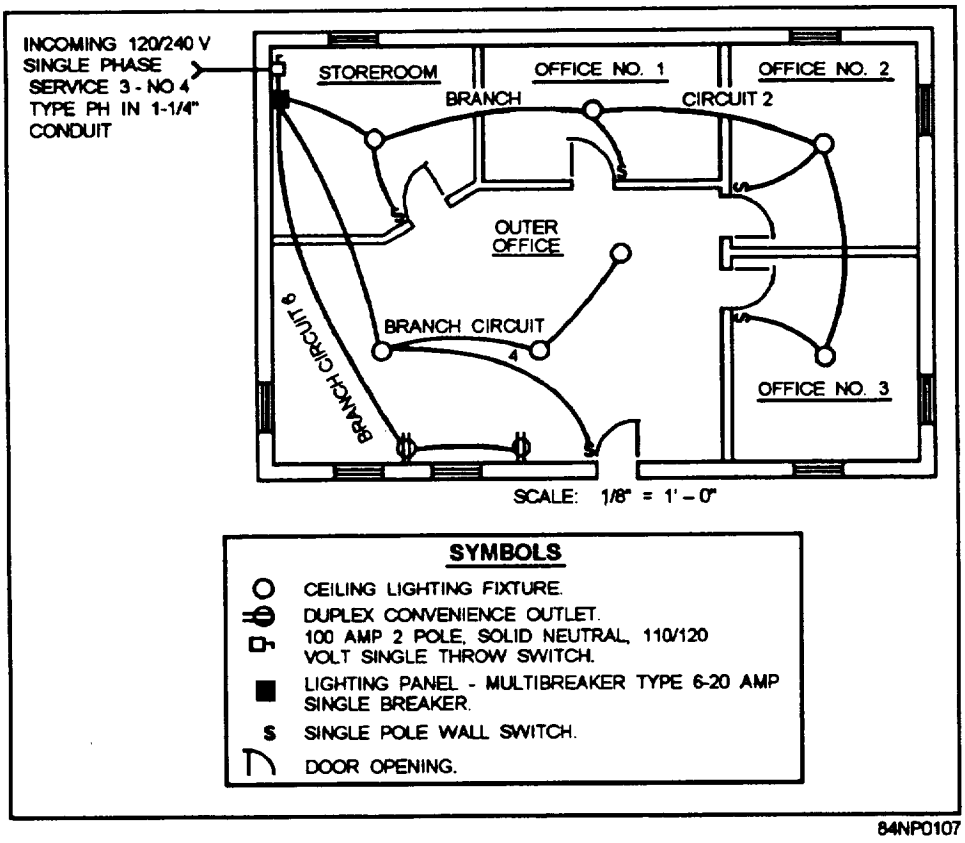


Figure 2-11.—Electrical floor plan layout.

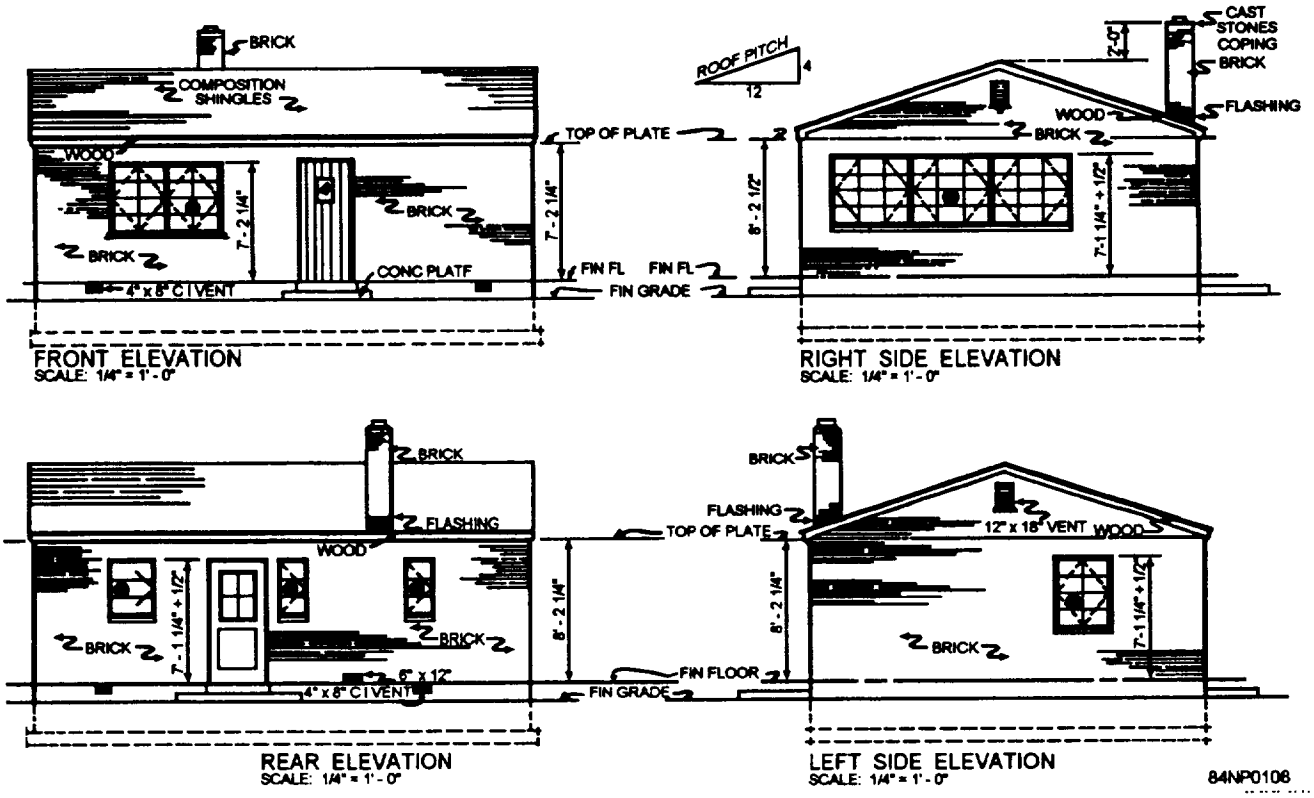


Figure 2-12.—Elevations.

Builders when they build the forms. The conduit will be placed in or through the form before the concrete is poured.

Mechanical Drawings

Mechanical drawings include all drawings and notes that have something to do with the water supply, sewage, drainage, heating and ventilating, refrigeration, air conditioning, and gas supply systems. It may also include other drawings that are necessary to present the system properly in relation to the other portions of the project.

Shop Drawings

Shop drawings are drawings and related data used to show some portion of the work prepared by the construction contractor, manufacturer, distributor, or supplier. Product data, such as brochures, illustrations, standard schedules, performance charts, and other information, are furnished by the contractor or the manufacturer to show a material, product, or system for some portion of the work. Engineering Aids are sometimes required to draft shop drawings for minor shop and field projects. These drawings may include shop items, such as doors, cabinets, and small portable buildings (prefabricated berthing quarters and modifications of existing structures), or they may come from portions of design drawings, specifications, or freehand sketches given by the design engineer. Working from a shop drawing is much like working from other working drawings. You convert the ideas you get from your interpretation of the lines and symbols into the product represented by the drawing.

ELECTRICAL DIAGRAMS

In addition to the construction drawings discussed above, you will be working with other types of electrical drawings or diagrams. These drawings show the arrangement and relationship of parts. Electrical diagrams are usually used to show how the parts of one or more pieces of equipment are wired together. There are several types of these diagrams. They are similar, yet different in some way. The short description of each that follows should enable you to recognize their differences.

Isometric Diagram

The isometric diagram is not often seen in electrical work. It may be used to show the electrical wiring system in multilevel buildings. Appliances sometimes have an isometric diagram glued to an access panel so that it may be referred to for a quick look at an entire wiring system. (See fig. 2-13.)

Block Diagram

A block diagram is a simple drawing showing the relationships of major parts of a wiring circuit or system. Figure 2-14 shows a block diagram of a motor control system You can easily see how it gets its name. Sometimes the blocks are connected with only one line that may represent one or more conductors or cables. Either major or minor components or parts may be represented by blocks. This type of diagram is often used to show something of the relationship of components in a power distribution system. The block diagram provides little help in troubleshooting.

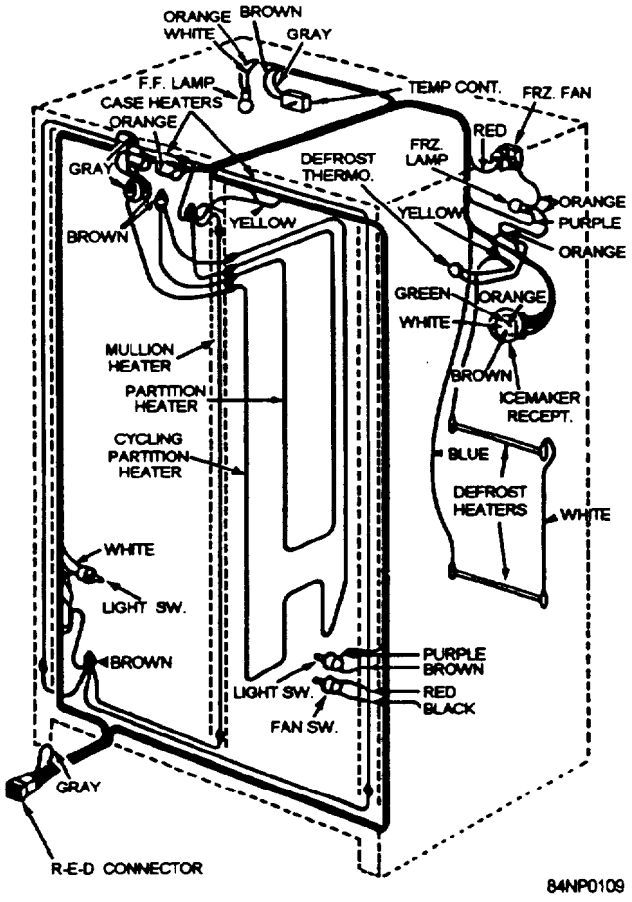


Figure 2-13.—Isometric wiring diagram.

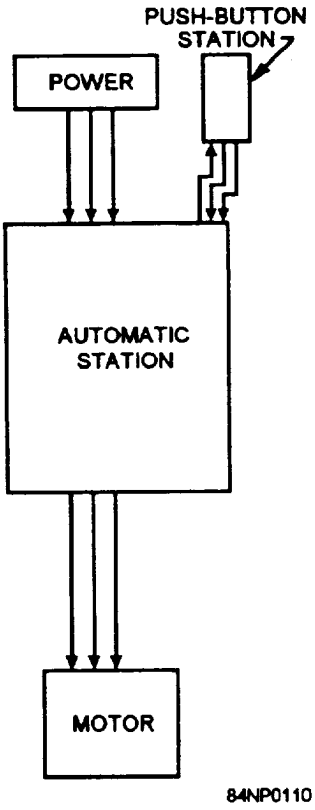


Figure 2-14.—Block diagram.

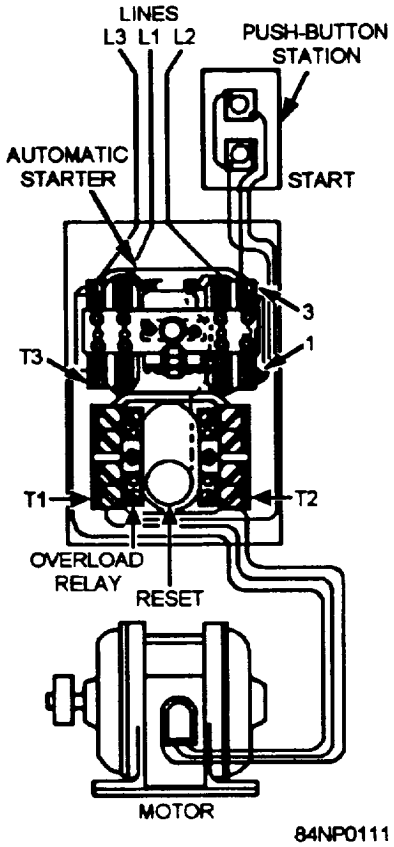


Figure 2-15.—Wiring diagram.

Wiring Diagram

The wiring diagram is almost a picture drawing. It shows the wiring between components and the relative position of the components. Figure 2-15 shows a wiring diagram of the same motor control system represented by the block diagram in figure 2-14. In the wiring diagram, components are shown much as they would appear in a picture. The lines representing wires are marked with numbers or letter-number combinations. Lines L1, L2, and L3 are incoming power leads. The diagram shows which terminals these power leads are connected to in the motor starter. Leads connected to terminals T1, T2, and T3 are the motor leads.

The numbers without letters mark the control terminals of the starter. Wiring diagrams are often used along with a list of repair parts. Wiring diagrams may be of some help in troubleshooting circuit problems.

Connection Diagram

Figure 2-16 is a connection diagram. By comparing the symbols from this diagram to those in figure 2-6, you can see that graphic symbols are used to represent parts or components in the connection diagram. The connection diagram in figure 2-16 is a combination of basic symbols (like the open-contact symbol). You can see how the controller pictured in figure 2-15 works internally.

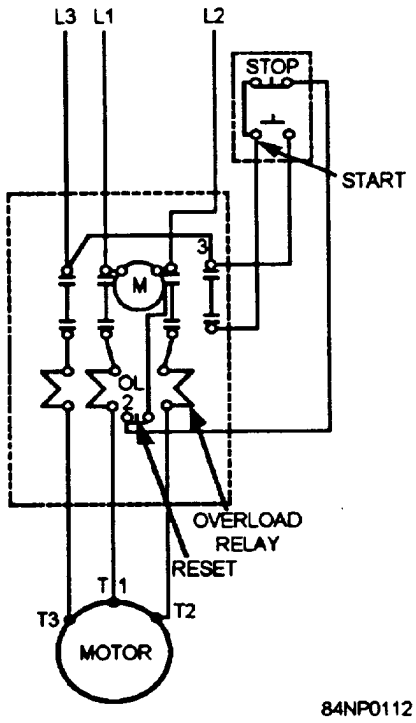


Figure 2-16.—Connection diagram.

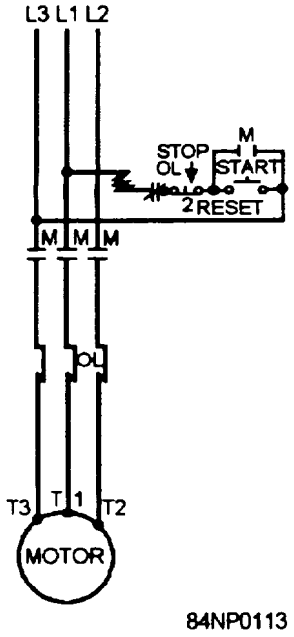


Figure 2-17.—Schematic diagram.

The connection diagram shows all the internal and external connections. The circuitry can be traced more easily than on the wiring diagram. The components are still shown in their relative positions. This diagram can be used to help you connect all the wiring and trace any part of the circuit. The connection diagram is a valuable troubleshooting tool. This type of diagram is often found inside the access cover of a piece of equipment.

Schematic Diagram

The schematic or elementary diagram (fig. 2-17) is a drawing that shows the electrical connections and functions of a specific circuit arrangement. It facilitates tracing the circuit and its functions without regard to the physical size, shape, or relative position of the component device or parts. The schematic diagram, like the connection diagram, makes use of symbols instead of pictures. Figure 2-17 shows, by a schematic diagram, the same motor control system shown in figures 2-14, 2-15, and 2-16. This diagram is laid out in a way that makes the operation of the components easy to understand. This type of schematic diagram with the components laid out in a line is sometimes called a one-line or single-line diagram.

Most schematic diagrams are more complicated than ‘the one shown in figure 2-17. The more complicated ones can be broken down into one-line diagrams, circuit by circuit. You can draw (or freehand sketch) your own one-line diagram by tracing only one circuit, component by component, through a multicircuit schematic, using the symbols in figure 2-6. Circuits "A" and "B" in figure 2-18 show only the control circuit from figure 2-16 laid out in one-line form. From these simple circuits, it is easy to see that as soon as the start button is pushed, the “M” coil (operating coil of the motor controller) will be energized. The operating coil is now held closed through the "M" contacts.

Your own freehand sketches can help you understand other types of diagrams as well as the schematic. You may vary these sketches to suit your needs. You may draw a one-line diagram, using symbols, from a wiring diagram, an isometric diagram, or a connection diagram, as long as all the necessary details are there for you to convert to lines and symbols.

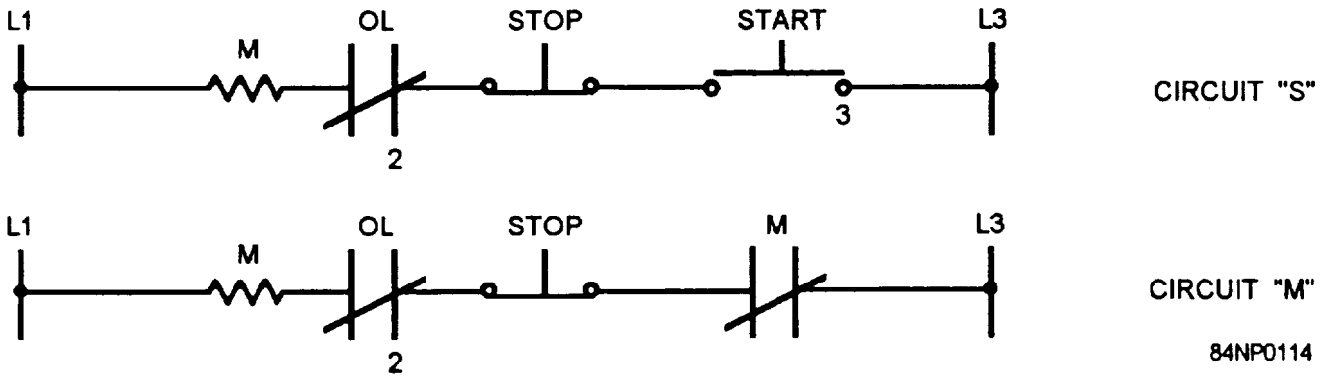


Figure 2-18.—One-line diagram of a motor control circuit.

CHAPTER 3

POWER GENERATION

Generators play an important part in your assignment with the Seabees. Whether operating a generator as a main power source or as standby power or as emergency power, you need a through knowledge of their hookup, operation, and maintenance.

At the completion of this chapter, you should know how to install generators of the advanced-base type, stand a generator watch, perform preventive maintenance, and make minor repairs on power generators and control equipment.

Theory for both dc and ac generators is included in Navy Electricity and Electronics Training Series (NEETS), Module 5. Generator theory will not be covered in this chapter. Keep in mind that the generator (alternator) in an automobile works on the same principle as does the huge turbine generator used in a nuclear power station.

INSTALLATION AND SERVICING GENERATORS

Most of the generators you are likely to work with in the Naval Construction Force (NCF) range in size from 5 kW to 200 kW. Generators in these sizes range in weight from 488 pounds (221.4 kg) to 10,500 pounds (4770 kg). All of these units are mounted on skid bases. Lifting and tie-own attachments are provided. All have provisions for lifting with a forklift of the appropriate capacity (with the exception of the 5-kW gas-driven generator set, which does not include the forklift provision).

Several factors should be considered before a final decision is made about where to locate a generator. The noise levels of generators sized from 5 kW to 200 kW range from 77 dBa to 93 dBa (adjusted decibels) at 25 feet. Generator noise is a problem in low-noise level or quiet areas (libraries, offices, hospitals, chapels, etc.). The operating 60-kW generator, for example, presents a noise hazard (84 dBa to 91 dBa, depending on the model) to all personnel in the immediate area. The noise level near the unit exceeds the allowable limits for unprotected personnel. Therefore, everyone working around the generator needs single (noise < 84 dBa) or double hearing protection (noise > 104 dBa).

Placing a generator set near points of large demand will reduce the size of wire required, hold the line losses to a minimum, and afford adequate voltage control at the remote ends of the lines.

The following points should be considered before an exact site is chosen for a generator set:

1. Generators must not be closer than 25 feet (7.6 meters) to a load because of noise, fire hazard, and air circulation.

2. The set must be placed on a stable, preferably level, foundation. It should not be operated while inclined more than 15 degrees from level.

3. The site must be within 25 feet (7.6 meters) of any paralleled generator set and within 25 feet (7.6 meters) of any auxiliary fuel supply.

4. When preparing a temporary installation, you should move the generator set as close to the jobsite as practical. In an area where the ground is soft, do not remove the wood-skid base if you have not already done so. The wood-skid base will establish a firm foundation on soft ground, mud, or snow; otherwise, use planks, logs, or other material for a base in an area where the ground is soft.

Although advanced-base portable generators are designed to be operated outdoors, prolonged exposure to wind, rain, and other adverse conditions will definitely shorten their lives. When the generators are to remain on the site for any extended period of time, they should be mounted on solid-concrete foundations and should be installed under some type of shelter.

There are no predrawn plans for shelters for a small advanced-base generating station. The shelter will be an on-the-spot affair—the construction of which is determined by the equipment and material on hand plus your ingenuity, common sense, and ability to cooperate with personnel in other ratings. Before a Builder can get started on the shelter, you will have to furnish information, such as the number of generators to be sheltered, the dimensions of the generators, the method of running the generator load cables from the generator to the panelboard and from the panelboard to the feeder

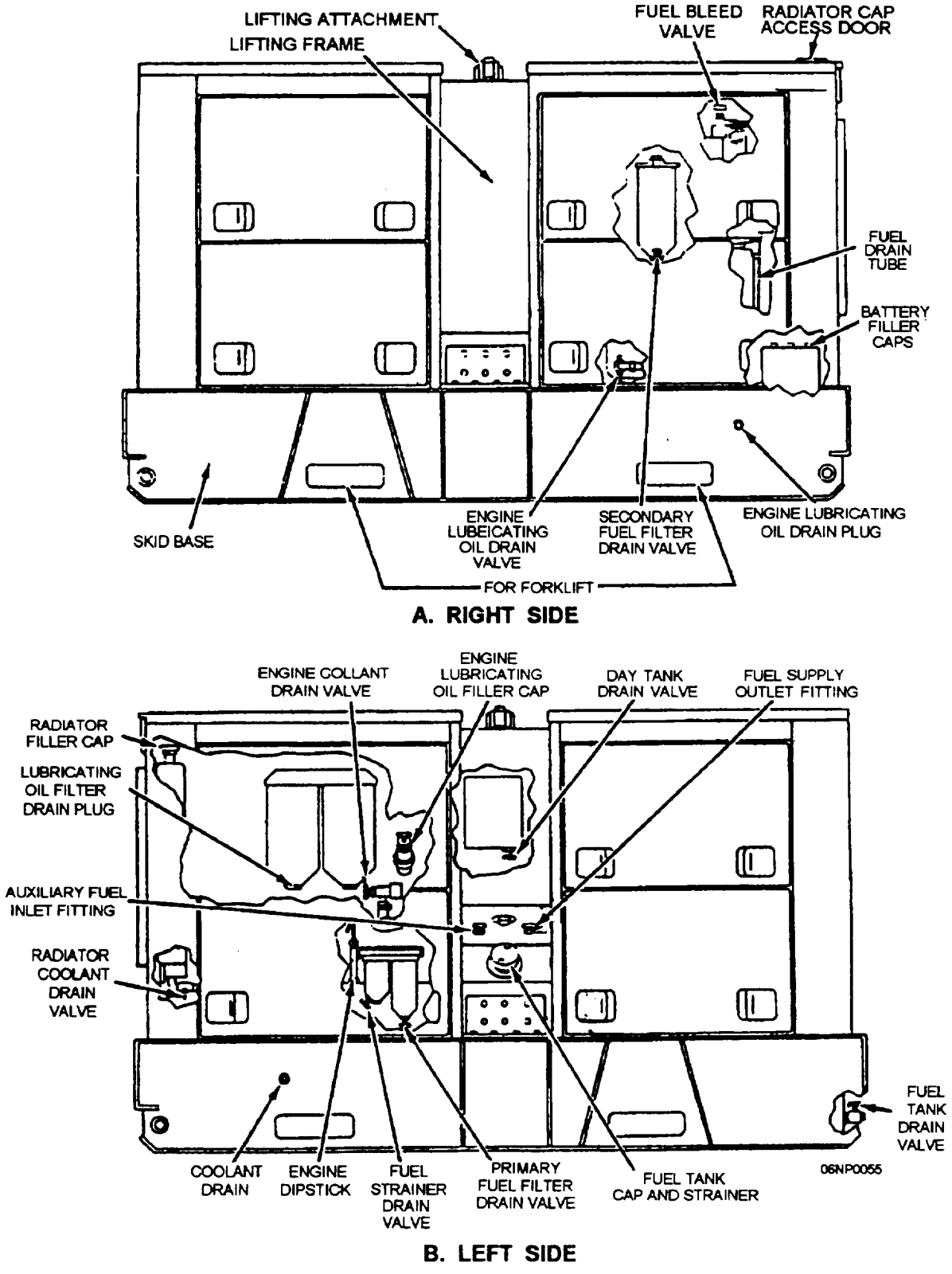


Figure 3-1.—Typical 60-kW generator set.

system outside the building, and the arrangement of the exhaust system.

Large generator units may have, connected or attached to them, engine equipment that requires extra space and working area. Included in this equipment are air-intake filters, silencers for air intake and exhaust, fuel and lubricating oil pumps, tanks, filters, and strainers. Also included are starting gear, isochronous regulating governors with over-speed trips, safety alarm and shutdown devices, gauges and thermometers, turning gear, along with platforms, stairs, and railings.

An even larger and more complete power plant may require separate equipment, such as a motor-driven starting air compressor and air storage tanks; motor-driven pumps for jacket water and lubricating oil cooling, or heat exchangers with raw cooling water pumps and lubricating oil coolers; and tanks that include day-fuel storage.

Be sure to provide enough working space around each unit for repairs or disassembly and for easy access to the generator control panels.

Installation specifications are available in the manufacturer's instruction manual that accompanies each unit. Be sure to use them. Consulting with the Builder about these specifications may help cut installation costs and solve future problems affecting the shelter of the generator.

SERVICING THE GENERATOR

Before the set is operated, it must be serviced. We will use the 60-kW generator set as an example for discussing the servicing of the set after you receive it. As you read this discussion, refer to figure 3-1 for locating fill and drain points and drain valves.

Batteries

All 5-kW through 750-kW generator sets are furnished with dry-charged batteries less the electrolyte. Battery electrolyte must be requisitioned separately.

You must be cautious when installing, activating, or maintaining batteries. Before we discuss connecting and servicing batteries, let's look at a few safety points you must know about.

WARNING

Do not smoke or use an open flame in the vicinity of batteries when servicing them. Batteries generate hydrogen a highly explosive gas. When removing batteries, always remove both negative cables before removing the positive cables (fig. 3-2).

Battery electrolyte contains sulfuric acid and can cause severe burns. It is highly toxic to the skin, eyes, and respiratory tract. Skin, eyes, and face (chemical splash goggles, face shields) and respiratory protection are required. Whenever electrolyte comes into contact with the body, the eyes, or the clothing, you must rinse immediately with clean water, remove contaminated clothing, and then go to sickbay or the medical clinic for a thorough examination.

The 60-kW generator set is equipped with two 12-volt, 100-ampere-hour batteries. The batteries are located under the radiator (fig. 3-1, view A) on aroll-out tray (fig. 3-3). They are connected in series to supply 24 volts dc for starting the generator set and operating direct current components. Two slave receptacles (fig. 3-2), connected in parallel, permit easy connection to the batteries to supply or obtain battery power. As we

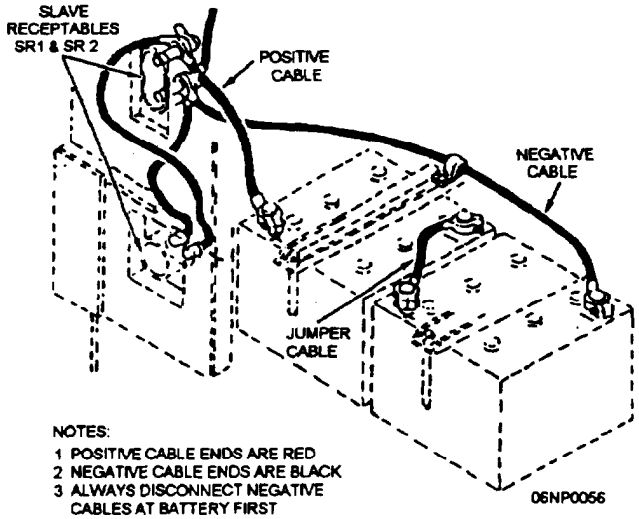


Figure 3-2.—Battery cable connections and slave receptacles.

discuss activating the batteries, refer to steps 1 through 3 (following) and figure 3-3.

1. Open the battery compartment door and secure it to the radiator grille with the door holder.

2. Depress the button on top of the quick-release pins, lift up the pins, and pull the roll-out tray assembly out.

3. Remove the filler caps. When you have electrolyte of the correct specific gravity, do not dilute it, but fill the battery cells to the cell slots.

When you prepare your own electrolyte, consult a mixing chart (table 3-1). In this case, use the specific gravity value recommended in the instruction manual.

Table 3-1.—Electrolyte Mixing Chart

SPECIFIC GRAVITY DESIRED	USING 1.835 SPECIFIC GRAVITY ACID		USING 1.400 SPECIFIC GRAVITY ACID	
	PARTS OF WATER	PARTS OF ACID	PARTS OF WATER	PARTS OF ACID
1.400	3	22	..	..
1.345	2	1	1	7
1.300	5	2	2	5
1.290	8	3	9	20
1.275	11	4	11	20
1.250	13	4	3	4
1.225	11	3	1	1
1.200	13	3	13	10

The temperature of the electrolyte when placed in the cells should be between 60°F and 90°F. IT SHOULD NEVER EXCEED 90°F.

WARNING

Be sure to add the acid to the water s-l-o-w-l-y, stirring constantly and thoroughly.

A chemical reaction occurs when you add electrolyte to the battery, thereby causing the battery to heat. Cool it artificially (cooling fans) or allow it to stand at least 1 hour before placing it in service.

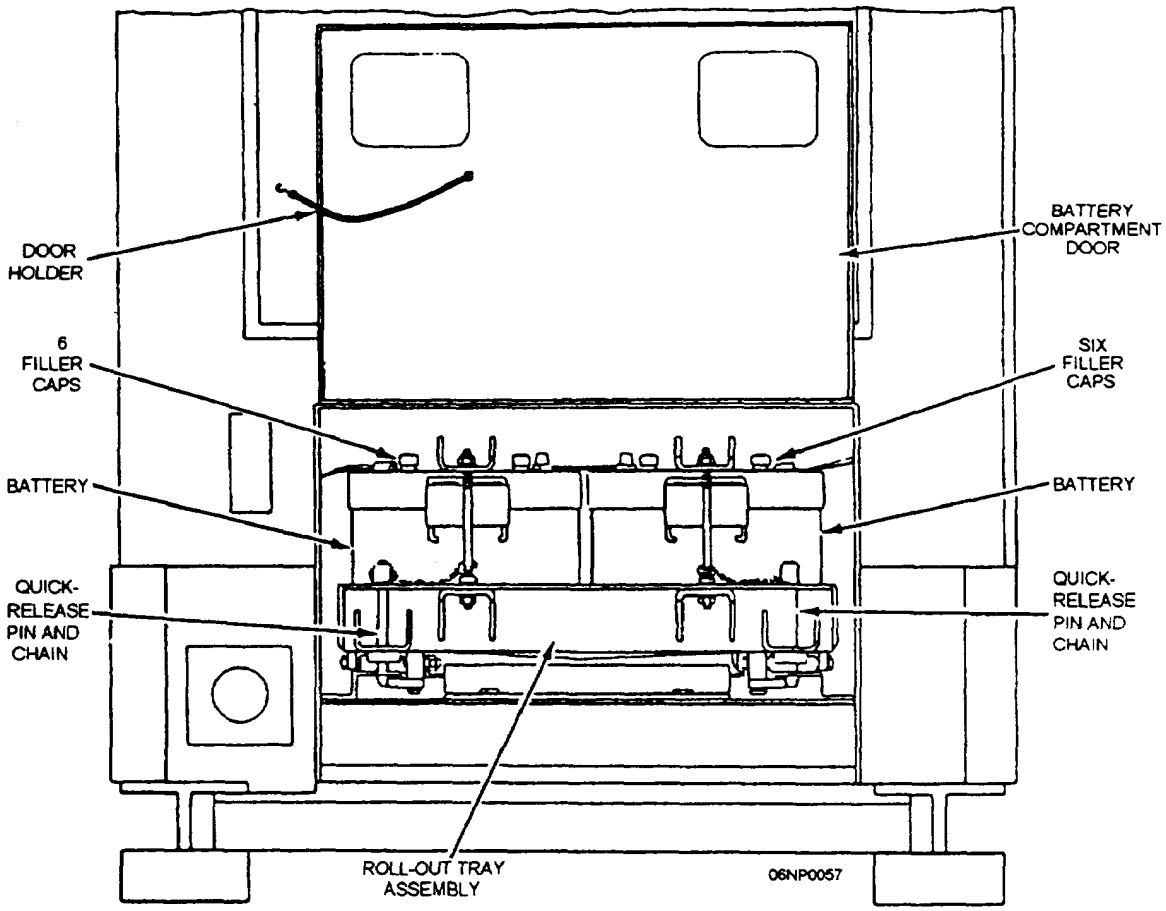


Figure 3-3.—Battery compartment.

You will notice at the end of the cooling period that the level of the electrolyte has dropped because of the electrolyte soaking into the plates and separators. Before placing the battery in service, restore the electrolyte to its proper level. Remove any electrolyte spilled on the battery, using a cloth dampened with a solution of bicarbonate of soda and water.

Although you can place the battery in service 1 hour after filling it with electrolyte, do so only in an emergency. If at all possible, give the battery an initial light charge.

After the battery has been charged, connect the battery into the starting system of the prime mover, as shown in figure 3-2. Always connect the negative cable last.

4. Push in the roll-out tray assembly and install the quick-release pins (fig. 3-3).

Battery Charging

The manufacturer's manual may specify charging procedures for the type of battery you are to charge. If so, follow those procedures.

There are several types of battery charges, but you will generally use a normal charge, an equalizing charge, or a fast charge. We will discuss these three types of charges briefly. For more information on storage or dry-cell batteries and battery charging, refer to the Navy Electricity and Electronics Training Series (NEETS), NAVEDTRA 172-01-00-88 (Module 1).

NORMAL CHARGE.—A normal charge is a routine charge that is given according to the battery nameplate data during the ordinary cycle of operation to restore the battery to its charged condition,

EQUALIZING CHARGE.—An equalizing charge is a special extended normal charge that is given periodically to batteries as part of a maintenance routine. It ensures that all the sulfate is driven from the plates and that all the cells are restored to a condition of maximum specific gravity. The equalizing charge is continued until the specific gravity of all cells, corrected for temperature, shows no change for a 4-hour period.

FAST CHARGE.—A fast charge is used when a battery must be recharged in the shortest possible time. The charge starts at a much higher rate than is normally used for charging. It should be used only in an emergency, as this type of charge may be harmful to the battery.

CHARGING RATE.—Normally, the charging rate of Navy storage batteries is given on the battery nameplate. If the available charging equipment does not have the desired charging rates, the nearest available rates should be used; however, the rate should never be so high that violent gassing occurs.

CHARGING TIME.—The charge must be continued until the battery is fully charged. Frequent readings of specific gravity should be taken during the charge and compared with the reading taken before the battery was placed on charge.

GASSING.—When a battery is being charged, a portion of the energy breaks down the water in the electrolyte. Hydrogen is released at the negative plates and oxygen at the positive plates. These gases bubble up through the electrolyte and collect in the air space at the top of the cell. If violent gassing occurs when the battery is first placed on charge, the charging rate is too high. If the rate is not too high, steady gassing develops as the charging proceeds, indicating that the battery is nearing a fully charged condition.

WARNING

A mixture of hydrogen and air can be dangerously explosive. No smoking, electric sparks, or open flames should be permitted near charging batteries.

CHARGING PROCEDURE.—If the instruction manual for the generator set is not available or if it does not give the battery a charging procedure, proceed as follows: Connect the positive battery charger terminal to the positive battery terminal and the negative charger terminal to the negative battery terminal.

Charge the battery at a low rate (about 5 amperes) until the voltage and specific gravity, corrected to 80°F (27°C) remains constant for at least 4 hours. If the temperature of the electrolyte reaches 110°F (43°C), reduce the charging rate or stop the charge until the battery cools. NEVER PERMIT THE TEMPERATURE TO EXCEED 115°F (46°C). During the charging, replenish any water lost by evaporation.

Hydrometer

A hydrometer is the instrument used to measure the amount of active ingredients in the electrolyte of the battery. The hydrometer measures the SPECIFIC GRAVITY of the electrolyte. Specific gravity is the ratio of the weight of the electrolyte to the weight of the same volume of pure water, The active ingredient, such as sulfuric acid or potassium hydroxide, is heavier than water. Because the active ingredient is heavier than water, the more active the ingredient in the electrolyte, the heavier the electrolyte will be; the heavier the electrolyte, the higher the specific gravity.

A hydrometer is a glass syringe with a float inside it. The float is in a hollow, glass tube, weighted at one end and sealed at both ends, with a scale calibrated in specific gravity marked on the side. The electrolyte to be tested is drawn into the hydrometer by the suction bulb. Enough electrolyte should be drawn into the hydrometer so that the float will rise. Hydrometers should not be filled to the extent that the float rises into the suction bulb. Since the weight of the float is at its base, the float will rise to a point determined by the weight of the electrolyte. If the electrolyte contains a large concentration of the active ingredient, the float will rise higher than if the electrolyte has a small concentration of the active ingredient.

To read the hydrometer, hold it in a vertical position and take the reading at the level of the electrolyte. Refer to the manufacturer's technical manual for battery specifications to find the correct specific gravity ranges. An example of what your manual may say about the specific gravity is that for a fully charged battery the specific gravity should be 1.280 ± 0.005. The manual may tell you to recharge the battery if the specific gravity is less than 1.250.

Always return the electrolyte in the hydrometer to the cell of the battery from which it was taken.

NOTE: Hydrometers should be flushed with fresh water after each use to prevent inaccurate readings. Storage battery hydrometers must not be used for any other purpose.

Perhaps it should be said that adding the active ingredient (sulfuric acid, for example) to the electrolyte of a discharged battery does not recharge the battery. Adding the active ingredient only increases the specific gravity of the electrolyte and does not convert the plates back to active material, and so does not bring the battery back to a charged condition. A charging current must be passed through the battery to recharge it.

Oil

You must check the engine crankcase oil level before operating the generator set. The engine dipstick (fig. 3-1, view B) is the crankcase oil level gauge. The dipstick in the generator engine is the shielded type, which allows checking the oil level while the engine is either stopped or running. The dipstick is stamped on both sides to indicate the two different oil levels. The engine running side is stamped as follows: "ADD," "FULL," and "RUNNING." The engine stopped side is stamped as follows: "ADD," "FULL," and "STOPPED." Be sure to use the appropriate add and full marks, depending on whether the engine is stopped or running. Also, ensure that the appropriate side of the dipstick is up when inserting it since the underside will be wiped in the gauge tube when the dipstick is removed, therefore, indicating a false oil level reading.

To check the oil level, first remove and wipe the oil from the dipstick. Loosen and remove the oil filler cap (fig. 3-1) to allow the pressure to escape. Reinsert the dipstick (with the appropriate side up) and remove it to observe the oil level. Add oil through the fill tube, as required, to obtain the "full" level on the dipstick. Be sure to use the proper grade of oil. A lubricant chart in the instruction manual furnished with each generator will show the proper grade of oil to use at the operating temperature.

Water

Check that the level of coolant is within 2 inches (51 mm) of the top of the radiator.

WARNING

Do not attempt to remove the radiator cap until the radiator has cooled to a point where there will be no built-up steam pressure. Failure to observe this warning could result in second- or third-degree bums.

Using an antifreeze solution tester, check that the antifreeze content is sufficient for the existing ambient temperature. Add antifreeze as required.

Whenever you fill the radiator with coolant after it has been drained, fasten a tag near the radiator cap. The tag should indicate the type of coolant and the degree of protection the coolant gives.

Regardless of the air temperature, be sure to use an antifreeze solution in the proportions recommended in the instruction manual for the generator.

Fuel

The fuel tank should be filled with clean fuel oil, strained if necessary. Service the fuel tank as follows:

WARNING

Always maintain constant metal-to-metal contact between the fuel tank filler neck and the spout of the fuel supply. That will prevent the possibility of sparking caused by static electricity.

Remove the fuel tank filler cap (fig. 3-1, view B), and fill the fuel tank with the proper fuel. (Refer to the instruction manual.) Replace the filler cap and wipe up any spilled fuel.

Remove the cap from the fuel tank drain valve and open the valve. Let water and sediment drain into an approved nonflammable container. When clean fuel runs out of the tank, close the drain valve and install the cap on the valve.

A day tank is one of the major components of the fuel system. It has a capacity to permit engine operation for a minimum of 5 minutes. The day tank also provides a settling point for contaminants (to prevent their entry into the engine) and supplies fuel to the engine fuel pump.

The day tank contains a dual type of float switch. The upper float operates in conjunction with the fuel solenoid valve to maintain a predetermined fuel level in the tank. The lower float initiates an engine shut-down sequence. This sequence is initiated in the event that the fuel level in the tank will permit operation of the generator set at the rated load for only 1 minute.

You must drain sediment and water from the day tank as you did from the fuel tank. Remove the cap from the day tank drain valve and open the valve. (Refer to fig. 3-1, view B, for the location of the tank and its drain valve.) Drain water and sediment into a container. Close the valve when clean fuel runs out of the tank, and install the cap back on the valve.

VENTILATION

WARNING

Do not operate the generator set in an enclosed area unless the exhaust gases are piped to the outside. Inhalation ofexhaust gases will result in serious injury or death.

Keep the area around an operating generator set well ventilated at all times so that the generator set will receive a maximum supply of air.

Consider ventilation when you install the units inside a building. Every internal combustionengine is a HEAT engine. Although heat does the work, excess amounts of it must be removed if the engine is to function properly. This can be accomplished by setting the radiator grille of the engine near an opening in the wall and providing another opening directly opposite the unit. In this manner, cool air can be drawn in and the hot air directed in a straight line outdoors. These openings can be shielded with adjustable louvers to prevent the entrance of rain or snow. In addition, when the generator is operating in extremely cold weather, the temperature in the room can be controlled by simply closing a portion of the discharge opening. Additional doors or windows should be provided in the shelter if the plants are installed in localities where the summer temperatures exceed 80°F at any time.

EXHAUST SYSTEM

The muffler and the exhaust pipe are connected to the turbocharger exhaust elbow (fig. 34) and provide a path for engine exhaust gases to exit the generator set. The muffler reduces the noise level of the engine exhaust. The discharge opening of the muffler is covered by a hinged cap to prevent water from entering the exhaust system when the generator is not operating.

Let's look at an example of an indoor installation. After bolting the generator set to the concrete pad and enclosing it in a shelter, you are about to vent the exhaust system to the outside. You lift the exhaust cap (fig. 3-4) and connect the gastight exhaust pipe to the discharge opening. You then extend the pipe through the wall (or roof) of the building in a route that includes no obstructions and a minimum number of bends. If you have arranged the pipe to slope away from the engine, condensation will not drain back into the cylinders. If the exhaust pipe has to be installed so that loops or traps are necessary, place a drain cock at the lowest point of the system. All joints must be perfectly tight; and where the exhaust pipe passes through the wall, you must take care to prevent the discharged gas from returning along the outside of the pipe back into the building. Exhaust piping inside the building must be covered with insulation capable of withstanding a temperature of 1500°F.

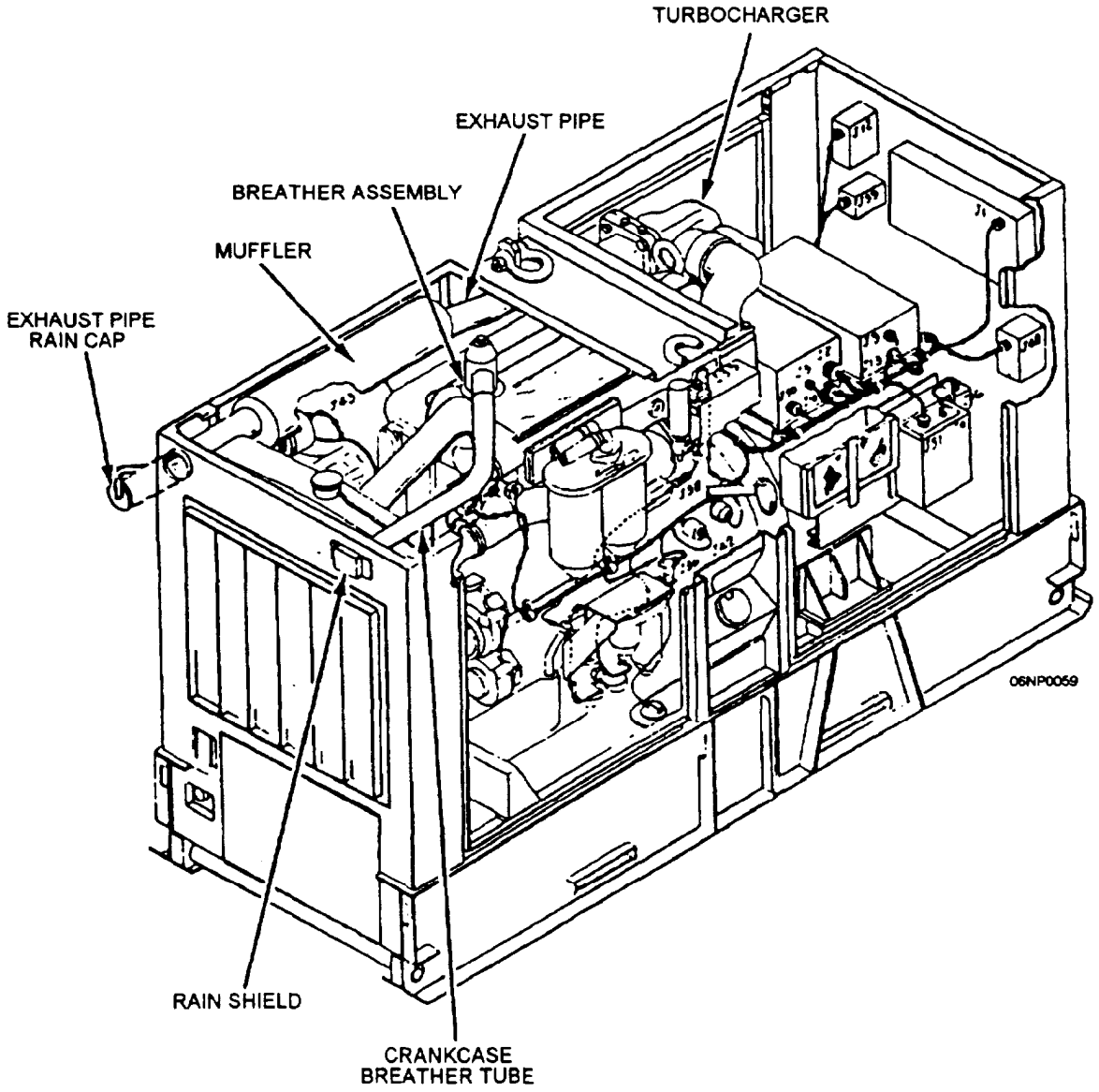


Figure 3-4.—Exhaust and breather system.

The crankcase breather tube (fig. 3-4) is clamped to the engine breather assembly. The breather tube provides a path for engine crankcase vapors to exit the generator set. A rain shield is provided at the tube outlet to prevent rain from entering the tube when the generator is used outdoors.

GROUNDING

The generator set must be connected to a suitable ground before operation.

WARNING

Electrical faults in the generator set, load lines, or load equipment can cause injury or electrocution from contact with an ungrounded generator.

The ground can be, in order of preference, an underground metallic water piping system (fig. 3-5, view A), a driven metal rod (fig. 3-5, view B), or a buried metal plate (fig. 3-5, view C). A ground rod must have a minimum diameter of 5/8 inch (41 mm) if solid or 3/4 inch (44 mm) if pipe. The rod must be driven to a minimum depth of 8 feet (2.44 M). A ground plate must have a minimum area of 2 square feet (0.186 square meter) and, where practical, be embedded below the permanent moisture level.

The ground lead must be at least No. 6 AWG (American Wire Gauge) copper wire. The lead must be bolted or clamped to the rod, plate, or piping system. Connect the other end of the ground lead to the generator set ground terminal stud (fig. 3-6, view A).

Use the following procedure to install ground rods:

1. Install the ground cable into the slot in the ground stud and tighten the nut against the cable.

2. Connect a ground rod coupling to the rod and install the driving stud in the coupling (fig. 3-6, view B). Make sure that the driving stud is bottomed on the ground rod.

3. Drive the ground rod into the ground until the coupling is just above the ground surface.

4. Connect additional rod sections, as required, by removing the driving stud from the coupling and installing another rod section in the coupling. Make sure the new ground rod section is bottomed on the ground rod section previously installed. Connect another coupling on the new section and again install the driving stud.

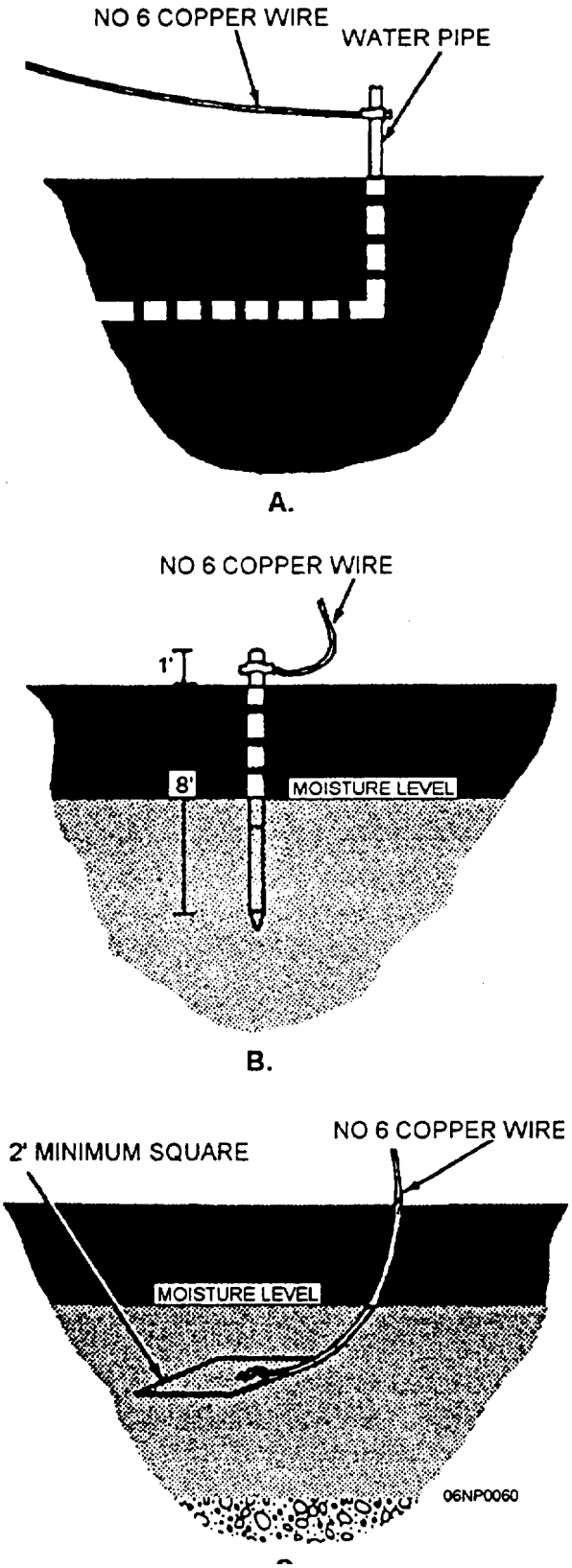


Figure 3-5.—Methods of grounding generators.

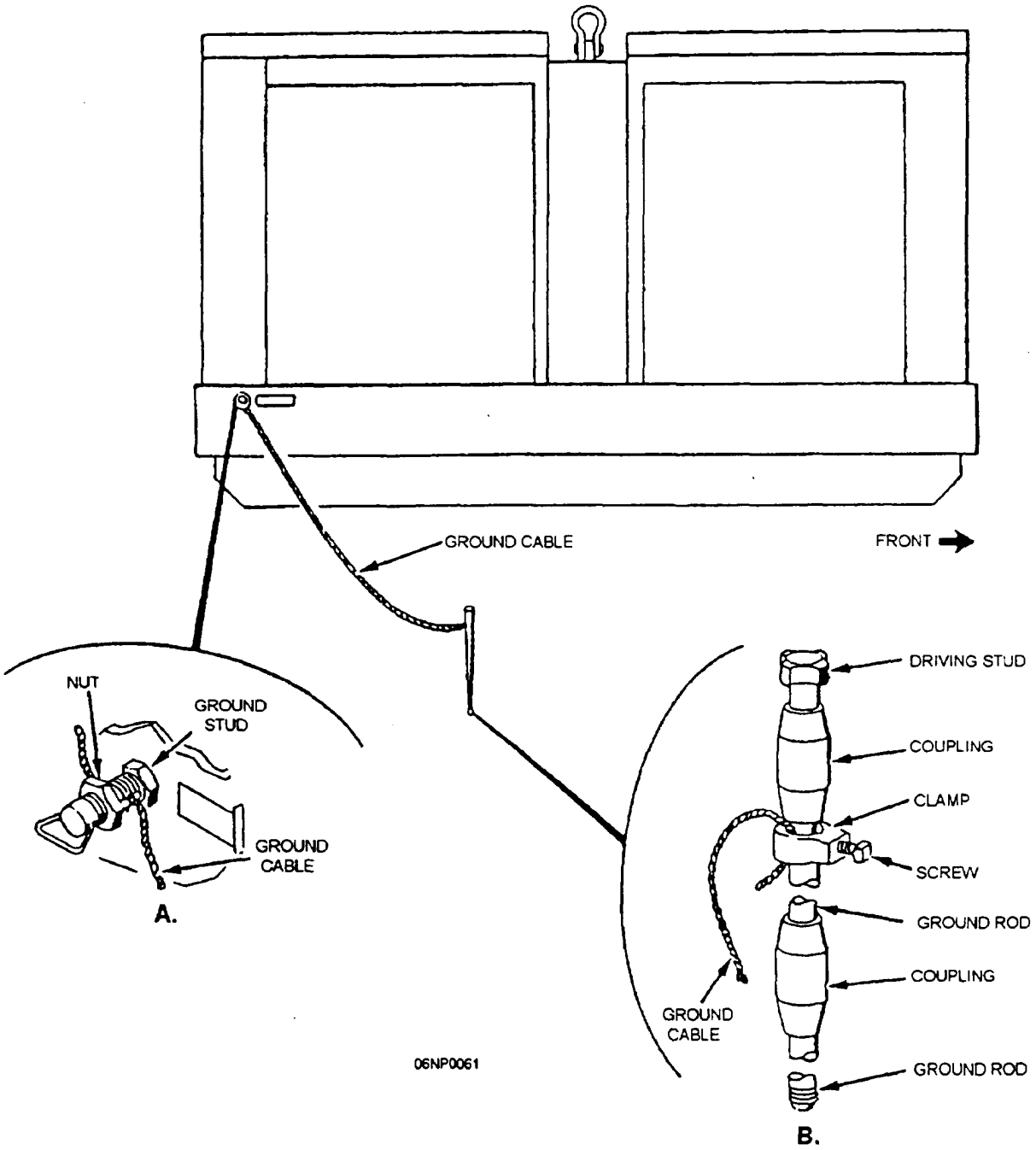


Figure 3-6.—Grounding procedure.

5. After the rod(s) have been driven into the ground, remove the driving stud and the top coupling.

NOTE: The National Electrical Code© states that a single electrode consisting of a rod, pipe, or plate that does not have a resistance to ground of 25 ohms or less will be augmented by additional electrodes. Where multiple rod, pipe, or plate electrodes are installed to meet the requirements, they will be not less than 6 feet apart.

The resistance of a ground electrode is determined primarily by the earth surrounding the electrode. The diameter of the rod has only a negligible effect on the resistance of a ground. The resistance of the soil is dependent upon the moisture content. Electrodes should be long enough to penetrate a relatively

permanent moisture level and should extend well below the frost line. Periodic earth resistance measurements should be made, preferably at times when the soil would be expected to have the least moisture.

You need to test the ground rod installation to be sure it meets the requirement for minimum earth resistance. The earth resistance tester may be used to perform the test. You should make this test before you connect the ground cable to the ground rod.

When ground resistances are too high, they may be reduced by one of the following methods:

1. Using additional ground rods is one of the best means of reducing the resistance to ground; for example, the combined resistance of two rods properly spaced and connected in parallel should be 60 percent of the resistance of one rod; the combined resistance of three rods should be 40 percent of that of a single rod.

2. Longer rods are particularly effective where low-resistance soils are too far below the surface to be reached with the ordinary length rods. The amount of improvement from the additional length on the rods depends on the depth of the low-resistance soils. Usually, a rather sharp decrease in the resistance measurements is noticeable when the rod has been driven to a low-resistance level.

3. Treating the soil around ground rods is a reliable and effective method for reducing ground resistance and is particularly suitable for improving high-resistance ground. The treatment method is advantageous where long rods are impractical because of rock strata or other obstructions to deep driving. There are two practical ways of accomplishing this result, as shown in figure 3-7. Where space is limited, a length of tile pipe is sunk in the ground a few inches from the ground rod (fig. 3-7, view A) and tilled to within 1 foot or so of the ground level with the treatment chemical. The best treatment chemicals for all situations cannot be covered within the scope of this manual. You may work with your engineering office to determine the possible corrosive effect on the electrode. Examples of suitable noncorrosive materials are magnesium sulfate, copper sulfate, and ordinary rock salt. The least corrosive is magnesium sulfate, but rock salt is cheaper and does the job.

The second method is applicable where a circular or semicircular trench can be dug around the ground rod to hold the chemical (fig. 3-7, view B). The chemical must be kept several inches away from coming into direct contact with the ground rod to avoid corrosion of the rod. if you wish to start the chemical action promptly, you should go ahead and flood the treatment material. The first treatment usually contains 50 to 100 pounds of material. The chemical will retain its effectiveness for 2 to 3 years. Each replenishment of the chemical extends the effectiveness for a longer period so that the necessity for future retreating becomes less and less frequent.

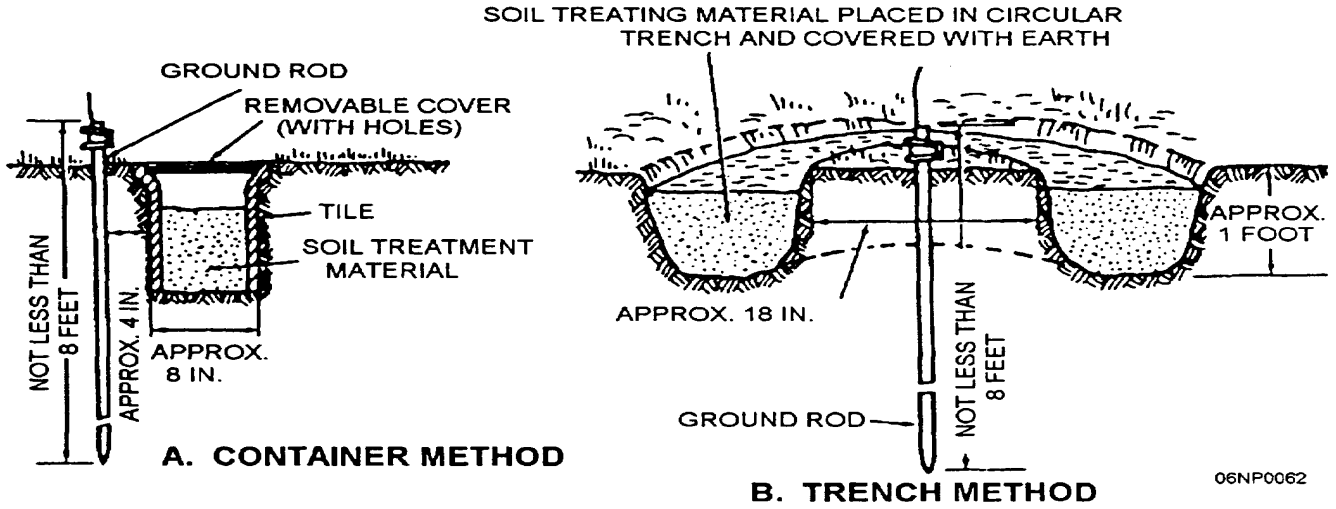


Figure 3-7.—Methods of soil treatment for lowering of ground resistance.

4. A combination of methods may be advantageous and necessary to provide desired ground resistance. A combination of multiple rods and soil treatment is effective and has the advantages of both of these methods; multiple long rods are effective where conditions permit this type of installation.

After you are sure you have a good ground, connect the clamp and the ground cable to the top ground rod section (fig. 3-6, view B), and secure the connection by tightening the screw.

CONNECTIONS

A typical generator set is outlined in figure 3-8, showing the load cables and output load terminals.

WARNING

Before attempting to connect the load cables to the load terminals of a generator set, make sure the set is not operating and there is no input to the load.

Refer to figure 3-8 as you follow this procedural discussion for making load connections.

1. Open the access door and disconnect the transparent cover by loosening six quick-release fasteners. Remove the wrench clipped to the cover.

NOTE: Be sure to maintain the proper phase relationship between the cable and the load terminals; that is, A0 to L1, B0 to L2, and so forth.

2. Attach the load cables in the following order: L0, L3, L2, and L1 as specified in step 3 below.

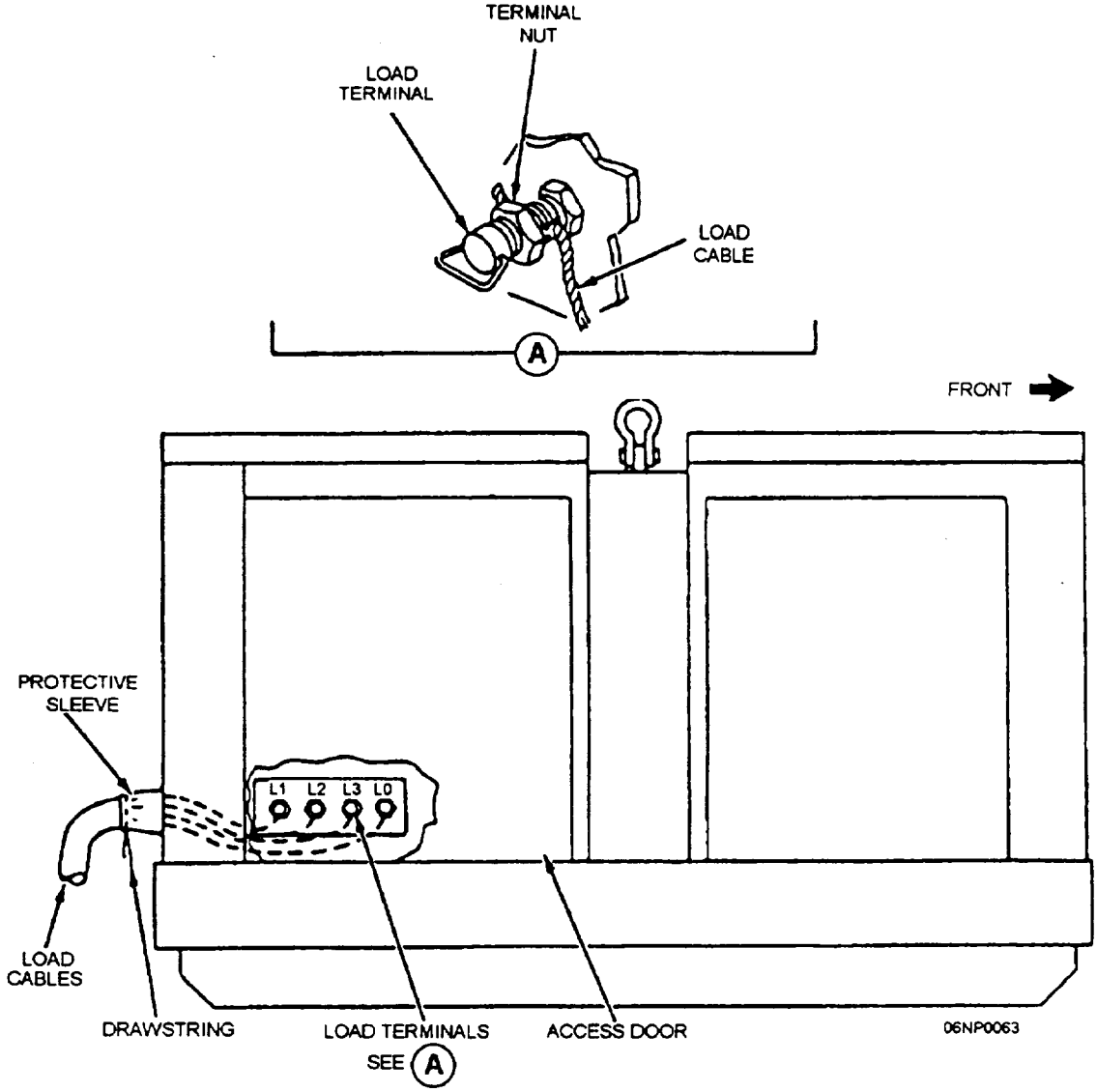


Figure 3-8.—Load cable connections.

3. Insert the load cables through the protective sleeve. Attach the cables to their respective load terminals, one cable to each terminal, by inserting the cable in the terminal slot and tightening the terminal nut with the wrench that was clipped to the transparent cover. Install the wrench on the cover and install the cover.

4. Tighten the drawstring on the protective sleeve to prevent the entry of foreign matter through the hole around the cable.

You may convert the voltage at the load terminals to 120/208 volts or 240/416 volts by properly positioning the voltage change board (fig. 3-9). The board is located directly above the load terminal board.

The procedure for positioning the voltage change board for the required output voltage is as follows:

1. Disconnect the transparent cover by loosening the six quick-release fasteners.

2. Remove the 12 nuts from the board. Move the change board up or down to align the change board arrow with the required voltage arrow. Tighten the 12 nuts to secure the board.

3. Position and secure the transparent cover with the six quick-release fasteners and close the access door.

PHASE SEQUENCE INDICATORS

The phase sequence indicator is a device used to compare the phase sequence of three-phase generators or motors. Examples of its use are as follows: to compare the phase rotation of an incoming alternator that is to be operated in parallel with an alternator already on the line or to determine the phase rotation of motors being put into use for the first time.

One type of phase sequence indicator is a tiny three-phase induction motor. The three leads of the motor are labeled "A," "B," and "C," as shown in figure 3-10. The insulating hoods over the clips are of different colors: red for A, white for B, and blue for C.

The rotor in the instrument can be observed through the three ports as it turns so that you can note the direction in which it rotates. The rotor can be started by means of a momentary contact switch: it, stops again when you release the switch.

You also may use a solid-state phase sequence indicator with two lights. Whichever light is on indicates the phase sequence of the voltage in the conductors that the instrument is connected to; for example, the light labeled "ABC" indicates one phase sequence, while the other light, labeled "BAC," indicates another. If you are working with three-phase conductors (all of the same color) that are installed but not labeled, you may connect the phase sequence indicator to the three conductors, turn on the power, check the phase sequence of the conductors as connected to the instrument, and turn off the power. You may then label the conductors with numbers, letters, or colored marking tape.

You also may check the phase sequence of an incoming alternator before paralleling it with an operating load-side alternator. Connections must be made so that the phase sequence of the two generators will be the same.

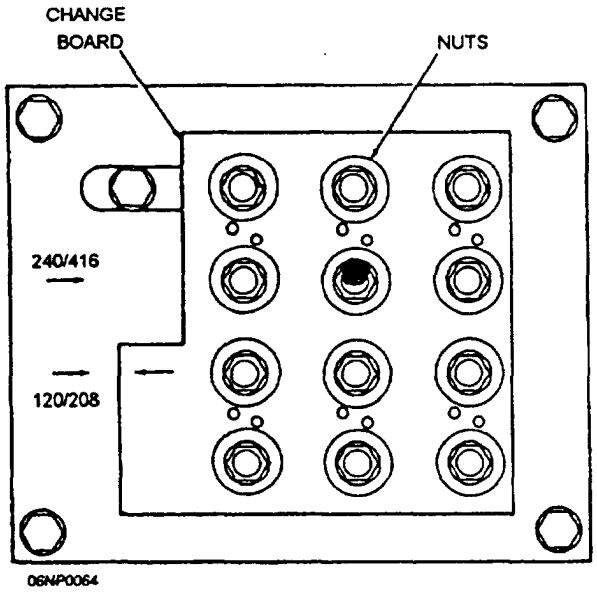


Figure 3-9.—Voltage change board.

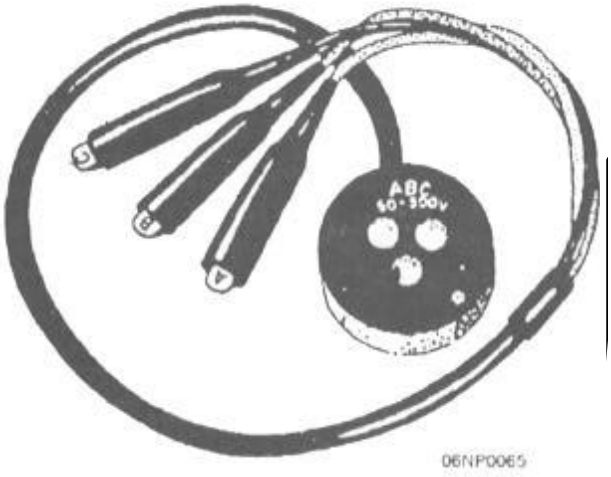


Figure 3-10.—Phase sequence indicator.

Figure 3-11 shows the leads of two generators to be parallel. The proper procedure for ensuring phase sequence with a phase sequence indicator is as follows: Connect indicator terminals A to X_1, B to Y_1, and C to Z_1, press the contact switch, and note the direction of rotation of the rotor.

Now move the A terminal to X, the B to Y, and the C to Z, and again press the switch. If the rotor turns in the same direction as before, the phase rotation is the same for the alternators, and the connection can be made X to X_1, Y to Y_1, and Z to Z_1. If the rotor turns in the opposite direction, transpose the connections of any two of the incoming alternator leads before making the connection.

It is not absolutely necessary that A be connected to the left-hand terminal, B to the center terminal, and C to the right-hand terminal. This is a practical method, however, used to avoid the danger of confusing the leads. The important thing is to ensure that the phase sequence indicator that was used on X_1 be brought down to X, the one used on Y_1 to Y, and the one used on Z_1 to Z. Reversing any two of the leads will reverse the direction of rotation of the rotor of the instrument.

INSPECTION OF THE GENERATOR

Open all access doors of the generator set and make a thorough visual inspection of the generator for loose or missing mounting hardware and damaged or missing parts (look for broken or loose electrical and hose connections, for example, and for loose bolts and cap screws). Also, check the fault indicator panel and control cubicle for broken or missing bulbs and fuses.

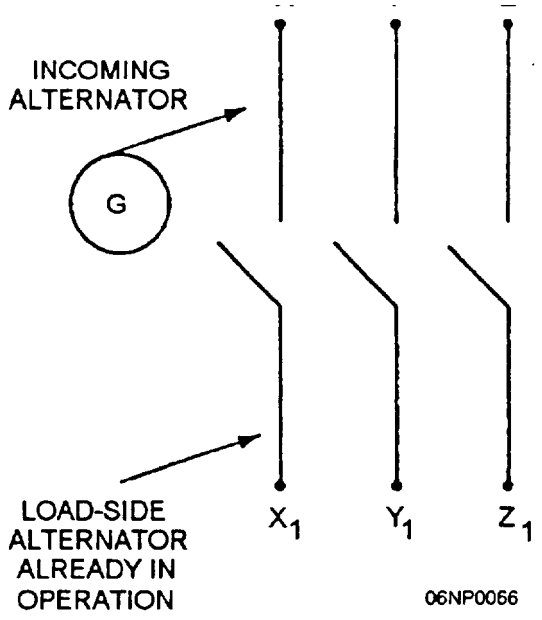


Figure 3-11.—Diagram for checking phase sequence of alternators.

WARNING

While performing your visual inspection, look for service tags. If service tags are present, do not attempt to start or run the generator.

Check the wiring diagrams in the instruction manual furnished with the generator to see whether any wire is connected improperly. If you find faults, correct them immediately.

Be sure to check the levels of the following:

1. Crankcase lubricant.
2. Radiator coolant.
3. Fuel.
4. Electrolyte in the batteries. After donning the proper personnel protective equipment (chemical gloves, goggles, and face shield), add to the actual level to bring it up to the required level, if necessary.

On large generators you should check the area ventilation; the fan cover must be opened and latched in that position. There must be no cover or obstructions over the radiator section. The bypass shutters or doors may be closed to shorten the warming-up period, and roof hatches and side louvers may be opened for additional ventilation, if required.

DISTRIBUTION PANELBOARDS

Power from the generator set must be delivered to various connected loads safely and efficiently. The relatively large cables connected to the load terminal board of the generator, if sized properly, can conduct all the power the generator can produce. This power has to get to the different connected load equipment without overloading the conductors or overheating conductor insulations.

In this section, the makeup of panelboards, connections to them, and the installation of the advanced-base type of portable panelboards are presented.

OVERCURRENT PROTECTION

If the load cables come into contact with each other and short-circuit the generator, the generator windings could be damaged by excessive current unless the generator windings and load cables are protected by a circuit breaker. The circuit breaker "breaks" or interrupts the circuit anytime there is a short circuit or overload condition in the load cables.

One large load, consuming an amount of power at or near the maximum power output of the generator, could theoretically overload the generator in the event of a fault. In this case, one circuit breaker could trip the circuit and protect both the generator and the load. But small-load conductors connected directly to the larger generator load cables could likely burn up without drawing enough current to cause the circuit breaker of the generator set to open the circuit.

In the interest of safe operation of load circuit conductors and safety of area personnel, you must use properly sized overcurrent devices (circuit breakers or fuses).

DISTRIBUTION

The generator load cables are terminated at a type of distribution bus bar from which one or more overcurrent protective devices are connected. Current through each of the overcurrent devices is limited by the overcurrent rating or setting of the device. In this way power from the generator may be safely distributed through protected conductors to the various connected loads.

PANELBOARDS

A panelboard includes buses and automatic overcurrent protective devices placed in a cabinet or cutout box and mounted in (flush) or against (surface) a wall or partition. The panelboard is accessible only from the front. A panelboard serves the purpose mentioned above for the distribution of electric power.

PHASE RELATIONSHIP

When you connect the generator load to the panelboard, be careful to match the cable markings to the panelboard terminals. The same phase relationship should be maintained throughout the wiring system from the generator to the load. You may see terminals marked with numbers, such as L1, L2, L3, and L0 (fig. 3-12, view A) or the letters and symbols A0, B0, C0, and N (fig. 3-12, view B). Wire in different parts of the system may be marked with numbered, lettered, or colored tape. (The color sequence is black, red, blue, and white.) Either way, the phase sequence is the same.

You may have to "ring out" (identify) unmarked cables or conductors in the conduit (fig. 3-12, view C) before connecting them to the power source or load. This identification process can be accomplished in any one of several ways. You may use a bell and battery, buzzer and battery, or ohmmeter, for example. Any of these devices may be used to check for continuity through each conductor to ground (a conduit, for example). After a conductor is identified, it is then marked.

PORTABLE POWER DISTRIBUTION PANELBOARDS

Portable, weatherproof, power distribution panelboards are available, similar to the one shown in

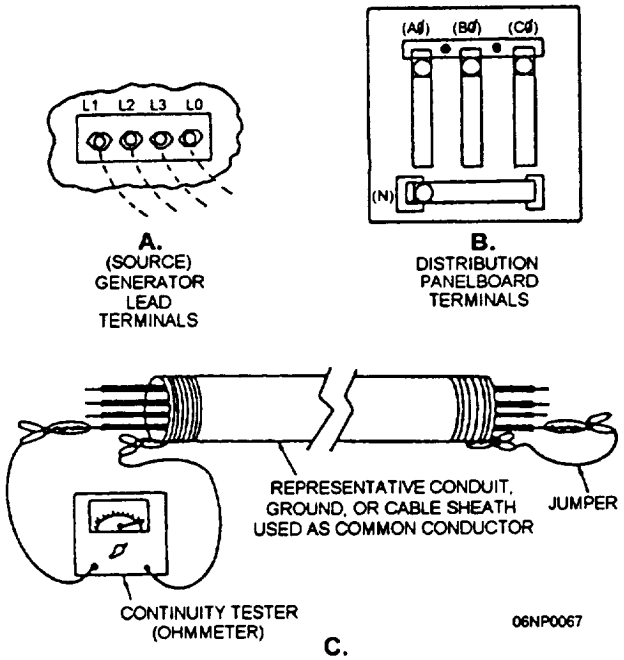


Figure 3-12.—Conductor identification.

figure 3-13. Load cables can be plugged into the receptacles along the front (fig. 3-13, view A). With the cover raised (fig. 3-13, view B), access to the circuit breakers and test jacks is provided. This panelboard is an advanced-base distribution center. A single-line diagram of the bus and circuit breakers is shown in figure 3-14.

Portable generators and panelboards can be placed into service quickly and with relatively little effort, compared to a permanent installation. Do not let expedience cause you to become careless, though, in placing the equipment and routing the load cables. Careful planning can result in a much safer and more efficient installation for both you and your fellow Seabees.

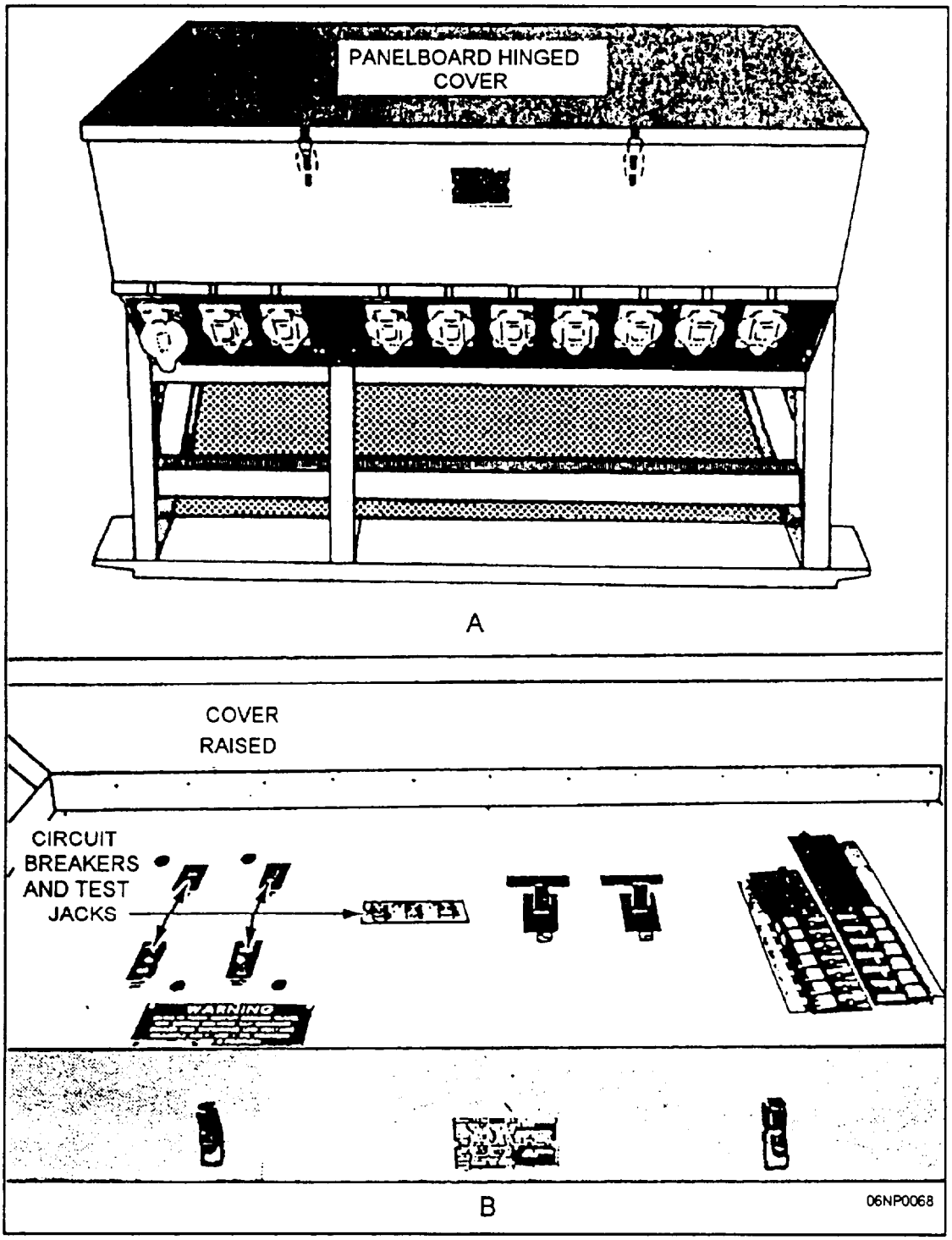


Figure 3-13.—Portable power distribution panelboard.

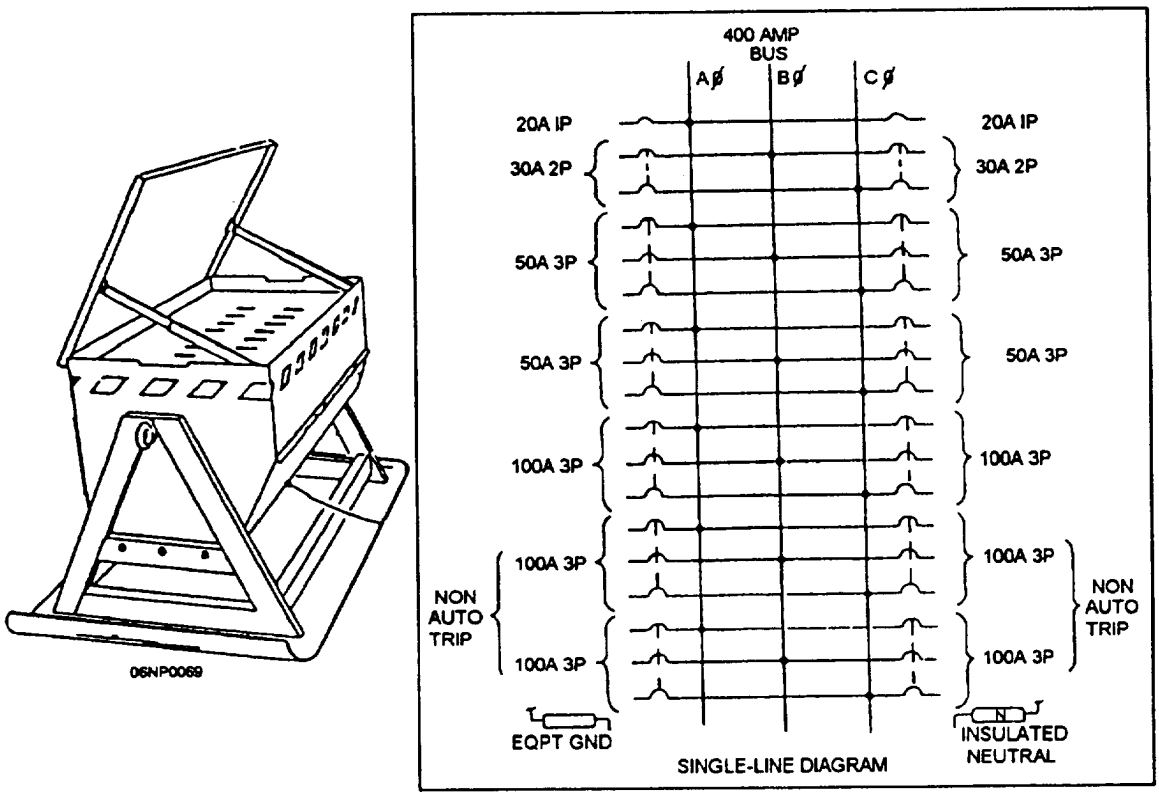


Figure 3-14.—Diagram of the portable power distribution panelboard.

GENERATOR WATCH

While standing a generator watch, you must be alert and respond quickly when you recognize a problem. You might not have control of every situation but at least you can secure the generator and prevent serious problems.

Your primary purpose is to produce power in a safe and responsible manner. You may notice maintenance or repair actions that need to be rectified but do not require immediate attention and do not affect your watch Make note of these problems so that they will be taken care of by the repair crew. In addition, concentrate on doing your job properly, and your efforts will pay off.

A generator watch involves performing operator maintenance, maintaining the operator's log, operating a single generator, or operating paralleled generators.

OPERATOR MAINTENANCE

Operator maintenance generally includes whatever you have to do to start the generator set and keep it running smoothly and safely. Equipment must be inspected systematically so that defects can be discovered before a serious failure occurs. Operator maintenance includes both prestart checks and operating checks.

Prestart Checks

When starting the generator set and preparing to put it on line, you expect everything to go well. A systematic inspection before start-up will help ensure that the generator will operate properly. To do a prestart checkonthe generator, make the following inspections:

1. Ground cable. See that the cable is intact and that the connections are tight.

2. Engine. Compare the actual lube oil level to the appropriate markings (running level or stopped level) on the dipstick. The stopped level is, of course, appropriate for prestart checks. Add oil as required.

Check the engine for loose connections; free action of all moving parts, such as the throttle linkage and the emergency shut-off lever; and for leaking oil, fuel, or coolant.

3. Coolant system. Check that the coolant is at the required level. Add coolant as required. Using an antifreeze solution tester, check that the antifreeze

content is sufficient for the existing ambient temperature. (Refer to the manufacturer's manual for the type and quantity of antifreeze. Add antifreeze as required.) Check the hoses and clamps for security.

4. Batteries. Check the batteries for the required electrolyte level; add distilled water or, if distilled water is not available, clean tap water as required to raise the electrolyte level to the slots in the filler wells.

5. Air intake system. Check the air intake system cleaner for excessive dirt (see AIR CLEANER PANEL FILTER, fig. 3-15); remove and clean the air cleaner panels as required. Check the air intake louvers and radiator grille for freedom of motion, and ensure that they are not clogged.

6. Exhaust extension. Inspect the exhaust extension (where extended through the roof or wall) for condition and tightness at the seams and at the point of coupling near the housing.

7. Alternator (fig. 3-16) and belts. Inspect the alternator for signs of overheating, frayed or loose wiring, and corrosion. Inspect the alternator drive belts and fan belts for proper tension and for cracks, fraying, and other signs of deterioration.

8. Breather. Inspect the breather extension for tightness, general condition, and leakage. Check that the breather coupling is not restricting the flow of air and that the breather exit port is clear.

9. Fuel system. Inspect the electric fuel transfer pumps for secureness, tight fittings, signs of damage, corrosion, leaks, and loose electrical connections.

Look over the fuel filters and strainers for leaks and tight fittings. Drain water and sediment from the

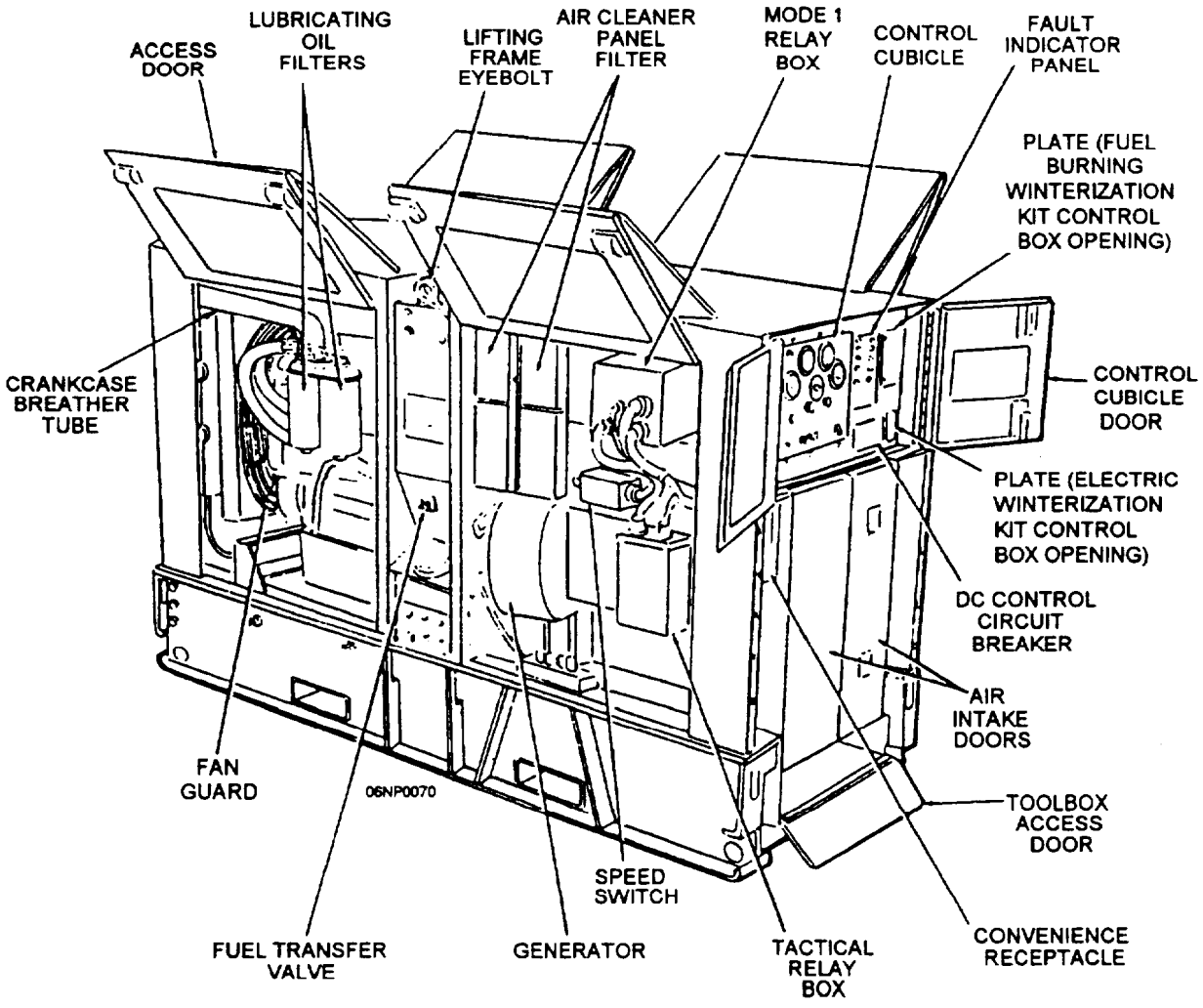


Figure 3-15.—Generator set, left rear, three-quarters view.

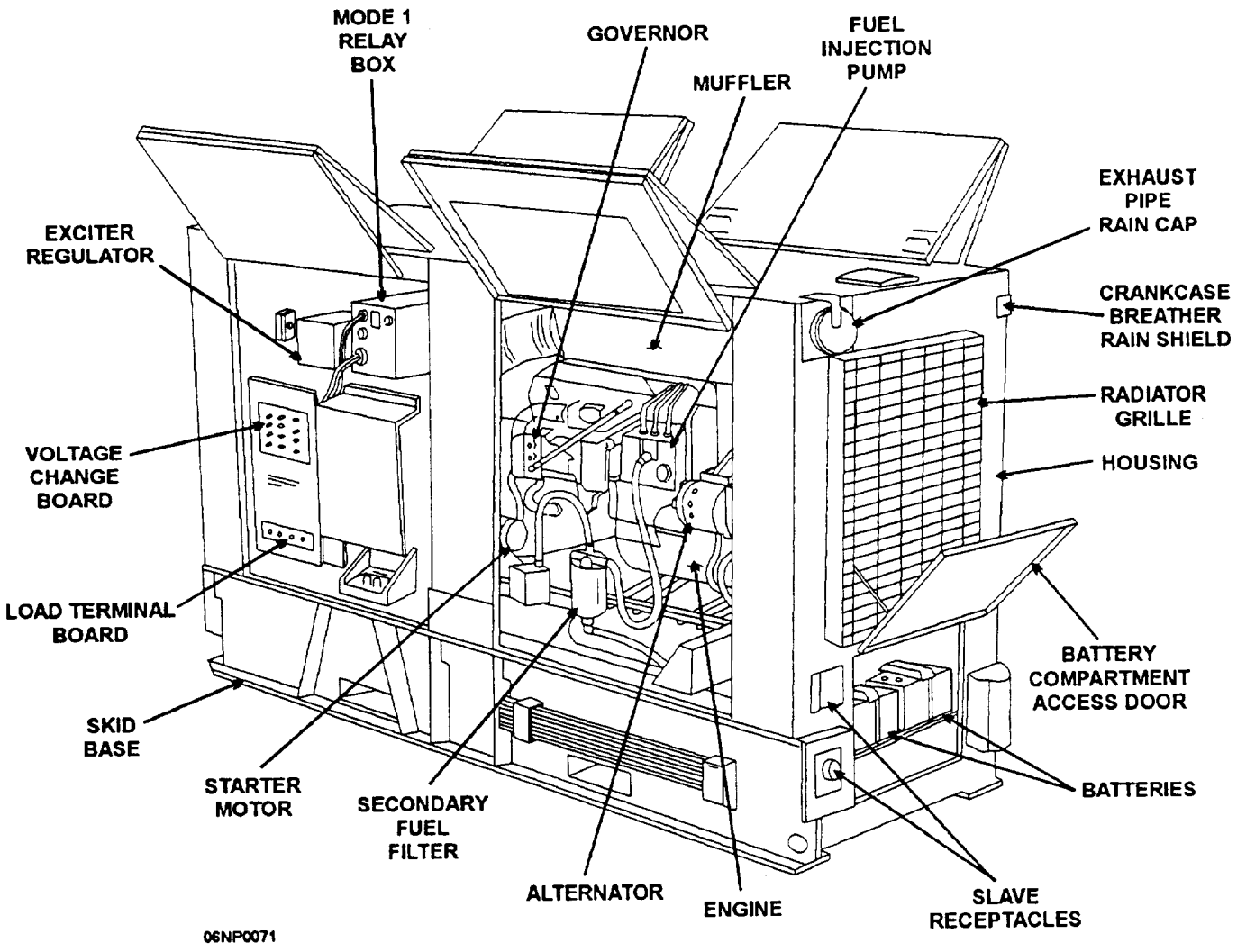


Figure 3-16.—Generator set, right front, three-quarters view.

primary filter and strainer and from the secondary filter, using rags to catch the waste.

Check the day tank for leakage or signs of obvious damage. Remove the cap from the day tank drain valve and open the valve. Drain the water and sediment into a suitable container, close the valve, and replace the cap.

Inspect the fuel lines, valves, and fittings for bent, leaky, or loose connections and signs of obvious damage. Inspect the fuel tank for leakage or obvious damage.

Service the fuel tank as follows:

WARNING

Always maintain constant metal-to-metal contact between the fuel tank filler neck and the spout of the fuel supply. That will prevent the possibility of sparking caused by static electricity.

Remove the fuel tank filler cap and fill the tank with the proper fuel. Replace the filler cap and wipe up any spilled fuel. Remove the cap from the fuel tank drain valve and open the valve. Permit water and sediment to drain into an approved nonflammable container. Close

the drain valve when clear fuel runs out of the tank. Reinstall the cap on the valve.

Remove the fuel filler cap and strainer, as shown in figure 3-17. Check the cap vent valve for proper opening and closing. Inspect the strainer for holes, breaks, and tears. Also, inspect the parts for cracks, breaks, and other damage. Install the cap and strainer, as shown in figure 3-17.

NOTE: The fuel tank filler cap vent valve must be in the open position during operation of the generator set.

10. Ether system. Inspect the ether system (used to aid cold-weather starting). The ether cylinder is strapped to the day tank. Look for broken wires, loose connections, corrosion, and any other signs of obvious damage.

11. Set controls and instrumentation. Inspect meters and gauges at the control cubicle (fig. 3-15) for bent pointers, broken glass, unreadable dial faces, and restricted movement of pointers. Clean gauges and meter faces with a lint-free cloth.

Check for broken indicator lenses and for unreadable lettering. Set the panel light to ON; the panel lights should light.

Check all switches for positive action; each switch should snap from one position to the next.

Operating Checks

The operator can use his or her senses to detect many potential problems. The operator may smell overheated insulation, hear peculiar noises, see an indicating light signaling a fault, or feel unusual vibrations from the generator or engine.

Operator maintenance requirements vary with different types of generators. General operator inspections and tasks are as follows:

1. Oil level. Frequently, check the appropriate oil level. Add oil as needed to maintain the required level. (Intervals between oil checks and changes will vary for abnormal operation and severe conditions.)

2. Batteries. Check the electrolyte level and add water to maintain the required level.

3. Exhaust and breather systems.

WARNING

Components of both the exhaust and crankcase breather systems (muffler, pipe, tube, and hose) become extremely hot during generator set operation. Do not handle any of them while they are hot.

Inspect the muffler for holes, dents, signs of extreme corrosion, and metal deterioration. Also, check

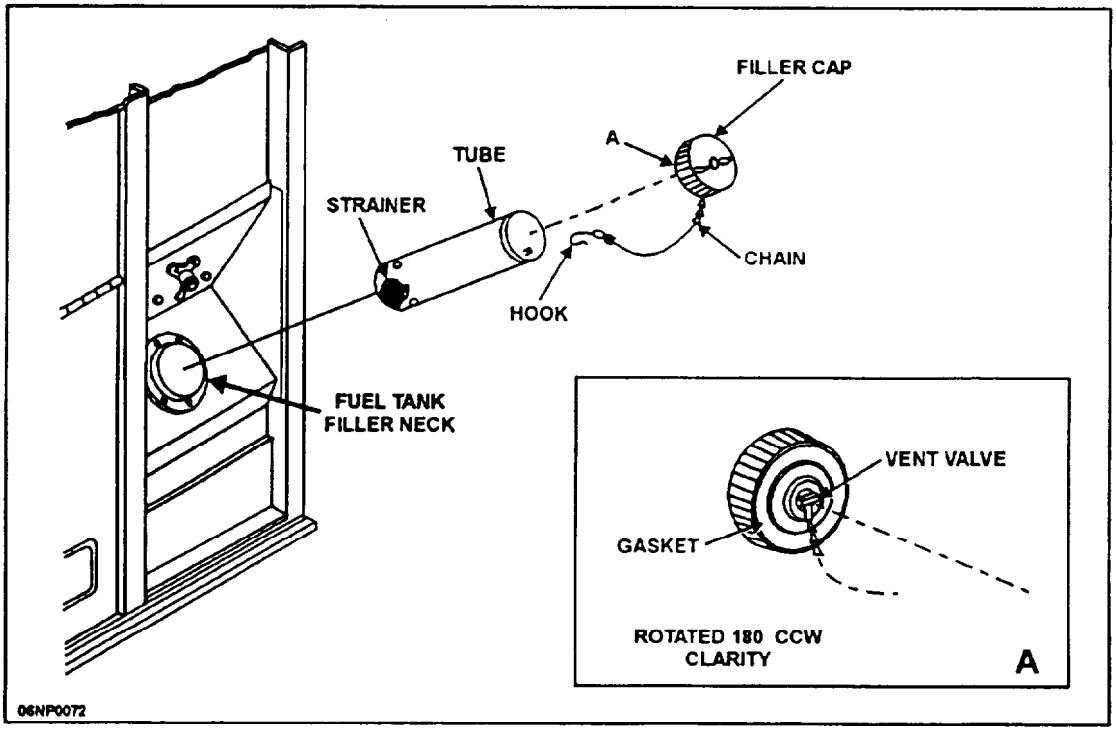


Figure 3-17.—Fuel filler cap and strainer.

for loose or broken clamps and general secureness of the muffler. Check all pipes and ducts associated with the exhaust system for holes, dents, signs of extreme corrosion, and metallic deterioration. Also, check for loose and broken bolts. Check the exhaust ram cap for signs of corrosion and freedom of movement. Check the breather tube and associated hoses for loose clamps, holes in the hoses, and loose bolts.

4. Cooling system. Check all hoses for cracks, cuts, signs of deterioration, and bulges (indicating the possibility of future rupture). Check all clamps for tightness and signs of corrosion.

WARNING

Do not attempt to remove the radiator cap until the radiator has cooled to a point where there will be no built-up steam pressure. Failure to observe this warning could result in second- or third-degree burns.

OPERATOR'S LOG

The operator's log (also called the station log) is a complete daily record of the operating hours and conditions of the generator set. The log must be kept clean and neat. Any corrections or changes to entries for a watch must be made by the person who signs the log for that watch.

The log serves as a basis for determining when a particular piece of electrical equipment is ready for inspection and maintenance. Current and previous logs can be compared to spot gradual changes in equipment condition. These changes might not otherwise be detected in day-to-day operation.

Defects discovered during operation of the unit should be noted for future correction; such correction to be made as soon as operation of the generator set has ceased.

Making accurate periodic recordings is particularly important. The intervals of these recordings will be based on local operating conditions.

The form used for log entries varies with the views of the supervisory personnel in different plants, and there is no standard form to be followed by all stations. Regardless of form, any log must describe the hourly performance not only of the generators but also of the numerous indicating and controlling devices.

Figure 3-18 shows one type of log that may be kept on the generator units of a power plant. This is only a

SUGGESTED FORM OF PLANT OPERATION LOG

Date	Time	UNIT NO. 1785			UNIT NO. 942			UNIT NO. 3465			REMARKS
		☐ speed Time Meter	Volts	Amperes	☐ speed Time Meter	Volts	Amperes	☐ speed Time Meter	Volts	Amperes	
2/8/93	1600	195.0	220	58	302.0	52	220	934.0	220	27	Started up
"	1730	196.5									added 2qts oil to #1785
"	2100	200.0	221	54	307.0	49	221				shut down #3465

OPERATOR _____

Figure 3-18.—Typical generating station operator's log.

suggested form, of course, and there may be many other forms at your generating station to keep records on.

OPERATING PROCEDURES FOR SINGLE GENERATOR SETS

The following operating procedures are general procedures for operating a single generator unit. Some procedures will vary with different types of generators. Study carefully the recommendations in the manufacturer's manual for the generator you are to operate. Learn about the capabilities and limitations of your machine(s). In the event of a problem, you will know what action is required to lessen the effects of the problem. You or your senior should make a checklist of operating procedures from the manual and post it near the generator.

The steps below will cover starting and operating a typical diesel-driven generator set. (This set uses a dc-powered motor for starting the diesel engine.) These steps will also cover applying an electrical load.

Starting the Generator Set

Proceed as follows to start the typical generator set:

WARNING

Do not operate the generator set unless it has been properly grounded. Electrical faults (such as leakage paths) in the generator set, feeder lines, or load equipment can cause injury or death by electrocution.

Before operating the set for the first time, ensure that service procedures were performed upon its receipt according to the manufacturer's literature. See also that all preventive maintenance checks have been performed. The voltage change board must be adjusted for the required voltage (fig. 3-11).

1. Open the CONTROL CUBICLE and AIR INTAKE DOORS (fig. 3-15). Close the HOUSING PANEL (ACCESS) DOORS,

2. Set the FUEL TRANSFER VALVE (fig.3-15) to the desired source of fuel, preferably the auxiliary tank, if it is connected.

NOTE: Refer to figure 3-19 for the CONTROL CUBICLE, FAULT INDICATOR PANEL, DC CONTROL CIRCUIT BREAKER, and ENGINE MANUAL SPEED CONTROL. Notice that the control cubicle is divided into an engine section and a generator section.

3. Set the PARALLEL OPERATION-SINGLE UNIT OPERATION select switch (located in the GENERATOR section of the CONTROL CUBICLE) to SINGLE UNIT OPERATION.

4. Set the VOLTAGE ADJUST-INCREASE control to the lower half of the adjustment range.

5. Depress the DC CONTROL CIRCUIT BREAKER (located to the lower right of the CONTROL CUBICLE) to ON.

6. Set the START-STOP-RUN switch (located in the ENGINE section of the CONTROL CUBICLE) to RUN.

7. Set and hold the TEST or RESET switch (on the FAULT INDICATOR PANEL) in the UP position. Each fault indicator light should be on Check and replace defective lamps or fuses.

8. Allow the TEST or RESET switch to return to the mid-position. Each fault indicator light, with the exception of the LOW OIL PRESSURE light, should go out. When the engine has started, the LOW OIL PRESSURE light should also go out.

NOTE: If the NO FUEL light stays lit, refill the set or auxiliary tank. Position the BATTLE SHORT switch (CONTROL CUBICLE) to ON (the fuel pump will run to fill the day tank). Set the TEST or RESET switch to the UP position and then release it; the NO FUEL light should go out when the switch handle is released.

9. Set the CKT BRK CLOSE-OPEN switch (CONTROL CUBICLE) to OPEN.

10. Push and release the AIR CLEANER CONDITION indicator, BATTLE SHORT indicator, and CKTBRK indicator. Each indicator light should go on as the indicator is pushed and go out when the indicator is released.

a. If the AIR CLEANER CONDITION indicator remains lit, the air cleaner must be serviced.

b. If the CKT BRK indicator remains on after you set the CKT BRK switch to OPEN, you cannot continue the procedure. The circuit breaker must function properly. The generator cannot be used until the problem is corrected.

11. Depress the lock button on the ENGINE MANUAL SPEED CONTROL (located below the DC CONTROL CIRCUIT BREAKER), and set the control.

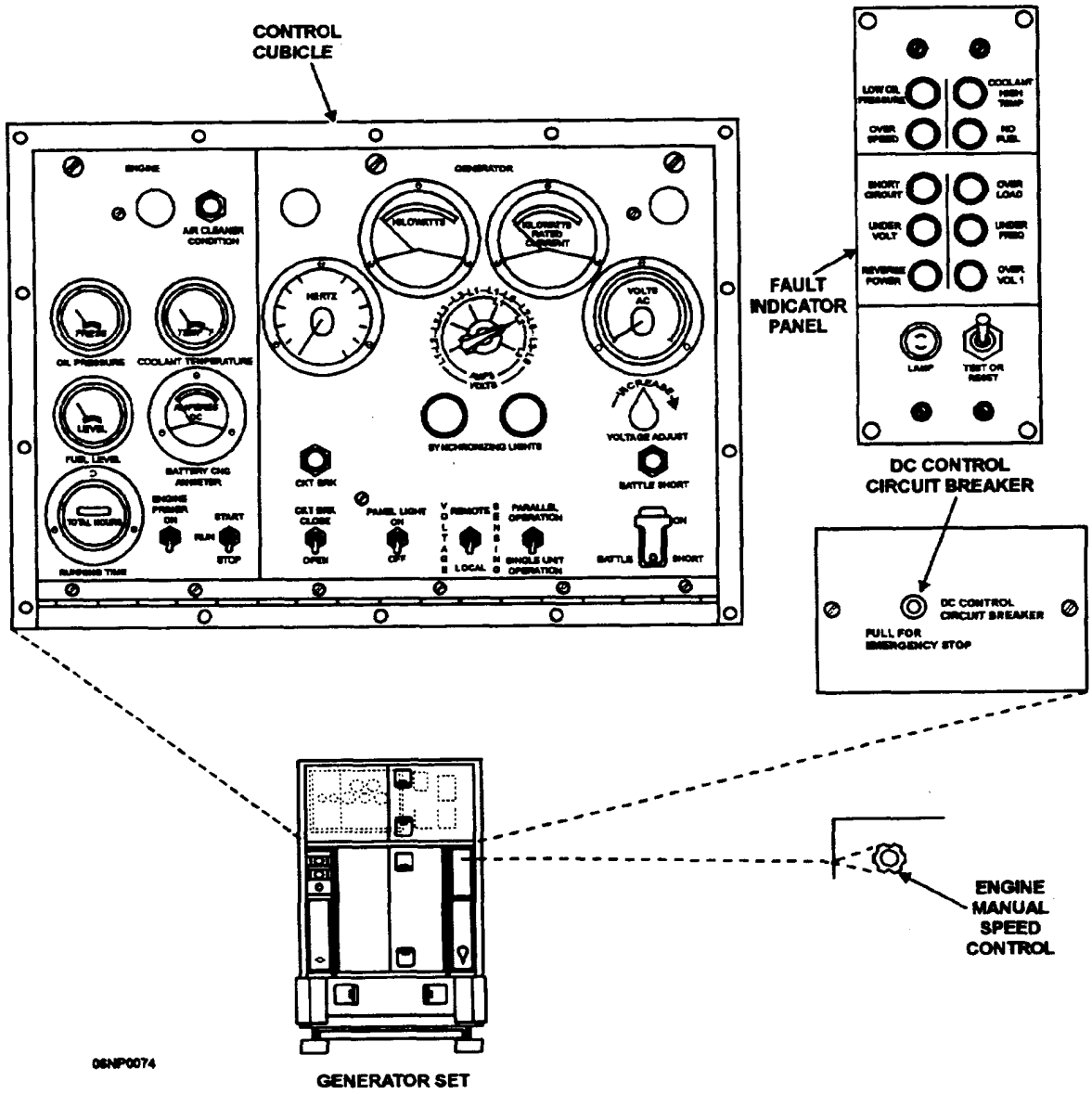


Figure 3-19.—Control cubicle, controls, and indicators.

CAUTION

Do not crank the engine in excess of 15 seconds at a time. Allow the starter to cool a minimum of 3 minutes between cranking.

WARNING

Operation of this equipment presents a noise hazard to personnel in the area. The noise level exceeds the allowable limits for unprotected personnel. Wear earmuffs or earplugs.

12. Set and hold the START-STOP-RUN switch to the START position until the engine starts. As the engine starts, observe the following:

a. The OIL PRESSURE gauge indicates at least 25 psig.

b. The VOLTS AC meter indicates the presence of voltage.

c. The LOW OIL PRESSURE indicator light on the FAULT INDICATOR PANEL goes out.

13. Release the START-STOP-RUN switch. Position the switch to RUN.

Operating the Generator Set

The procedures for operating a single generator set (single unit) are as follows:

1. Ensure that the PARALLEL OPERATION-SINGLE UNIT OPERATION switch (fig. 3-19) is set to SINGLE UNIT OPERATION.

2. Position the AMPS-VOLTS selector switch to the required position. Rotate the VOLTAGE ADJUST control to obtain the required voltage. Read the voltage from the VOLTS AC meter.

3. Depress the locking button, and slide the ENGINE MANUAL SPEED CONTROL in or out to obtain the approximate rated frequency; rotate the vernier knob (the knob on the control) clockwise or counterclockwise to obtain the rated frequency.

NOTE: If necessary, the load may be applied immediately.

4. Operate the engine for at least 5 minutes to warm it up.

5. Apply the load by holding the CKT BRK switch (on the CONTROL CUBICLE) to CLOSE until the CKT BRK indicator lights go out. Then release the switch.

6. Observe the readings from the VOLTS AC meter and the HERTZ (FREQUENCY) meter. The voltage readings should be 120/208 to 240/416 volts ac (depending on the positions of the AMPS-VOLTS select switch and the voltage change board). Let's say, for example, that you positioned the voltage change board for 120/208 volts before you started the generator set. When you position the AMPS-VOLTS selector switch to L2-L0 VOLTS/L2 AMPS while the generator is operating, the VOLTS AC meter should indicate 120 volts. The PERCENT RATED CURRENT meter will indicate the percent rated current (not more than 100 percent) between generator line 2 and neutral. The HERTZ (FREQUENCY) meter should indicate 50 or 60 hertz. The KILOWATTS meter should indicate no more than 100 percent with the HERTZ (FREQUENCY) meter showing 60 hertz. Readjust the voltage and frequency, if necessary.

7. Observe the KILOWATTS meter. If the meter indicates that more than the rated kilowatts are being consumed, reduce the load.

8. Rotate the AMPS-VOLTS selector switch to each phase position and monitor the PERCENT RATED CURRENT meter. If more than the rated load is indicated for any phase position, reduce or reapportion the load.

9. Periodically (not less than once per hour), monitor the engine and generator indicators to ensure their continued operation.

10. Perform any "during operation" preventive checks according to your checklist.

When in operation, the generator set should be monitored periodically (at least once an hour) for signs indicating possible future malfunctions.

After the warmup, the lubricating oil pressure should remain virtually constant. Check and record the level of lubricating oil while the engine is running normally. If any significant changes occur in the oil pressure, notify the maintenance personnel. Check and record the coolant temperature of the normally running engine. Notify maintenance personnel if the coolant temperature changes significantly.

Learn the sounds of a normally running generator set so that any unusual sounds indicating the possible start of a malfunction may be detected early enough to avoid major damage.

Stop the operation immediately if a deficiency that wouldd damage the equipment is noted during operation.

OPERATING PROCEDURES FOR PARALLELING GENERATORS

This section will include procedures for paralleling generators, removing a set from parallel operations, and stopping generator set operation.

NOTE: These procedures assume that one generator set is on line (operating and connected to the distribution feeder lines through the switchgear). The set that is to be paralleled is designated the incoming set (fig. 3-20).

CAUTION

When you are operating generator sets in parallel, they must have the same output voltage, frequency, phase relation, and phase sequence before they can be connected to a common distribution bus. Severe damage may occur to the generator sets if these requirements are not met.

Adjusting the engine speed of the incoming set while observing the output frequency and the

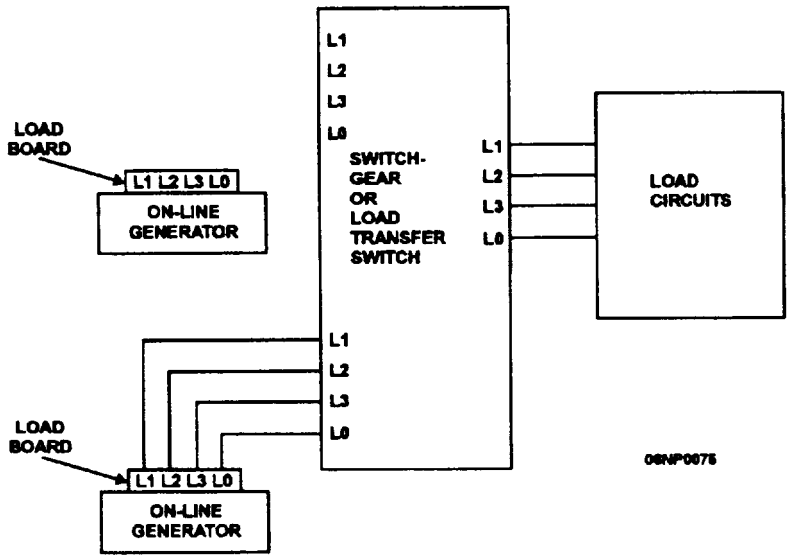


Figure 3-20.—Parallel operation connection diagram.

SYNCHRONIZING LIGHTS (fig. 3-19) will bring the phase and frequency into exact agreement. As the phase and frequency approach the same value, the SYNCHRONIZING LIGHTS will gradually turn on and off. When the blinking slows to a rate of once per second or slower, close the main circuit breaker of the incoming set while the SYNCHRONIZING LIGHTS are at a point of being dark. The phase sequence relates to the order in which the generator windings are connected. If the phase sequence is not correct, the SYNCHRONIZING LIGHTS will not blink on and off together. When the incoming set is first connected to the load through the appropriate switchgear (fig. 3-20). you should observe one of four occurrences. When the phase sequence, voltage, frequency, phase, and engine performance are the same, the changeover will be smooth with only the slightest hesitation in engine speed; if each output is slightly out of phase, one of the engines will shudder at the point of changeover; if the phase sequence or voltage levels are incorrect, the reverse power relay will trip on one of the generator sets and open its main circuit breaker contactors; if the incoming generator set loses speed significantly or almost stalls, the incoming engine may be defective.

CAUTION

Should either generator set lose speed, buck, or shudder when the incoming set is connected to the distribution feeder lines, immediately flip the CKT BRK switch of the incoming set to open, and then recheck the paralleling set-up procedures.

Refer to figures 3-19 and 3-20 to set up the generator sets for parallel operation.

WARNING

When performing step 1, make certain that the incoming set is shut down and that there are no voltages at the switchgear terminals being connected to the incoming set. Do not take anybody's word for it! Check it out for yourself! Dangerous and possibly deadly voltages could be present. Take extreme care not to cross the LO (neutral) with any of the other phases (L1, L2, or L3).

Paralleling Procedures

1. Connect the incoming set, as shown in figure 3-20.

2. Make certain that the voltage change board (reconnection board) (fig. 3-12) of the incoming generator is set up for the same output voltage as the on-line generator.

3. Set CKT BRK switch on the incoming set to OPEN. When the incoming set circuit breaker is open (CKT BRK indicator light will be out), operate the load switchgear so that the on-line output voltage is present at the voltage change board of the incoming set.

4. Set the PARALLEL OPERATION-SINGLE UNIT operation switch on both sets to PARALLEL OPERATION.

5. Start the incoming set. The on-line set should be in operation already.

6. After a 5-minute warmup, try the VOLTAGE ADJUST control on the incoming set until the output voltages of both sets are equal.

CAUTION

If the synchronizing lights do not blink on and off in unison, the phase sequence is incorrect. Shut down the incoming set and recheck the cabling to and from the incoming set.

7. On the incoming set, position the ENGINE MANUAL SPEED CONTROL until the SYNCHRONIZING LIGHTS blink on and off as slowly as possible.

8. With one hand on the CKT BRK switch, adjust the ENGINE MANUAL SPEED CONTROL vernier knob until the SYNCHRONIZING LIGHTS dim gradually from full on to full off as slowly as possible. Just as the SYNCHRONIZING LIGHTS dim to out, set and hold the CKT BRK switch to close. When the CKT BRK indicator light comes on, release the switch.

9. On both sets, check that the readings of the PERCENT RATED CURRENT meters and KILOWATTS meters are well within 20 percent of each other. If not, increase the engine power of the set with the lower readings (by adjusting the ENGINE MANUAL SPEED CONTROL to increase the speed) until the readings are about equal.

NOTE: The division of the kilowatt load is also dependent on the frequency droop of the two sets and must be adjusted at the next higher level of maintenance. If the current does not divide as described above, adjust the reactive current-sharing control located at the right side of the special relay box for equal reading on both percent rated current meters.

10. On the incoming set, readjust the voltage and frequency of the output until it is equal to the output of the on-line set.

Removing a Generator Set from Parallel Operation

Refer to figure 3-19 while following the procedure for removing a generator set from parallel operation.

CAUTION

Before removing the generator set(s) from parallel operation, make sure the load does not exceed the full-load rating of the generator set(s) remaining on the line.

1. On the outgoing set, position and hold the CKT BRK switch to OPEN until the CKT BRK indicator light goes out. Release the switch.

2. On the outgoing set, allow the engine to operate with no load for about 5 minutes.

3. On the outgoing set, pull the DC CONTROL CIRCUIT BREAKER to OFF.

4. On the outgoing set, set the START-STOP-RUN switch to STOP.

WARNING

Make certain the outgoing set is shut down and there are no voltages at the switchgear terminals connected to the outgoing set. Do not take anybody's word for it! Check it out for yourself!

5. Disconnect the cables going from the outgoing set to the load switchgear.

Stopping Generator Set Operation

Refer to figure 3-19 as you study this section.

1. Set the CKT BRK switch to OPEN until the CKT BRK indicator light goes out, then release the CKT BRK switch.

2. Allow the engine to cool down by operating at no load for 5 minutes.

3. Set the START-STOP-RUN switch to STOP.

4. Close all generator doors.

MAINTENANCE

There are actually three major categories (or levels) of maintenance. The three categories are (1) depot, (2) intermediate, and (3) organizational. In depot or intermediate maintenance, equipment is restored to like-new condition or subjected to some degree to detailed repairs. Under the organizational category, generator maintenance may consist of inspection, testing, adjustment, and so forth, and then perhaps

replacement of, rather than repair of, a faulty component.

Two types of organizational maintenance are (1) operator and (2) preventive. Each of the two types should complement the other.

Defects discovered during operation of the unit will be noted for future correction either by the operator or by maintenance personnel, as appropriate. The purpose of preventive maintenance is to keep the machinery running trouble-free. The operator will likely have fewer problems if the preventive maintenance work is done well.

In our previous discussion we have seen that operator maintenance includes many of the tasks you do before, during, and after you operate the generator set to produce power.

As a member of a unit or organization large enough to have a maintenance crew, you may serve as a member of the crew. As a crew member, you will perform organizational preventive maintenance functions on the generator set periodically according to the manufacture's specifications or to service maintenance manuals.

To prevent buildup of contaminants that may cause damage to the operating components or systems of the generator set, you should clean the set periodically. Cleaning operations must be performed only on generator sets that are not operating, that are connected to a parallel bus, or that are connected in a standby mode. To clean the generator set, heed the warnings and cautions given, and proceed as follows:

WARNING

Compressed air used for cleaning can create airborne particles that may enter the eyes. Pressure shall not exceed 30 psig (206 kPa). Wearing of goggles is required.

CAUTION

Exercise care to prevent dry-cleaning solvent from coming into contact with electrical components.

Painted metal surfaces should be wiped with a clean lint-free cloth moistened with cleaning solvent (P-D-680, type II). Hard deposits may be scrubbed off with a bristle brush that has been dipped in solvent. Dry the surfaces with a clean lint-free cloth.

WARNING

Dry-cleaning solvent, P-D-680, type II, is flammable and moderately toxic to the skin and eyes. Respiratory and eye protection are required.

Remove any dust, dirt, or sand from inside the generator set with a damp, lint-free cloth.

Disconnect the battery cables (negative cable first) and remove any corrosion from the battery terminals, cables, and hold-down with a wire brush. Clean the battery filler cap vent holes.

Clean the instrument faces with a clean, lint-free cloth.

CHAPTER 4

POWER DISTRIBUTION

A power distribution system includes all parts of an electrical system between the power source and the customer's service entrance. It includes the use of overhead and underground transmission methods and the equipment required for the control and protection of the system and personal. The power source may be either a local generating plant or a high-voltage transmission line feeding a substation that reduces the high voltage to a voltage suitable for local distribution. At most advanced bases the source of power will be generators connected directly to the load.

This chapter will be mainly concerned with the overhead distribution system. Generally speaking, an overhead distribution system can usually be installed and maintained more efficiently than an underground system. Also, for equivalent conductor size, an overhead system has higher current capacity and offers greater flexibility with regard to changes.

In this chapter you will learn about line work safety, pole climbing, and the tools and equipment a lineman uses. You will learn the basics in constructing and maintaining a power distribution system as well as the component parts of the system.

SAFETY IN POWER DISTRIBUTION

The topic of safety that is covered in this chapter is the most important. The potential for an accident is constantly present during construction and maintenance operations but is much greater when crew members are working on power distribution systems.

The presence of HIGH VOLTAGE in your work area increases your need for heightened awareness of the potential for serious injury or death that may be caused by carelessness and the necessity to take precautions to ensure the safety of all personnel.

EQUIPMENT REQUIREMENTS

Cranes, earth augers, bucket trucks, and line trucks with booms that are capable of contacting HIGH-VOLTAGE lines because of their height capabilities must be operated with caution. A minimum separation of 10 feet must be maintained between the equipment and the energized power circuits at all times. The equipment must be maintained in first-class mechanical condition. **SAFETY FIRST** must be the primary goal.

PERSONNEL SAFETY

To ensure the SAFETY of all personnel working on power distribution lines, you should observe the following safety precautions:

- Ensure that all hot-line equipment is routinely tested according to the manufacturer's specifications before use.

- Ensure that all hot-line equipment, including rubber gloves, is stored in appropriate containers to provide the required physical protection.

- Perform air leak tests on rubber gloves before each use.

- Never use rubber gloves without the leather outer protectors.

- Ensure that the hard hats of crew members are rated to withstand 20,000 Vac and that no metal devices are or have been attached to them.

- All members of the line crew must be trained in the application of the first-aid techniques required to treat victims of electrical shock.

- Ensure that no individual is ever allowed to work alone or near circuits or devices conducting electrical energy over 30 Vac.

- Tag and lock out all circuits that are de-energized to perform work.

- Install ground sets between the electrical source and your work on all de-energized circuits when the disconnecting means is not in sight or when the potential for contact between the de-energized circuit and an energized circuit is present.

- Maintain a minimum of 3-foot clearance between personnel and any live power circuit or device conducting between 600 and 20,000 Vac. Higher

voltages require an increased separation of personnel and energized circuits.

Many other safety procedures are required on the job—too many to list here. *The Lineman's and Cableman's Handbook,* the *Electrical Transmission and Distibution Safety Manual,* NAVFAC P-1060, and Occupational Safety and Health Administration instructions are a few references you need to read to learn more about job safety.

POWER LINE COMPONENTS

Power line components are the different items used to construct a power distribution line. The basic components of a power line are poles, guys, crossarms, insulators, and conductors.

POLES

The three types of poles used most frequently in pole-line construction are wood, concrete, and steel. You will find all three types of poles in the field, but most of your work will be with the wooden type.

All wooden poles used for line work are chemically treated to resist damage caused by insects and rotting. Many of the older poles now in use were treated with creosote. Most new poles are treated with less toxic chemicals and are therefore safer to work with.

WARNING

Creosote is a toxic compound that irritates the skin and sometimes causes blistering. You should use extra care when working around poles treated with creosote to prevent contact between these poles and the bare skin.

The supply of wood poles available for use in constructing electric power lines has decreased in recent years. Substitute materials, such as concrete, aluminum, fiber glass and laminated and composite wood poles, are now being used.

The classification of wooden poles is determined by the length, circumference at the top, and circumference measured 6 feet from the butt end. Pole sizes begin at 20 feet and are increased in 5-foot increments up to 90 feet in length. Pole-top circumference increases 2 inches for every class from Class 7 to Class 1. The Navy, however, does not normally order poles smaller than Class 5.

American National Standard, ANSI 05.1, entitled "Specifications and Dimensions for Wood Poles" provides technical data for wood utility poles.

POLE GUYS

When constructing power lines, you will need a means of strengthening poles and keeping them in position. To accomplish this, you can use guys, anchors, and braces. Anchors are buried in the ground, and guy wires are connected to the anchors and attached to the pole, or a push brace may be used. The guys and braces are used to counter the horizontal strain on the pole caused by conductors, pole-line components, and abnormal loads, such as snow, sleet, or wind.

Anchors

Anchors are designed to meet specific soil conditions. You must know the type of soil before you can select a certain type of anchor. Anchors come in many forms and have different methods of installation. Figure 4-1 shows the most common types of anchors. The expanding anchor, the most popular type, as shown in figure 4-1, view A, is designed to be placed in the ground and then expanded with the aid of the tamping bar. Once expanded, the anchor is secure and strong enough to secure the guy. Figure 4-1, view B, shows a plate of a never-creep anchor, and view C shows a screw anchor that is installed using an earth auger. These three types of anchors are manufactured and are commonly used because of their ease of installation.

Another type of anchor that is shown in figure 4-1, view D, is called a deadman. This anchor is made of a 6- to 8-foot-long piece of treated power pole and an anchor rod. It is installed 6 feet deep in loose or sandy type of soil, with an angle of pull for the guy wire and rod assembly equal to 45 degrees. The deadman is not widely used today because of the time and effort required to place it.

Anchor Rods

The anchor rod serves as the connecting link between the anchor and the guy cable. The rod must

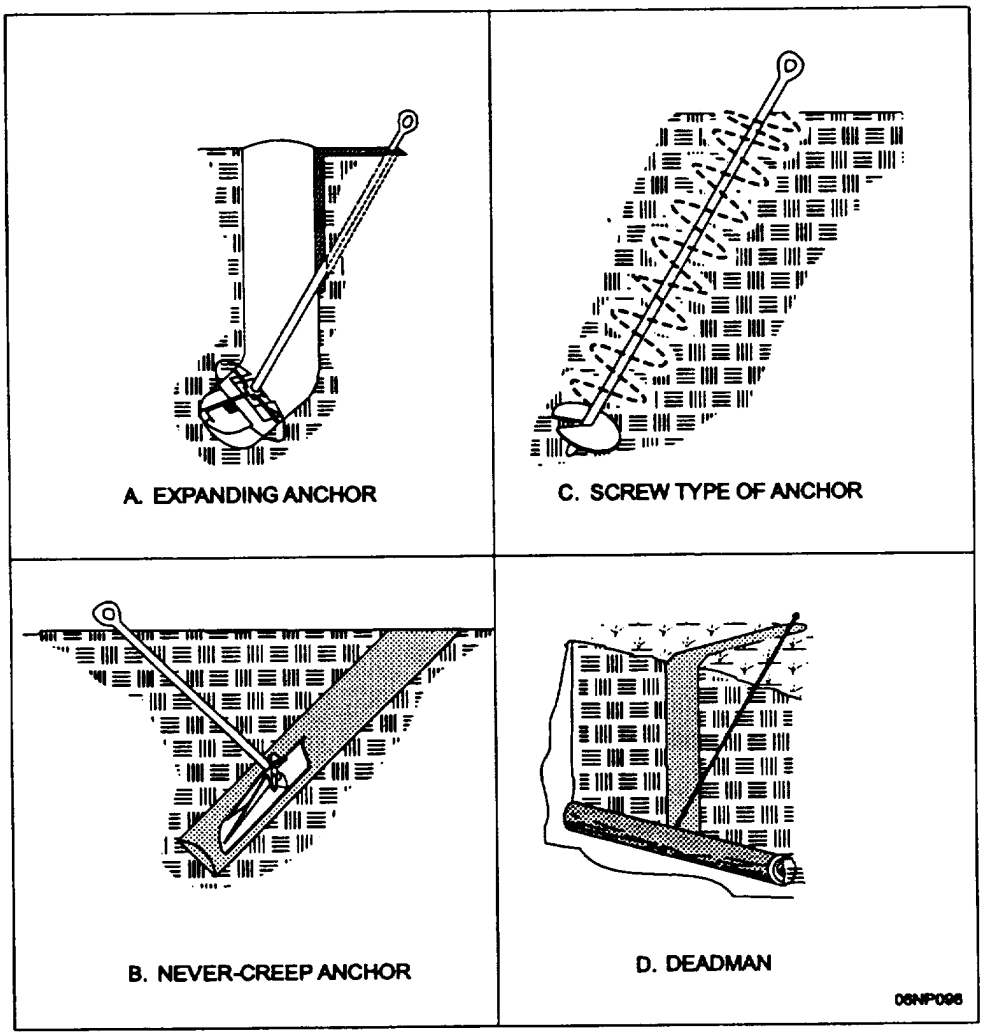


Figure 4-1.—Anchors.

have an ultimate strength equal to, or greater than, that required by the down-guy assembly. Anchor rods vary in diameter from 1/2 to 1 1/4 inches and in length from 3 1/2 to 12 feet.

Guy Wire

The wire, or cable, normally used in a down guy is seven-stranded galvanized steel wire or seven-stranded alumoweld wire. Alumoweld wire consists of steel wire strands coated with a layer of aluminum to prevent corrosion. Guy wire is used in various sizes with diameters from 1/8 to 1 3/4 inches.

Guys

A guy is a brace or cable fastened to the pole to strengthen it and keep it in position. Guys are used whenever the wires tend to pull the pole out of its normal position and to sustain the line during the abnormal loads caused by sleet, wind, and cold. Guys counteract the unbalanced force imposed on the poles by dead-ending conductors; by changing conductor size, types, and tensions; or by angles in the transmission or distribution line. The guy should be considered as counteracting the horizontal component of the force with the pole or supporting structure as a strut resisting the vertical component of the forces.

DOWN GUY.—A "down guy" consists of a wire running from the attachment near the top of the pole to

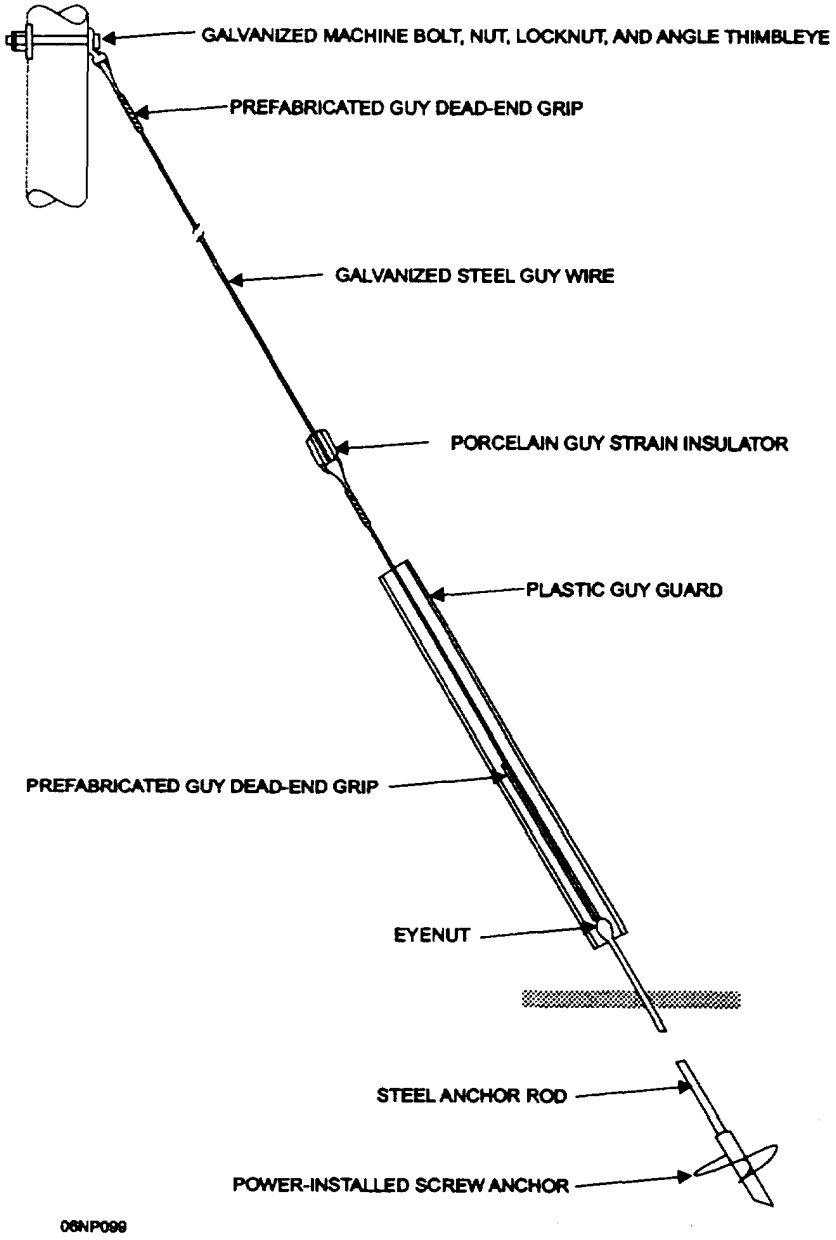


Figure 4-2.—Down-guy assembly.

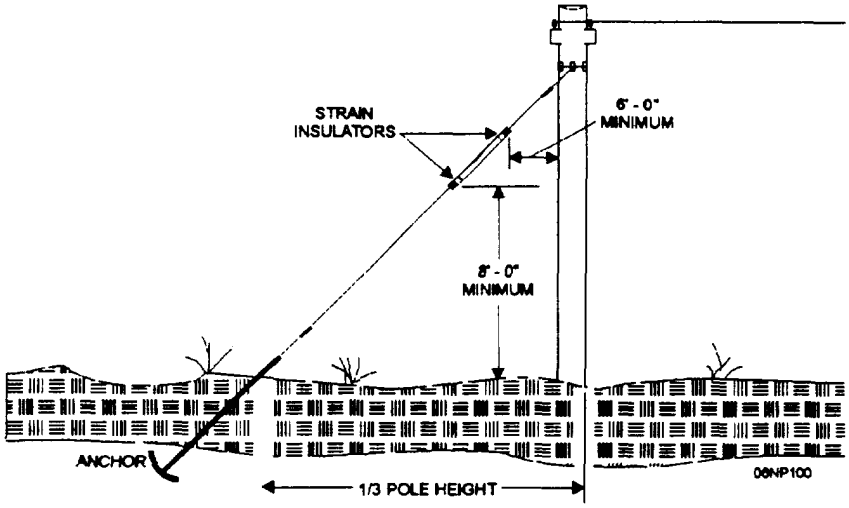


Figure 4-3.—Dead-end guy.

the rod and anchor installed in the ground (fig. 4-2). This type of guy is preferable if field conditions permit its installation since it transfers the unbalanced force on a pole or structure to the earth without intermediate supports.

A down guy used at the ends of pole lines to counterbalance the pull of the line conductors is called a "terminal guy" or a "dead-end guy" (fig. 4-3). All corners in the line are considered as dead ends. They should be guyed the same as terminal poles, except that there will be two guys, one for the pull of the conductor in each direction (fig. 4-4).

SIDE GUY.—When the line makes an angle, a side pull is produced on the pole. Side guys should be installed to balance the side pull (fig. 4-5). When a branch line takes off from the main line, an unbalanced side pull is produced. A side guy should be placed on the pole directly opposite to the pull of the branch line.

STORM GUY.—Guys are installed at regular intervals in transmission lines that extend long distances in one direction to protect the line from excessive damage as a result of broken conductors. Guys installed to protect the facilities and limit the damage if a conductor breaks are called "line guys" or "storm guys" (fig. 4-6).

SIDEWALK GUY.—An anchor guy with a horizontal strut at a height above the sidewalk to clear the pedestrians on the sidewalk is referred to as a "sidewalk guy" (fig. 4-7).

SPAN GUY.—A span, or overhead, guy consists of a guy wire installed from the top of a pole to the top of an adjacent pole to remove the strain from the line conductors. The span, or overhead, guy transfers the strain on a pole to another structure. This may be to another line pole or to a stub pole on which there is no energizer equipment. A span guy is always installed to extend from the strain pole to the same or lower level on the next line pole.

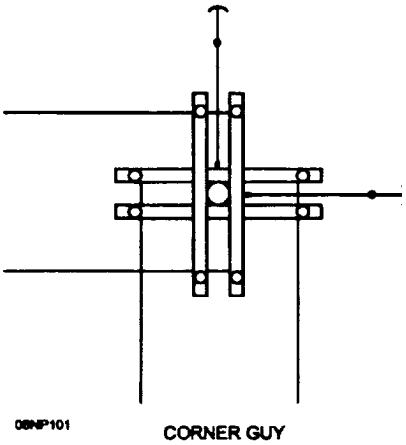


Figure 4-4.—Corner guy.

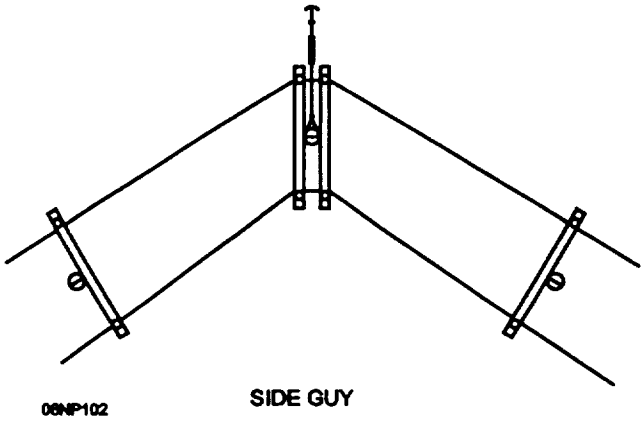


Figure 4-5.—Side guy.

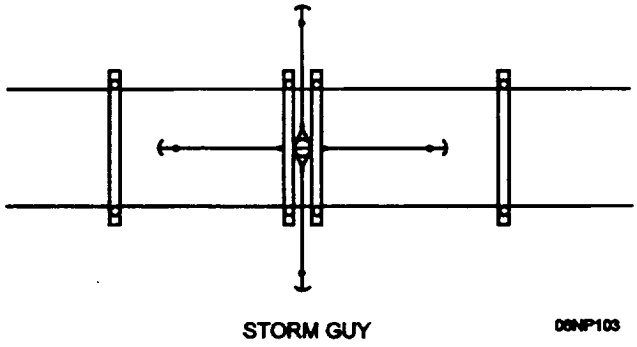


Figure 4-6.—Storm guy.

HEAD GUY.—A guy wire running from the top of a pole to a point below the top of the adjacent pole is

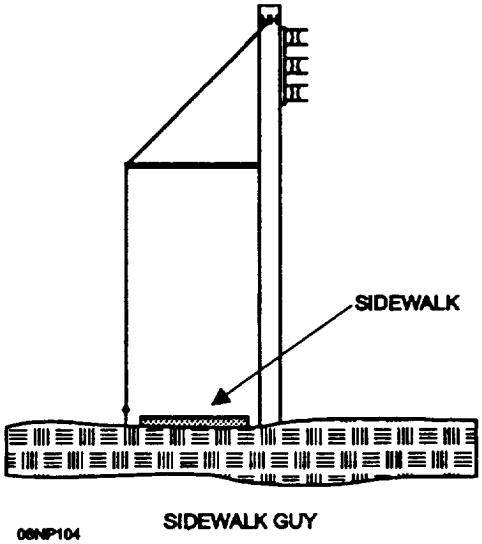


Figure 4-7.—Sidewalk guy.

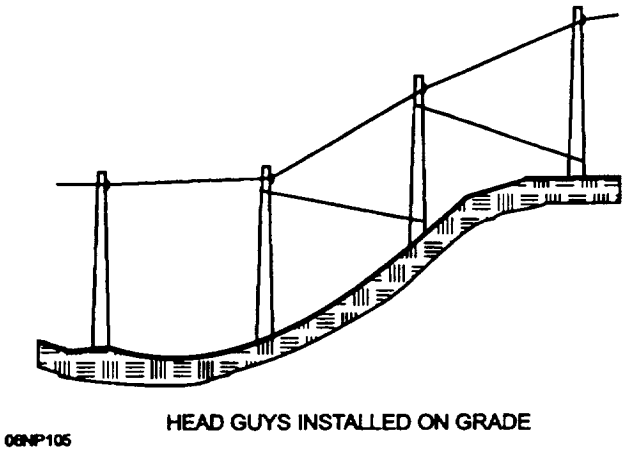


Figure 4-8.—Head guy.

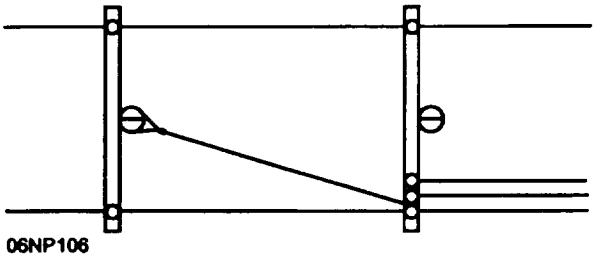


Figure 4-9.—Arm guy.

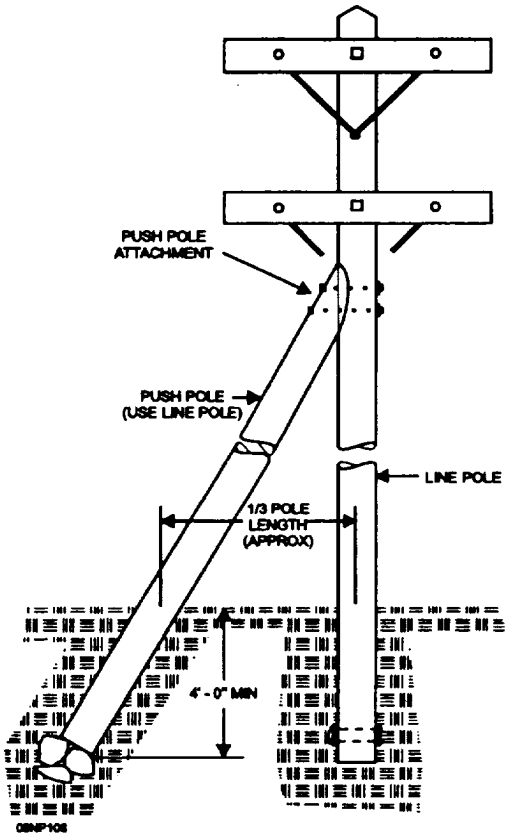


Figure 4-11 .-Push guy.

called a "head guy" (fig. 4-8). Lines on steep hills are normally constructed with head guys to counteract the downhill strain of the line.

ARM GUY.—A guy wire running from one side of a crossarm to the next pole is called an "arm guy." Arm guys are used to counteract the forces on crossarms that have more wires dead-ended on one side than on the other (fig. 4-9).

STUB GUY.—A guy wire installed between a line pole and a stub pole on which there is no energized equipment is called a "stub guy" (fig. 4-10). A down guy is used to secure the stub pole. This type of guy is often installed to obtain adequate clearance for guy wires extending across streets or highways.

PUSH GUY.—A push guy, or a push brace, is used when it is impossible to use down guys (fig. 4-11). When it is impossible to obtain sufficient right-of-way for a pole guy, the push brace can usually be installed. The push guy is constructed from an old power pole and a special bracket called a push brace attachment.

CROSSARMS

A crossarm is a specially treated wooden member that is secured to a pole and used to mount various types

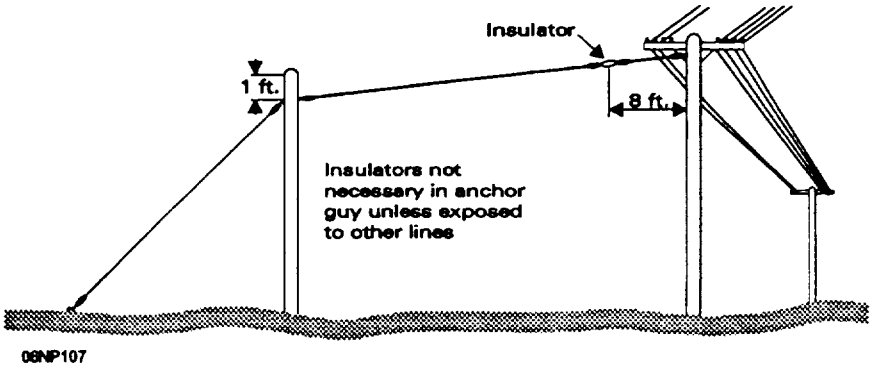


Figure 4-10.—Stub guy.

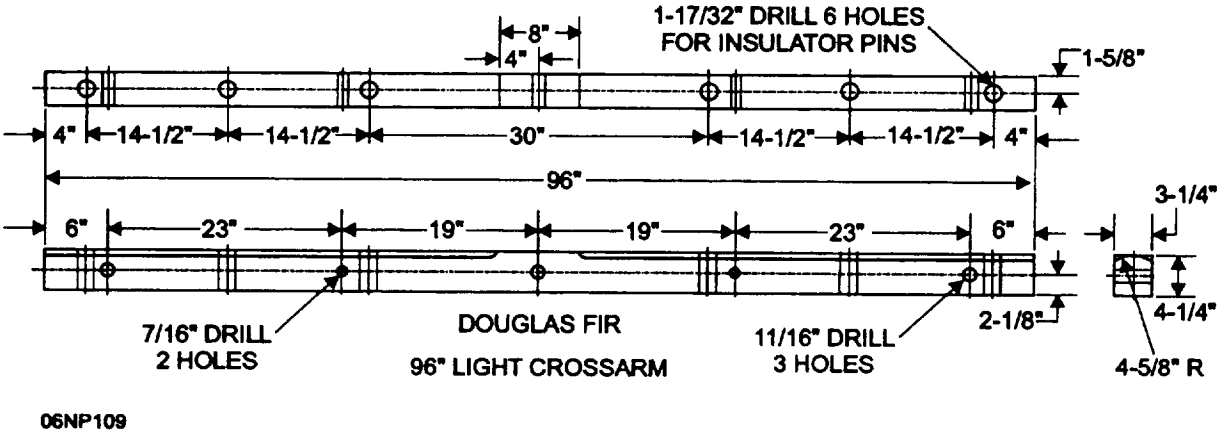


Figure 4-12.—Crossarm.

of circuit protection devices and to support the conductors. The crossarms used in power distribution come in three common sizes; namely, 3 1/4 inches by 4 1/4 inches, 3 1/2 inches by 4 1/2 inches, and 3 3/4 inches by 4 3/4 inches. The spacing for insulators on the crossarms, as shown in figure 4-12, meets the minimum standards for conductors at all distribution voltages used by the Navy. In your naval service you may come across larger wooden crossarms or crossarms made of steel. These crossarms are designed to support increased strain or to use with transmission lines carrying higher voltages.

SINGLE ARMS

Single arms are used on straight lines when no excessive strain needs to be provided (fig. 4-13). When crossarms are installed, every other crossarm faces in the same direction.

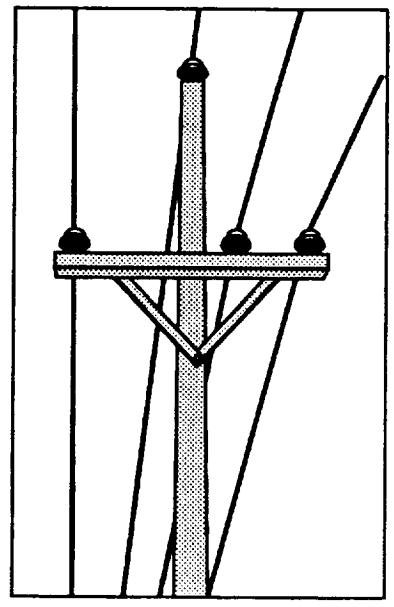


Figure 4-13.—Single-arm construction.

DOUBLE ARMS

A double arm should be used at line terminals, at corners, at angles, or at other points when there is an excessive strain (fig. 4-14). When lines cross telephone circuits or railroad crossings, double arms also should be used, as more than ordinary safety is required at such points. When two or more transformers are mounted on the same pole, double arms, as a rule, are used for their support.

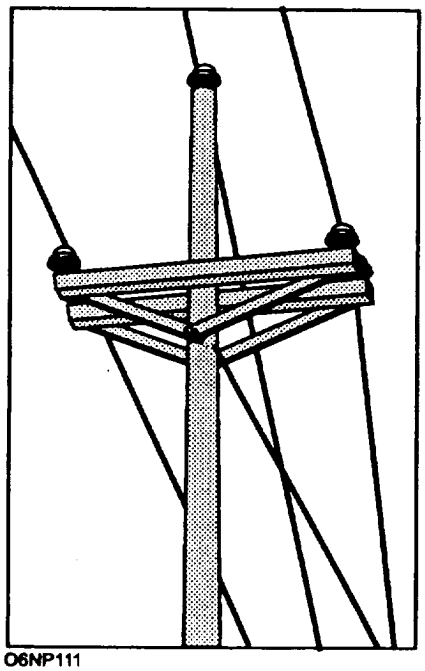


Figure 4-14.—Double-arm construction.

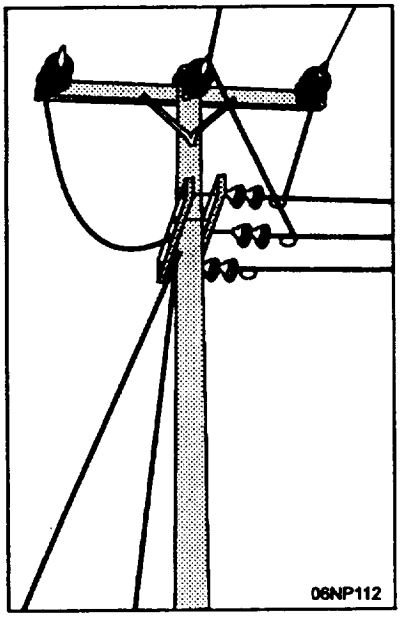


Figure 4-15.—Buck-arm construction.

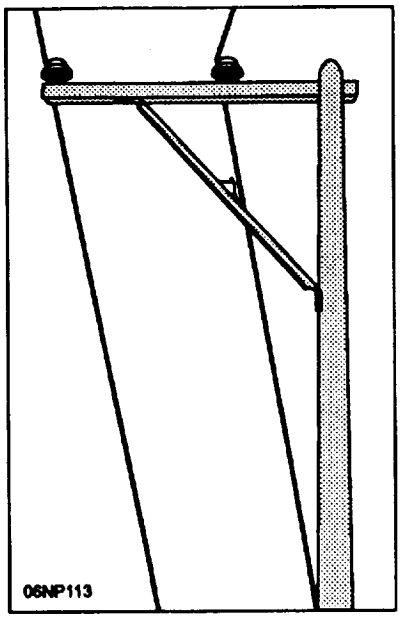


Figure 4-16.—Side-arm construction.

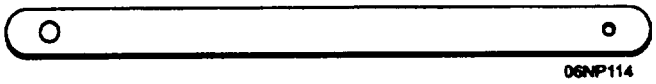


Figure 4-17.—Standard flat-strap crossarm brace.

BUCK ARMS

Buck arms are used at comers and at points when branch circuits are taken off at right angles to the main line (fig. 4-15).

SIDE ARMS

Side arms are used in alleys or other locations when it is necessary to clear buildings. (See fig. 4-16.)

CROSSARM BRACES

Braces are used to give strength and rigidity to the crossarm. Metal crossarm braces are made of either flat bar or light angle iron. The size used varies with the size of the arm and the weight of the conductors. The usual flat-strap brace for ordinary distribution work (fig. 4-17) is 38 inches long and 1/4 by 1 1/4 inches. One end is attached to the crossarm by means of a carriage bolt and the other to the pole by means of a lag screw.

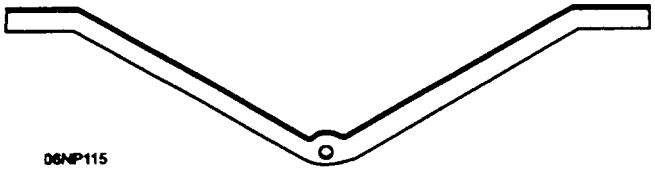


Figure 4-18.—A V-shaped angle-iron crossarm brace.

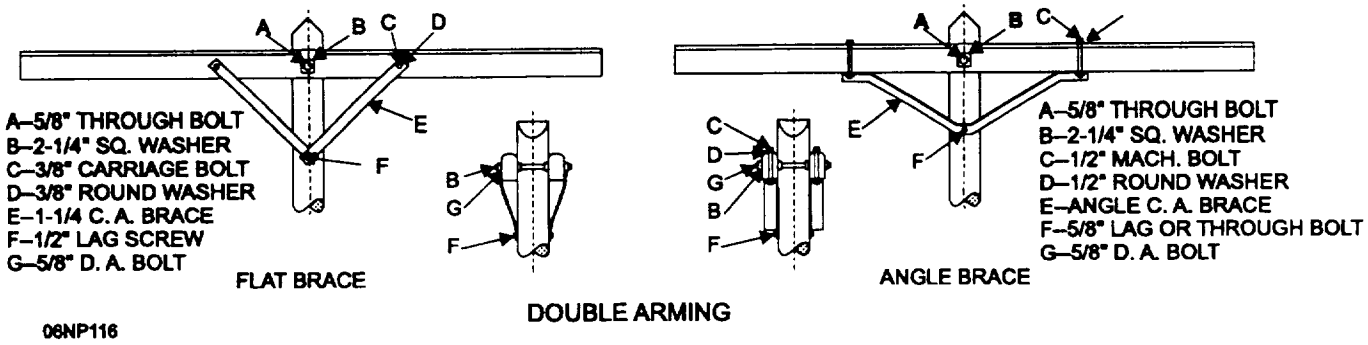


Figure 4-19.—Crossarm brace installation.

One brace extends to each side of the arm. Angle-iron braces are made in one piece and bent into the shape of a V, as shown in figure 4-18. These braces are fitted to the bottom of the crossarm instead of the side as is the flat type. Figure 4-19 gives an example of how these braces are used.

HARDWARE

Line hardware consists of the miscellaneous bolts, nuts, braces, and clamps used to fasten crossarms, guys, and other equipment to the pole. Figure 4-20 shows some samples of common hardware used in power distribution.

INSULATORS

An insulator is a material that prevents the flow of an electric current and can be used to support electrical conductors. The function of an insulator is to separate the line conductors from the pole. Insulators are fabricated from porcelain, glass, and fiber glass, treated with epoxy resins and rubberlike compounds. In determining the size and type you need, you should consider the designed voltage of the circuit, conductor size, length of the pole-line spans, and cost of the various insulators. The most common types of insulators found in Navy use are the pin, post, suspension, and strain insulators.

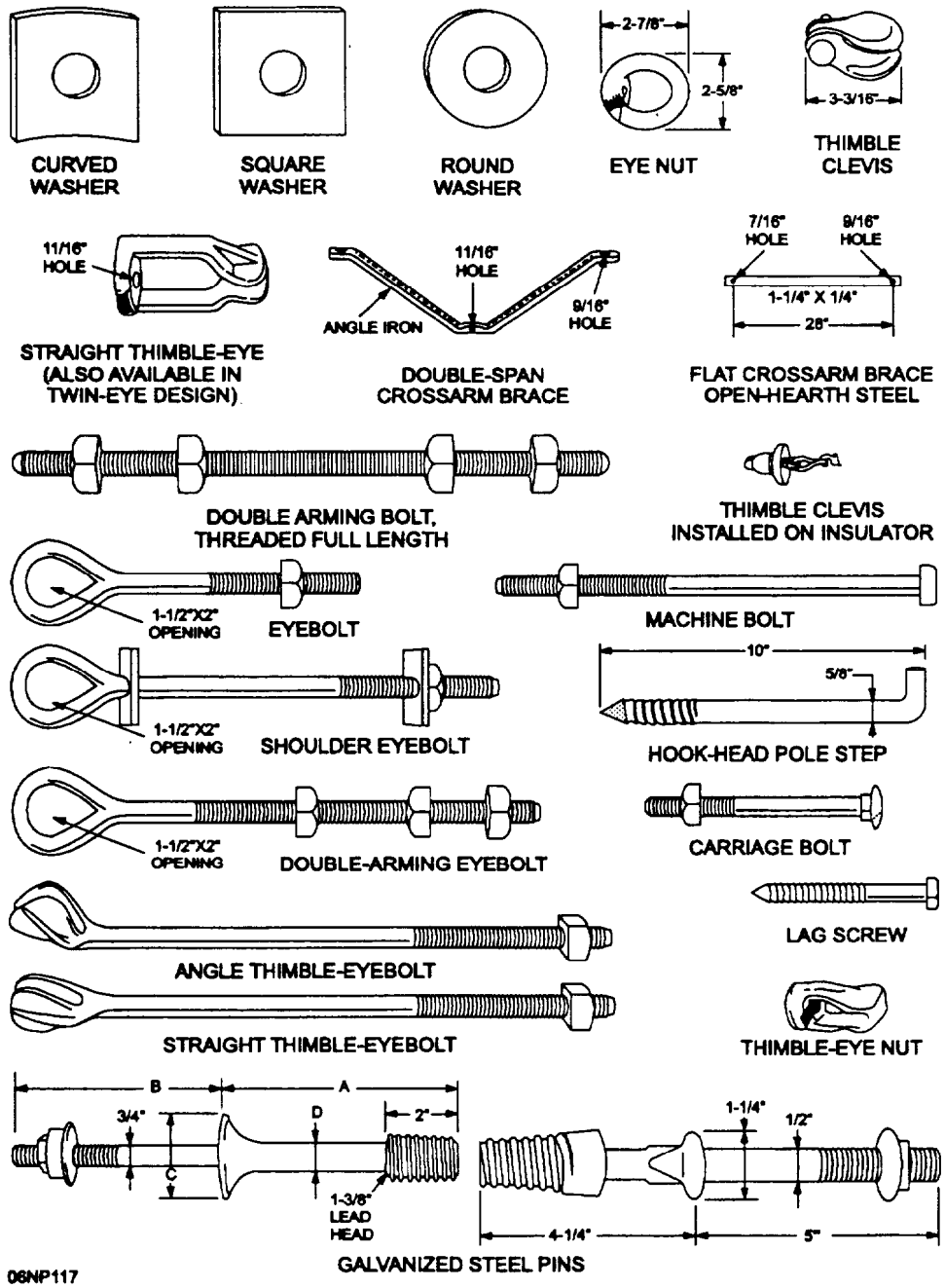


Figure 4-20.—Line hardware.



06NP118
Figure 4-21.—A single-layer porcelain pin insulator.

Pin Insulator

The pin insulator (fig. 4-21) gets its name from the fact that it is supported on a pin. The pin holds the insulator, and the insulator has the conductor tied to it. Pin insulators are made of either glass or porcelain. The glass insulator is always one solid piece. The porcelain insulator is also a one-piece insulator when used with low-voltage lines but will consist of two. three. or four layers cemented together to form a rigid unit when used on higher voltages (fig. 4-22).

Insulator Pins

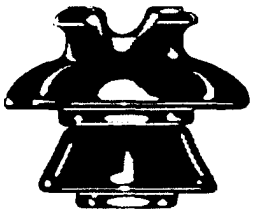
The function of an insulator pin is to hold the insulator mounted on it in a vertical position. Insulator pins are made of wood or metal. Wooden pins are usually made of locust. Locust is durable and retains its strength longer than other woods. Iron and steel pins are used whenever the pins must be extra long, because of high voltage, and whenever the tension on the conductor is great. One make is arranged to encircle the crossarm as a clamp pin—the clamp being held by bolts (fig. 4-23). In many cases. a steel rod is used as the base to permit the use of a 5/8 or a 3/4 hole to be drilled in the crossarm.

Steel pins are in general use. Steel pins have a broad base which rests squarely on the crossarm, as shown in figure 4-24.

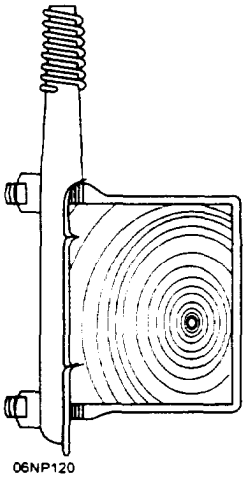
The spacing of the pins is generally suited to the voltage of the circuit. The spacing should provide sufficient working space for the lineman. For general distribution work, the spacing is 14 1/2 inches between centers.

Post-Type Insulators

The post insulators are used on distribution, substation, and transmission lines and are installed on

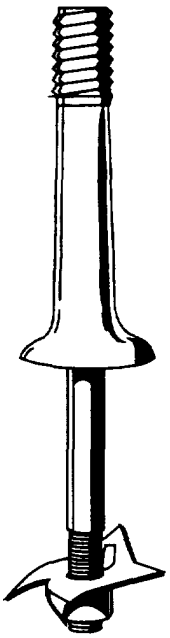


06NP119
Figure 4-22.—A two-layer porcelain pin insulator.

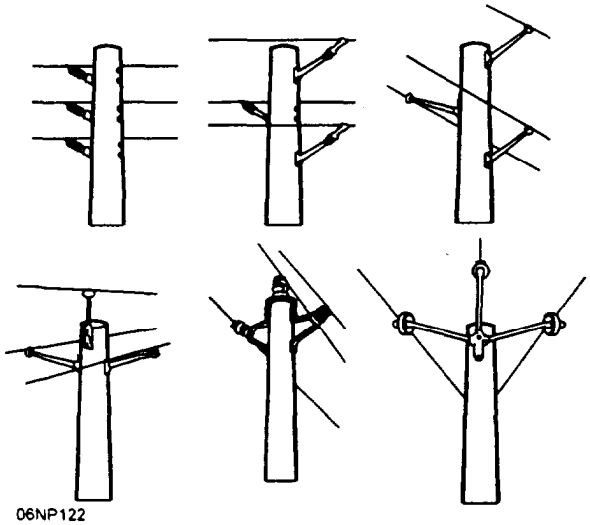


06NP120
Figure 4-23.—Steel clamp pin.

wood, concrete, and steel poles. The line-post insulators are manufactured for vertical or horizontal mounting. The line-post insulators are usually manufactured as one-piece solid porcelain units or fiber glass epoxy-covered rods with metal end fittings and rubber weather sheds. The insulators are fabricated with a mounting base for curved or flat surfaces, and the top is designed for tying the conductor to the insulator or fitted with a clamp designed to hold the conductor. Line-post insulators designed for vertical mounting are mounted on crossarms. This type of construction is often used for long span rural distribution circuits. Figure 4-25 showsdistribution circuits constructed with porcelain horizontal line-post insulators. This armless construction, using post insulators, permits the construction of subtransmission and transmission lines on narrow rights-of-way and along city streets.

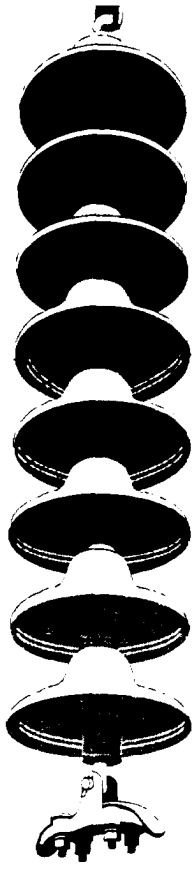


06NP121
Figure 4-24.—Steel pin.



06NP122

Figure 4-25.—Post insulators for armless construction.



06NP123

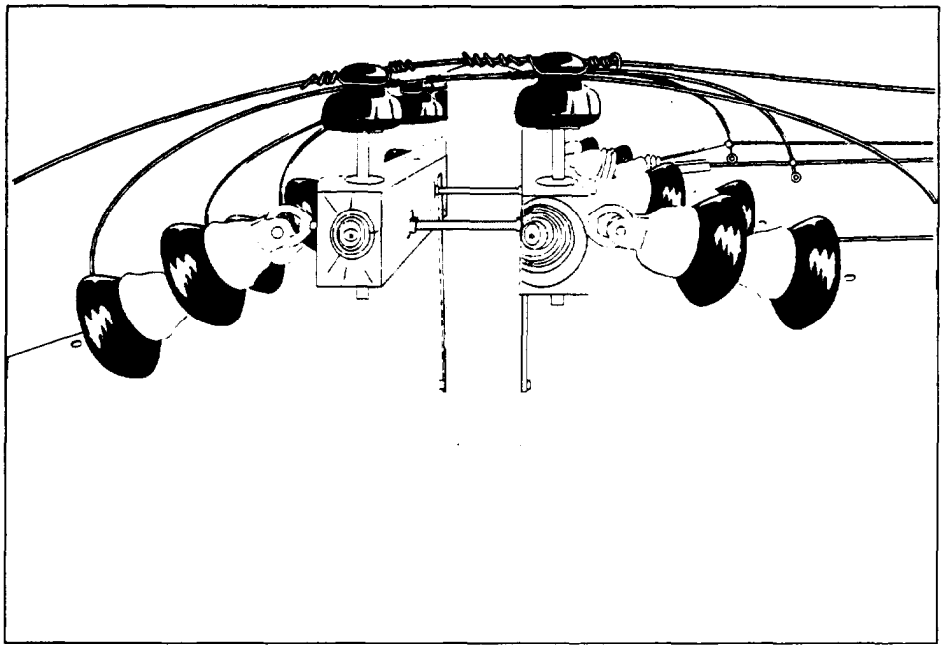
Figure 4-26.—Suspension insulator.

Suspension Insulator

In figure 4-26 you see the common suspension insulator. The suspension insulator, as its name implies, is suspended from the crossarm and has the line conductor fastened to the lower end. It is designed for ease of linking units together. Linking of these insulators gives you the versatility of ordering one insulator to be used with varying voltages.

Strain Insulator

The strain insulator looks exactly like the suspension insulator but is designed to hold much heavier physical loads. Strain insulators are used when a pull must be carried as well as insulation provided. Such places occur whenever a line is dead-ended, at comers, at sharp curves, at extra long spans, at river crossings, or in mountainous country. In such places the insulator must not only be a good insulator electrically but it also must have sufficient mechanical strength to counterbalance the forces due to tension of the line conductors. (See fig. 4-27.)



06NP124

Figure 4-27.—Strain insulator.

CONDUCTORS

The wires and cables over which electrical energy is transmitted are made of copper, aluminum, steel, or a combination of copper and steel or aluminum and steel. A conductor is a material that readily permits the flow of an electric current. Materials, other than those mentioned, that conduct electricity are not generally used to make wires and cables because of economic or physical reasons.

Copper Conductors

Copper is the most commonly used line conductor. It conducts electrical current very readily, ranking next to silver. It is very plentiful in nature, it can be easily spliced, and its cost is comparatively low. Three kinds of copper wire are in use: hard-drawn copper, medium-hard-drawn copper, and annealed copper, also called "soft drawn."

For overhead line purposes, hard-drawn copper wire is preferable on account of its greater strength. Medium-hard-drawn copper can be used for distribution lines usually for wire sizes smaller than No. 2.

Aluminum Conductors

Aluminum is widely used for distribution and transmission line conductors. Its conductivity, however, is only about two thirds that of copper. Compared with a copper wire of the same physical size, aluminum wire has 60 percent of the conductivity, 45 percent of the tensile strength, and 33 percent of the weight. The aluminum wire must be 100/60 = 1.66 times as large as the copper wire in cross section to have the same conductivity. When an aluminum conductor is stranded, the central strand is often made of steel that serves to reinforce the cable. Such reinforcement gives added strength for the weight of conductor. Reinforced aluminum cable called ACSR (aluminum-conductor steel-reinforced) is especially suited for long spans.

Copperweld Steel Conductors

In this type of conductor, a protective copper coating is securely welded to the outside of the steel wire. The copper acts as a protective coating to the steel wire, thus giving the conductor the same life as if it were made of solid copper. At the same time, the layer of copper greatly increases the conductivity of the steel conductor, while the steel gives it greater strength. This combination produces a satisfactory yet inexpensive line conductor. Its chief field of application is for rural lines, for guy wires, and for overhead ground wires.

The conductivity of copper-weld conductors can be raised to any desired percentage, depending on the thickness of the copper layer. The usual values of conductivity of wires as manufactured are 30 and 40 percent.

Classes of Conductors

Conductors are classified as solid or stranded. A solid conductor is a single conductor of solid circular section. A stranded conductor is composed of a group of small conductors in common contact. A stranded conductor is used when the solid conductor is too large and not flexible enough to be handled readily. Large solid conductors are also easily damaged by bending. The need for mechanical flexibility usually determines whether a solid or a stranded conductor is used, and the degree of flexibility is a function of the total number of strands. The strands in the stranded conductor are usually arranged in concentric layers about a central core. The smallest number of wires in a stranded conductor is three. The next number of strands are 7, 19, 37, 61, 91, 127, and so forth. Both copper and aluminum conductors may be stranded.

Conductor Sizes

Conductor sizes are ordinarily expressed by two different numbering methods: the American Wire Gauge (AWG) and the circular mil. The AWG conductor sizes are numbered from 30 to 1, then continuing with 0, 00, 000, and 0000 (or 1/0, 2/0, 3/0, and 4/0, respectively). Number 30 is the smallest size and 4/0 the largest in this system. As an example of the actual physical size of the conductors commonly used in transmission and distribution work, refer to figure 4-28.

The circular mil is the unit customarily used in designating the cross-sectional area of wires. A "circular mil" is defined as the area of a circle having a diameter of 1/1000 of an inch. The circular mils of cross section in a wire are obtained by squaring the diameter expressed as thousandths of an inch. For example, a wire with a diameter of 0.102 inches (102 thousandths of an inch) has a circular mils cross section of 102 x 102 = 10,404. Conductors larger than 4/0 AWG are designated in circular mils. These range from 250,000 to 2,000,000 circular mils (250 MCM or 2,000 MCM).

DISTRIBUTION SYSTEMS

A power distribution system is a system that delivers the energy from the generators or transmission lines to the customer. In the Seabees you will be mainly

Gage number	Diameter, in.	Full size, side view	Full size, end view
8	0.1285		
7	0.1443		
6	0.162		
5	0.1819		
4	0.2043		
3	0.2294		
2	0.2576		
1	0.2893		
0	0.3249		
00	0.3648		
000	0.4096		
0000	0.460		

06NP125

Figure 4-28.—American wire sizes for bare copper.

concerned with the construction, maintenance, and repair of the distribution system. Depending on the system, it will consist of a combination of the following components, substations, distribution transformers, distribution lines, secondary circuits, secondary service drops, and safety and switching equipment. The distribution system may be underground, overhead, or a combination of the two.

DISTRIBUTION SUBSTATIONS

Distribution substations change the transmission or generator voltage to a lower level, providing voltage sources for the distribution circuits supplying power to the customers.

DISTRIBUTION TRANSFORMERS

Distribution transformers are installed in the vicinity of each customer to reduce the voltage of the distribution circuit to a usable voltage, usually 120/240 volts.

DISTRIBUTION CIRCUITS

Distribution circuits (primary main circuits) are circuits that originate from the distribution substation. Primary mains are circuits carrying over 600 volts, but generally they operate between 2,400 and 34,500 volts. Primaries can be found in single-phase or three-phase configurations and generally operate as three-phase, three-wire or three-phase, four-wire circuits. Two types of primary circuits are in use today. One, the delta type (A) system, (fig. 4-29) is used when most of the load in

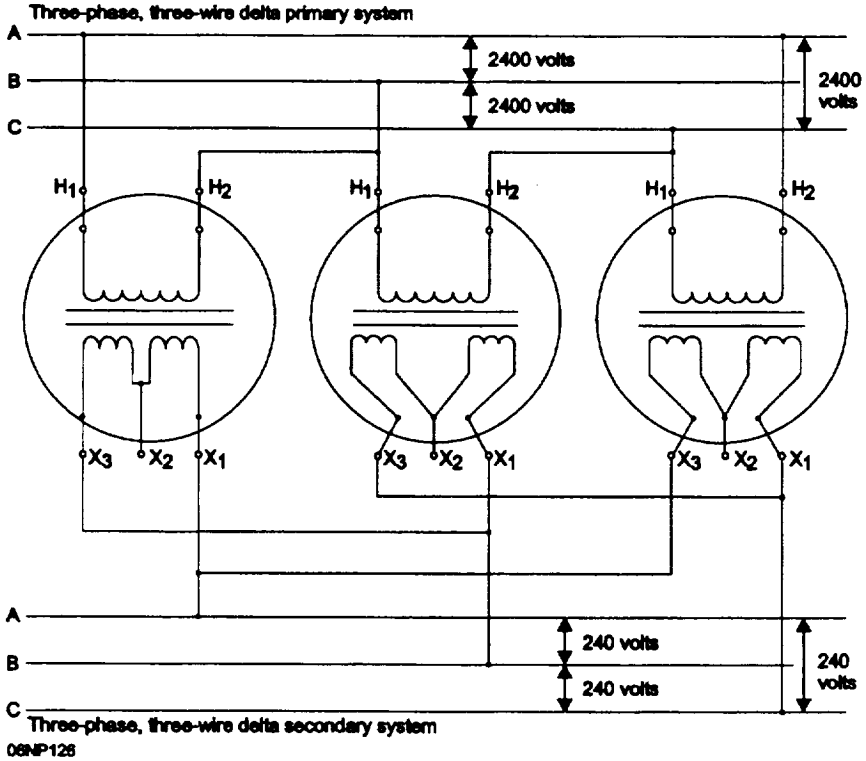


Figure 4-29.—Three-phase delta (A) primary and secondary system.

an area is commercial, consisting of motors and other three-phase equipment. The other type of circuit is called the wye (Y) system (fig. 4-30) and is used primarily for residential use.

SECONDARY CIRCUITS

Secondary circuits (secondary mains) are circuits that originate from the secondary windings of a distribution transformer and are 600 Vac or less. The secondary circuits are also configured either delta (A) (fig. 4-29) or wye (Y) (fig. 4-30) and are also used for the same type of loading as the primary circuits.

Secondary circuits are either three phase—meaning those with three live conductors—or single phase, which can be one live conductor and a neutral or two live conductors and a neutral.

SERVICE DROPS

A service drop is the combined conductors used to provide an electrical connection between a secondary distribution circuit and a user's facility. There are different ways of installing the service drop. Some typical secondary racks used to install service drops are shown in figure 4-31. Whether using the racks with individual conductors or self-supporting service cable, known as triplex or quadraplex, to provide a service drop, you must maintain a minimum aboveground distance. Aclearance of 12 feet over lawns or walkways accessible to pedestrians and 18 feet over roads or alleyways subject to truck traffic as recommended by the NEC©, as shown in figure 4-32. When the nearest distribution pole is over 125 feet from the facility to be connected, an intermediate support pole must be provided.

CONTROL AND PROTECTIVE DEVICES

A power distribution circuit, like any other electrical circuit, requires the use of special devices to provide control and to protect the system from internal or external influences that may damage the circuit.

DISTRIBUTION CUTOUTS

A distribution cutout provides a high-voltage mounting for the fuse element used to protect the distribution system or the equipment connected to it.

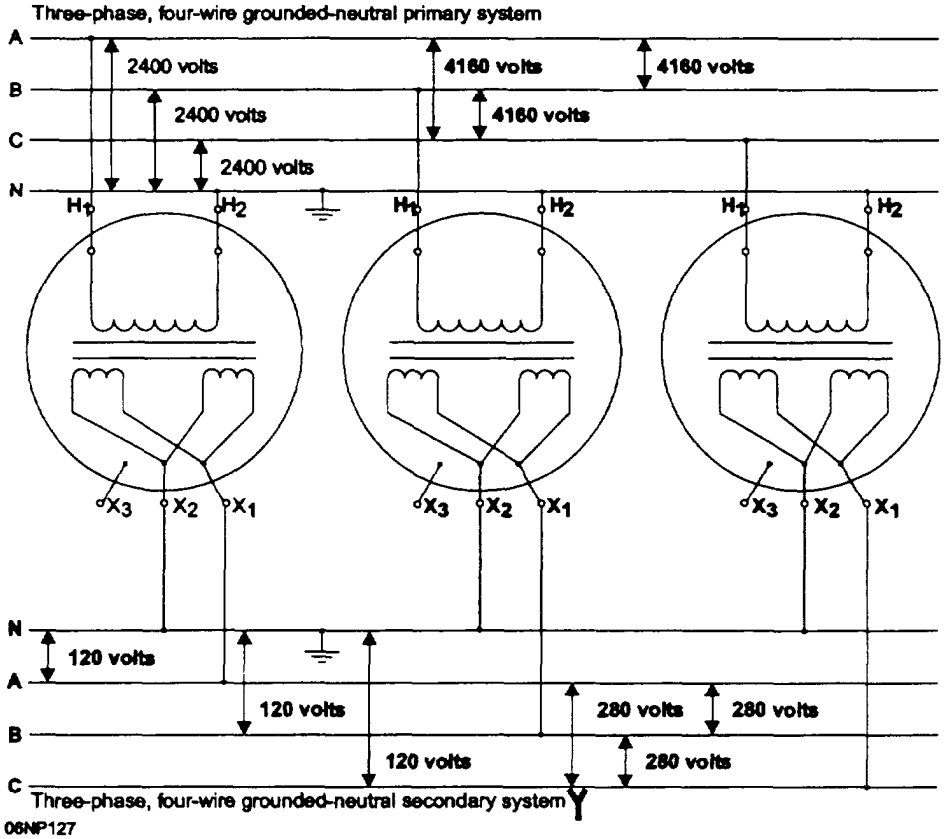


Figure 4-30.—Three-phase wye (Y) primary and secondary system.

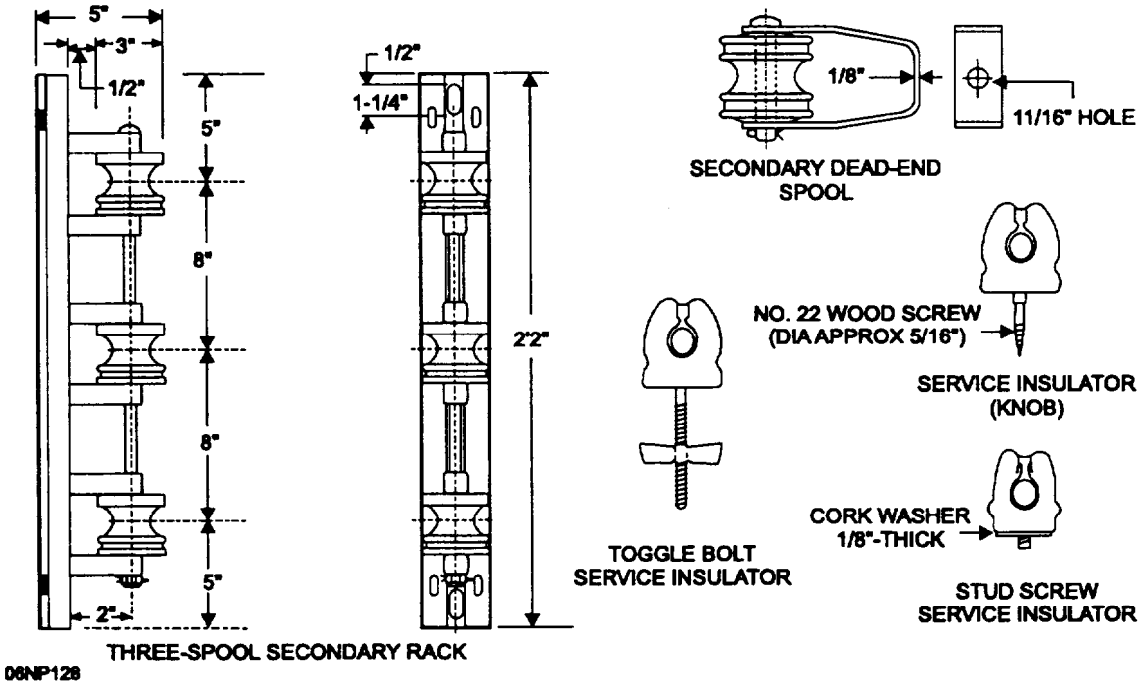


Figure 4-31.—Secondary racks and dead-end spools.

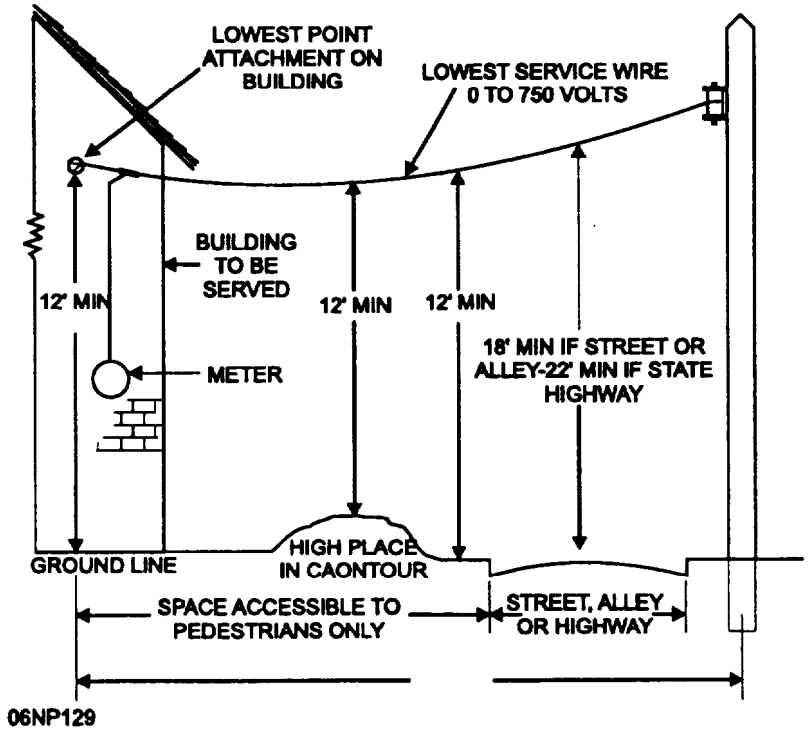


Figure 4-32.—Minimum ground clearances of service drops

Figure 4-33 shows an open types of distribution cutout being closed. Distribution cutouts are used with installations of transformers, capacitors, cable circuits, and sectionalizing points on overhead circuits.

Enclosed Distribution Cutout

An enclosed distribution fuse cutout is one in which the fuse clips and fuse holder are mounted completely within an enclosure (fig. 4-34, view A). A typical enclosed cutout has a porcelain housing and a hinged door supporting the fuse holder. The fuse holder is a hollow vulcanized-fiber expulsion tube. The fuse link is placed inside the tube and connects with the upper and lower line terminals when the door is closed. When the fuse blows or melts because of excessive current passing through it, the resultant arc attacks the walls of the fiber tube, producing a gas that blows out the arc. The melting of the fusible element of some cutouts causes the door to drop open, signaling to the lineman that the fuse has blown.

Open-link Distribution Cutout

This type of cutout differs from the open cutout in that it does not use the fiber expulsion tube (fig. 4-34, view B). The fuse link is supported by spring terminal contacts. An arc-confining tube surrounds the fusible element of the link. During fault clearing, the spring contacts provide link separation and arc stretching. The arc-confining tube is incorporated as part of the fuse link.

Open Distribution Cutout

Open cutouts are similar to the enclosed types, except that the housing is omitted (fig. 4-34, view C). The open type is made for 100- or 200-amp operation. Some cutouts can be up rated from 100 to 200 amps by using a fuse tube rated for 200-amp operation.

Lightning Arresters

Lightning arresters are designed to permit normal circuit operations at designed voltages, yet conduct any potentially destructive higher voltage, such as lightning

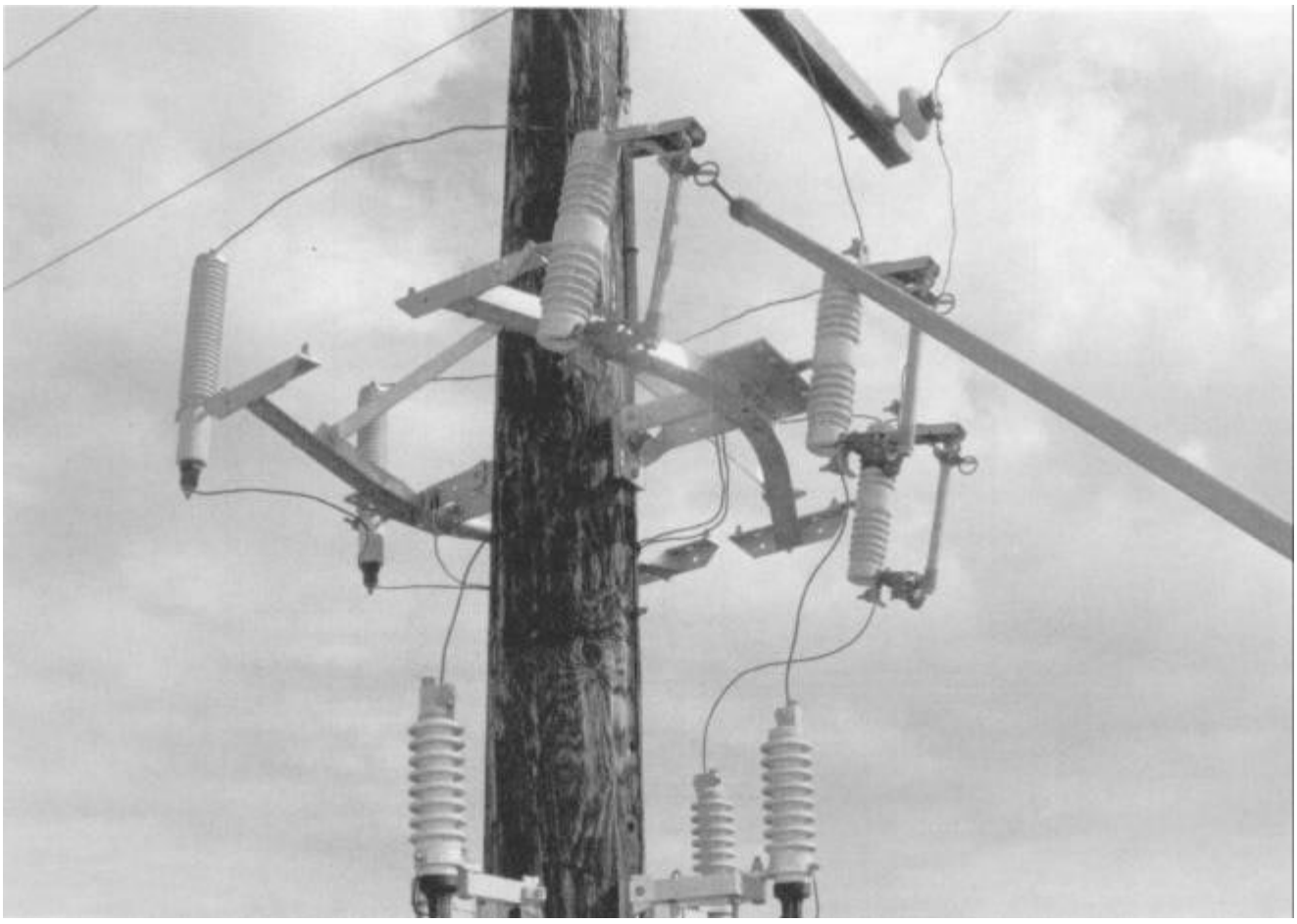
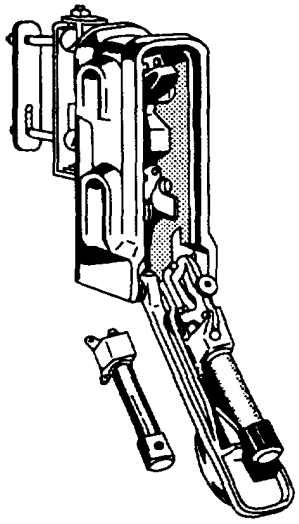
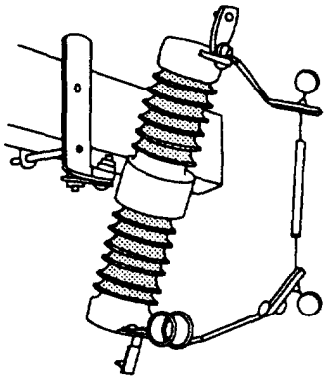


Figure 4-33.—Distribution cutout.

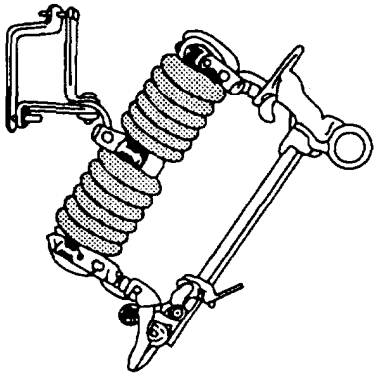
produces or transient currents, to ground without injury to line insulators, transformers, or other connected equipment. Use of lightning arresters is essential in all areas of power line construction. These include distribution, secondary, intermediate, and station distribution. The four different specifications of arresters, mentioned above, have different sparkover voltages, current discharge capabilities, and maximum surge discharge capabilities.



A. ENCLOSED CUTOUT



B. OPEN-LINK CUTOUT



C. OPEN CUTOUT

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Figure 4-34.—Distribution cutouts (fused).

Secondary arresters are used on service and other low-voltage alternating-current circuits. Distribution arresters are used on primary distribution systems to protect insulators, distribution transformers, and other equipment. Intermediate type of lightning arresters are often used on substation exit cables and other locations on the distribution system, needing a high level of lightning and surge protection. Substation types of arresters are used in substations and generating stations to provide a high level of surge protection for the major pieces of equipment. Surge voltages can be generated by operating switches in the electric transmission system as well as by lightning.

Various types of lightning arresters are in use today. The valve, pellet, and air gap (fig. 4-35) are the most common and likely-to-be-seen types in the field.

SWITCHES

A switch is used to disconnect or close circuits that may be energized. High-voltage switches are operated remotely using a variety of mechanisms or manually. Depending on their purpose in the system and their physical makeup, switches are divided into three general classes: air, oil, and vacuum switches. These three classes can be further subdivided (depending on their function) into what is referred to as disconnects, circuit breakers, or reclosers.

Air Switches

As their name implies, air switches are switches whose contacts are opened and use air to insulate their contacts when current flow is interrupted.

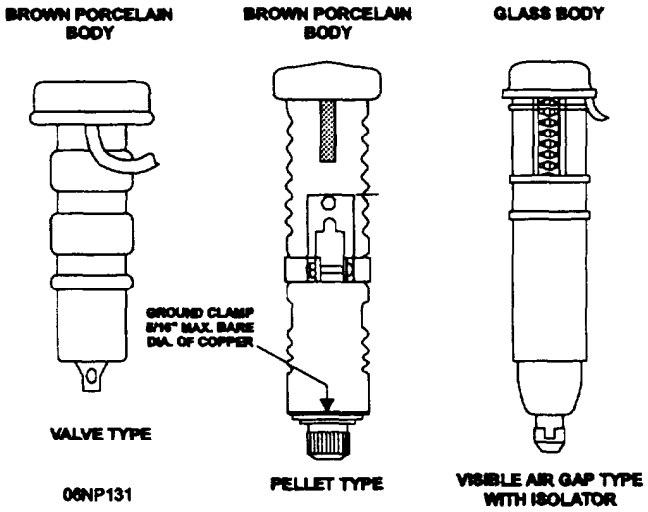


Figure 4-35.—Types of lightning arresters.

An **air-circuit breaker switch** can have both blade and stationary contacts equipped with arcing horns (fig. 4-36). These horns are pieces of metal between which the arc forms when a circuit-carrying current is opened. These arc horns are drawn further and further apart until the arc finally breaks. Air-break switches are usually mounted on substation structures or on poles and are operated manually from the ground. In a three-phase circuit all three switches—one for each phase—are opened and closed together.

An **air-disconnect switch** is not equipped with arcing horns or other load-break devices. It therefore cannot be opened while current is flowing (fig. 4-37). If the disconnect switch should be opened while current is flowing in the line, an arc would likely be drawn between the blade and its stationary contacts. The hot arc would melt part of the metal, thereby damaging the switch. The purpose of a disconnect switch is to isolate a line or a piece of equipment for the purpose of making the disconnected line or equipment dead electrically, thus making it safe for repairs, tests, or inspections.

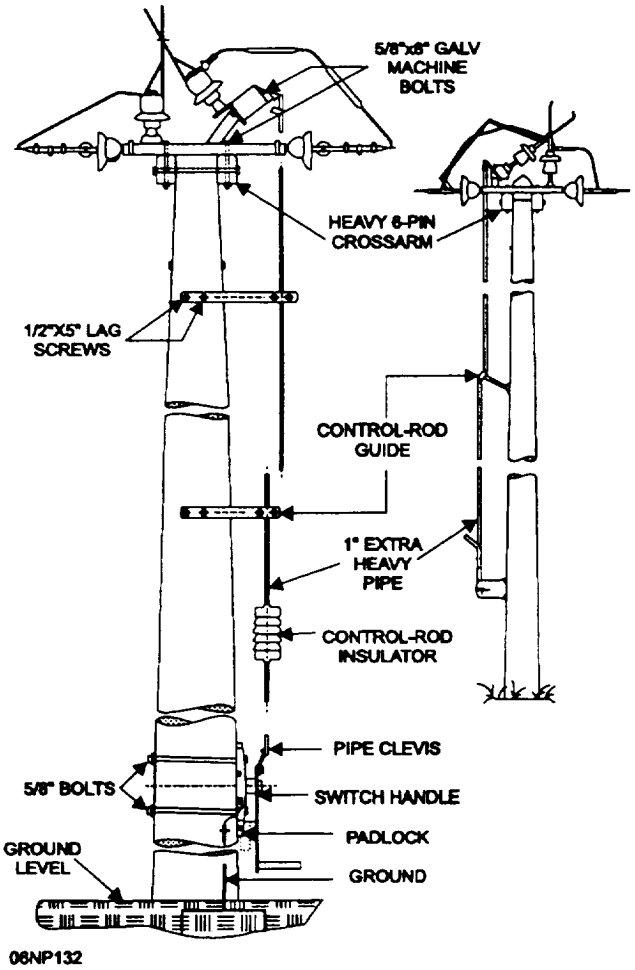


Figure 4-36.—Gang-operated air-circuit breaker.

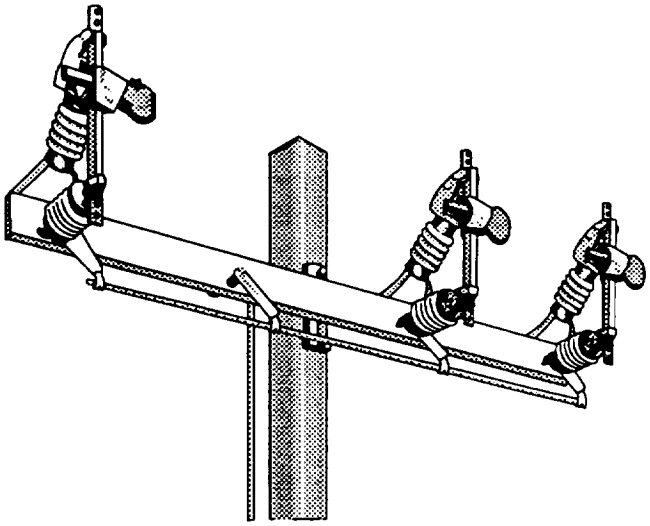


Figure 4-37.—Air-disconnect switch.

Oil Switches

An oil switch is a high-voltage switch whose contacts are opened and closed in oil. Oil switches may be used as disconnect, circuit breakers, or reclosers. The switch is actually immersed in an oil bath, contained in a steel tank, as shown in figure 4-38. The reason for placing high-voltage switches in oil is that the oil may help to break the circuit when the switch is opened. With high voltages, a separation of the switch contacts does not always break the current flow, because an electric arc forms between the contacts. If the contacts are opened in oil, however, the oil helps to quench the arc. Oil is an insulator and, therefore, helps to quench the arc between the contacts. The three lines of a three-phase circuit can be opened and closed by a single oil switch. If the voltage is not extremely high, the three poles of the switch are generally in the same tank. But if the voltage of the line is high, the three poles of the switch are placed in separate containers.

Circuit Reclosers

The circuit reclosers most commonly used in power distribution are electronic reclosers, oil reclosers, or vacuum reclosers. These reclosers basically operate in the same manner.

Reclosers come in single- or three-phase models and can either be pole-mounted or installed in a substation. These reclosers are for overload protection and are designed to open a circuit in an overload condition and then automatically reclose the circuit. If the fault on the system has cleared, the recloser remains closed. If the fault has not cleared, the recloser trips

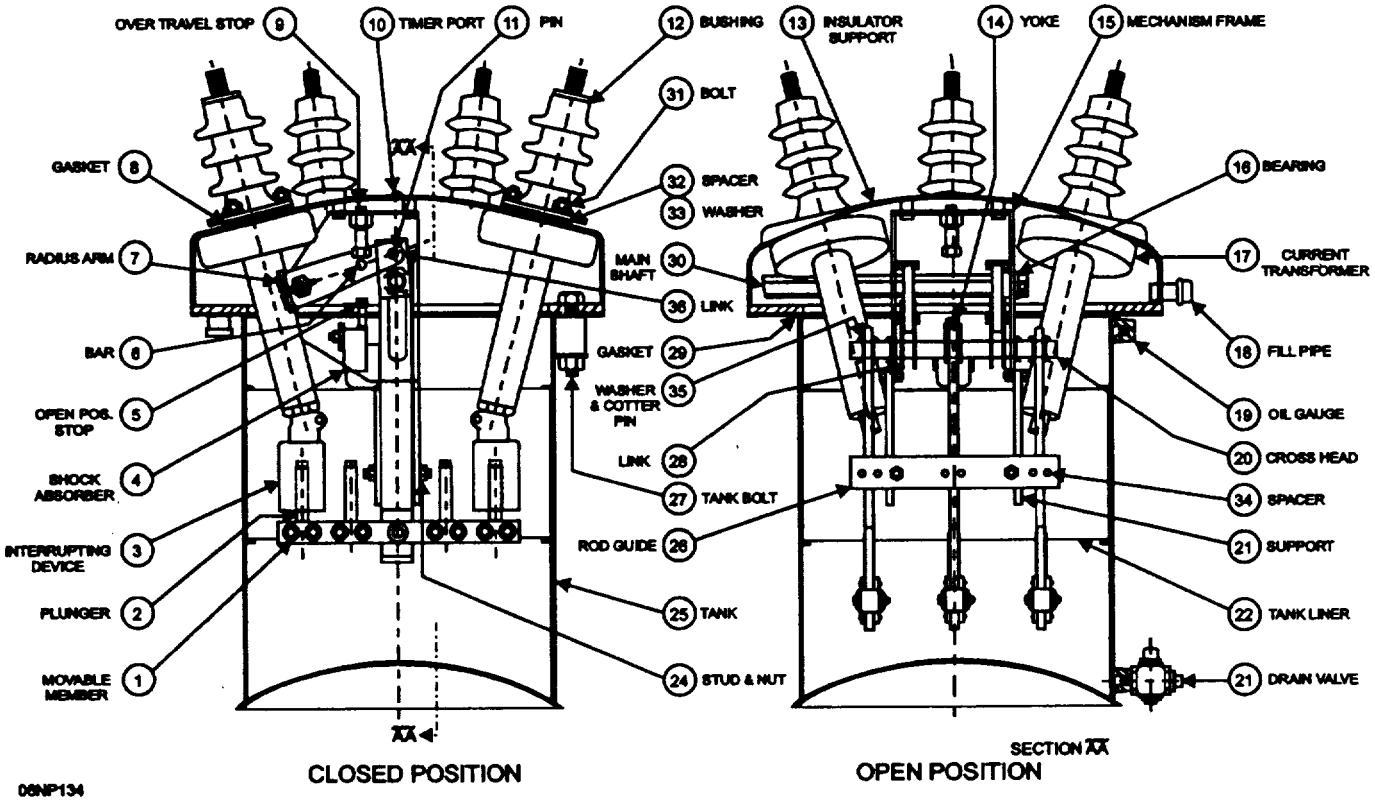


Figure 4-38.—Internal and external components of an oil circuit breaker.

again, and after a short interval, recloses the system for the second time. If the fault has not cleared on the third time, the system will open and stay open. The recloser also has a manual lever or electronic control to set the recloser on what is commonly referred to as "single-shot" action. When linemen are working in the general area of a circuit, they place the recloser in the single-shot mode. Then should a mistake be made, causing the circuit to trip, it will not reset itself automatically.

POWER DISTRIBUTION EQUIPMENT

The equipment most commonly used for construction and maintenance of Navy power distribution systems consists of the utility truck, aerial bucket truck, earth auger, pole trailer, wire trailer, and various manual lifting devices.

UTILITY TRUCK

The utility truck is a specially designed piece of equipment that, used effectively, provides the lineman with transportation, tool and material storage, and the capability to accomplish most tasks safely, efficiently, and quickly.

AERIAL BUCKET TRUCK

The aerial bucket truck comes in various shapes and sizes. It is used at most naval installations or battalions for maintenance or construction of the power distribution system. The aerial bucket truck provides the power lineman with an efficient, comfortable, and safe working platform and is especially useful in areas where concrete or steel poles are used.

The aerial bucket truck has storage bins for material and tools. Depending on the make of the vehicle and the desired use, the truck may have a telescoping single- or double-arm boom, it may be equipped with hydraulic outrigger jacks for stability, and the bucket may be powered by the truck engine or an auxiliary engine mounted on the back of the truck. Because of the various designs of bucket trucks, each one will have some capabilities that are not common to all. When using an aerial bucket truck, you should follow the manufacturer’s operation, maintenance, and testing procedures at all times. This promotes smooth

operation and extends the usable life of the vehicle. When you are operating the bucket, safety of operation should be your prime concern. Although the bucket is insulated, all personnel should maintain a constant awareness of the hazards of operating in and around high-voltage power lines.

EARTH AUGER

Another high-production piece of line equipment is the earth auger. This truck-mounted unit, as shown in figure 4-39, is designed to dig holes up to 7 feet deep and comes with different sizes of auger bits to enable you to vary the diameter of the hole. The auger truck usually has a winch attached that enables it to be used to set poles and other attachments that allow it to install some types of guying anchors. These features are normally used when a framing crew is assigned with the auger truck. They install all line hardware on the pole before they set it in place (except when the hardware is too heavy) and place the anchors. This method is used when long power lines are being constructed. It requires less pole time for the linemen and enables them to devote more time to stringing conductors, installing the line equipment, and making connections on the poles.

MANUAL LIFTING EQUIPMENT

There are many different types of manual lifting equipment used in line work. Some of the various types and uses of manual lifting equipment are discussed in the paragraphs below.

Pole Gin

The pole gin, as shown in figure 4-40, is designed for temporary attachment to a pole. It provides a secure point for attaching other lifting equipment, such as a block and tackle used in lifting heavy objects, for mounting on the pole. Transformers, capacitors, regulators, heavy lighting fixtures, and heavy crossarms are a few examples of the types of equipment that may be lifted by using the pole gin.

When you are lifting a distribution transformer, it should be handled carefully. Bushings and other equipment on the transformer can be damaged easily. The windings of the transformer may be damaged if the



Figure 4-39.—Earth auger.

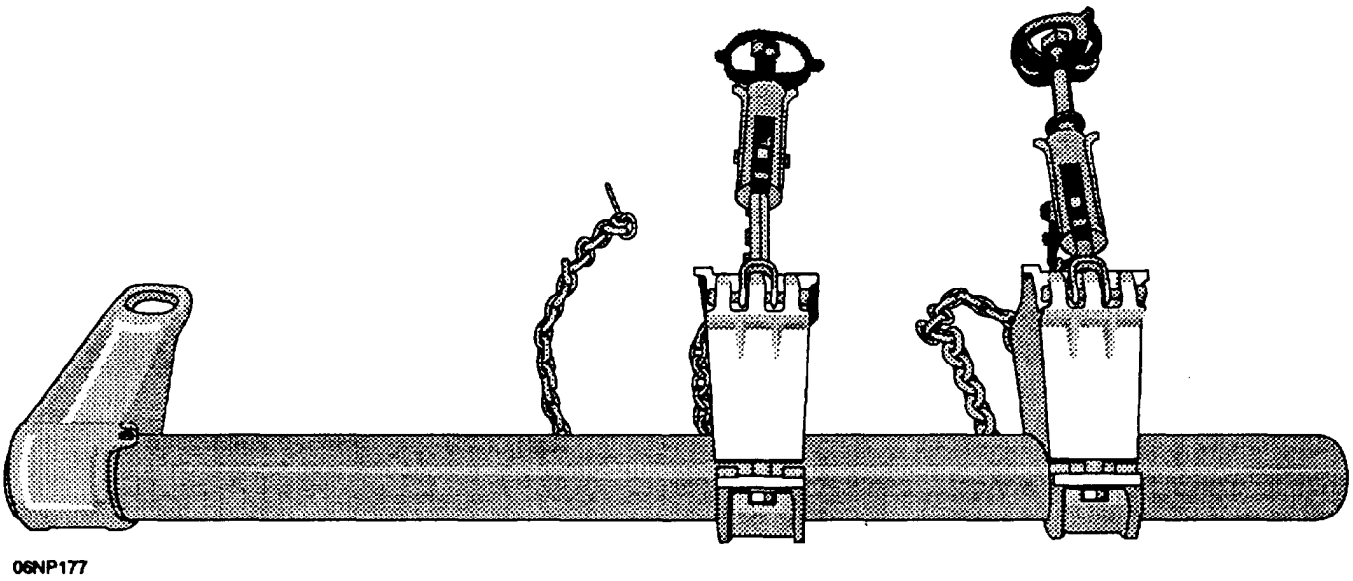


Figure 4-40.—Pole gin.

transformer is dropped or severely jolted. The lifting equipment, including the slings, should be carefully inspected before the operation is started. The linemen and groundmen should stay clear, while the transformer is raised into position. Appropriate personal protective equipment must be worn at all times.

Block and Tackle

Block and tackle are used for applying tension to line conductors when sagging in, for applying tension to guy wires when hoisting transformers, and for other general-purpose hoisting. The use of block and tackle has two advantages: (1) the user can stand on the ground and pull downward while hoisting or lifting a load and (2) the manual force applied need only be a fractional part of the load lifted.

To find the pull required to lift a given weight with a block and tackle, divide the weight by the number of ropes running from the movable block. The lead line, or haul line, is not to be counted. Some friction loss always occurs around the sheaves. This can be estimated at 10 percent per sheave and added to the load to be lifted. The load that may be lifted is therefore the mechanical advantage times the safe load on the rope. Safe lifting load requirements for rope can be found in chapter 3. The block and tackle, as shown in figure 4-41, is called a four part block and tackle because it has four times the mechanical advantage for lifting an object. Again this is determined by the number of ropes (four), not counting the hauling line running from the movable block.

Lifting Straps and Slings

Whether lifting with the block and tackle or a winch, you will also need lifting straps or slings to secure the equipment being lifted to the lifting apparatus.

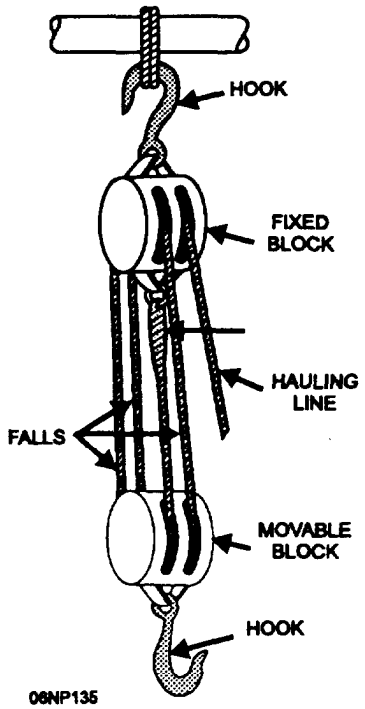


Figure 4-41.—Block and tackle.

Figure 4-42 shows examples of a lifting strap and a chain. For a detailed explanation of uses, strengths, and various types of lifting straps and slings, refer back to chapter 3.

Snatch Block

A snatch block (fig. 4-43) is a single sheave block made so that the shell opens on the side at the base of the hook to permit a rope or line to be slipped over a sheave without threading the end of it through the block. Snatch blocks ordinarily are used when it is necessary to change the direction of the pull on a line.

Handline

While working on a power pole, every lineman should carry a handline. It can be used for lifting or lowering smaller objects and also for holding transformers and other equipment away from the pole as it is being raised. The handline is usually made of 1/2-inch manila rope, approximately 30 to 35 feet long, and has a manufactured or self-made metal hook attached to one end. The handline is personal equipment and can be configured to best suit the individual or the job to be accomplished.

Pulley Line

The pulley line, as shown in figure 4-44, is another lifting tool and is used to replace the handline when large quantities of material must be lifted to the top of the pole. When the pulley line is used in this way, the lineman can continue working, while the materials are being supplied by the groundman.

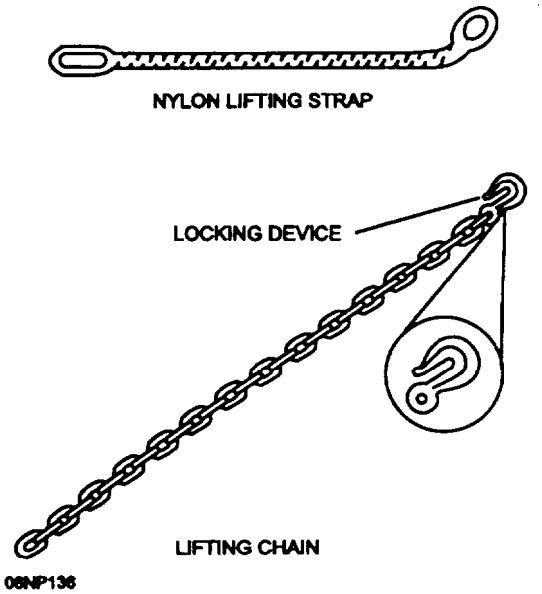


Figure 4-42.—Lifting strap and chain.

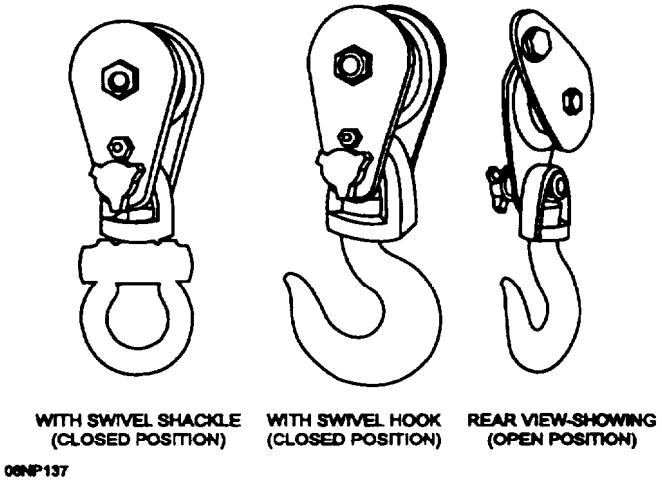


Figure 4-43.—Top dead-end snatch block.

Pole Jack

Another manual lifting device is the pole jack, as shown in figure 4-45. It is designed for easy attachment and removal from the pole and provides an unpowered mechanical lift that is used to straighten or remove power poles.

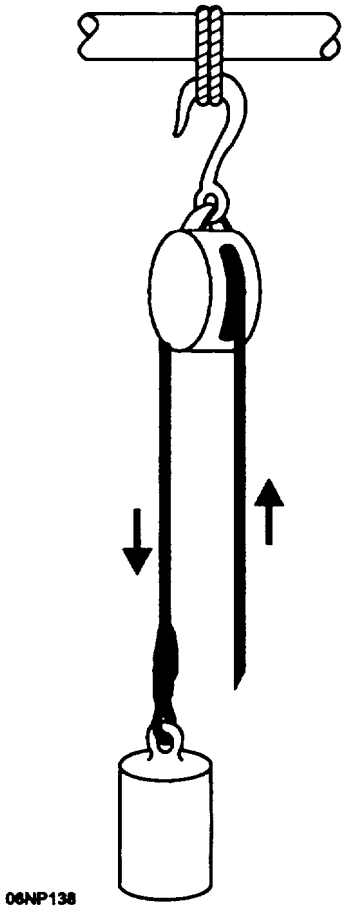


Figure 4-44.—Pulley line.

Come-along

The come-along, a pulling tool, is normally used for dead-ending line conductors or installing guy wires (fig. 4-46). It is designed with a ratchet action that can be used to pull or release strain by placing the forward or reverse lever in the desired setting.

Grips

The wire grips, as shown in figure 4-47, view A, are engineered to grip the wire and hold it when pulling or slow release is desired. It is used in the sagging operation and also in applying strain to the guy wire during installation. Different designs of wire grips are used, and you should ensure that you have the right one before you attempt to pull with them.

A grip that is similar to the wire grip is called the bulldog grip. This grip, as shown in figure 4-47, view B, is made for pulling large objects, such as ground rods. When pulling conductors, do not use this grip; it will cause damage that cannot be repaired.

SETTING POLES AND INSTALLING HARDWARE AND CONDUCTORS

Constructing a pole line involves such functions as framing; setting poles; and installing crossarms, hardware, and conductors. The paragraphs that follow will cover these elements of work and give you a better understanding of how the construction is accomplished.

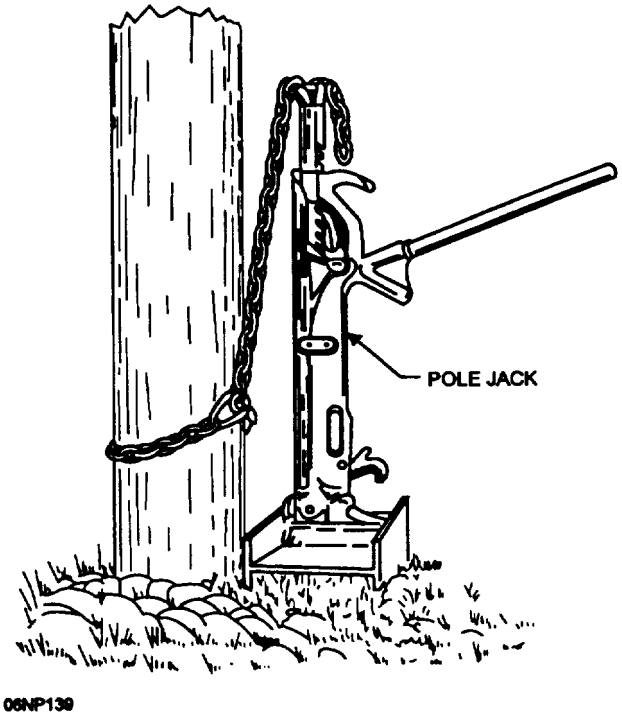


Figure 4-45.—Pole jack.

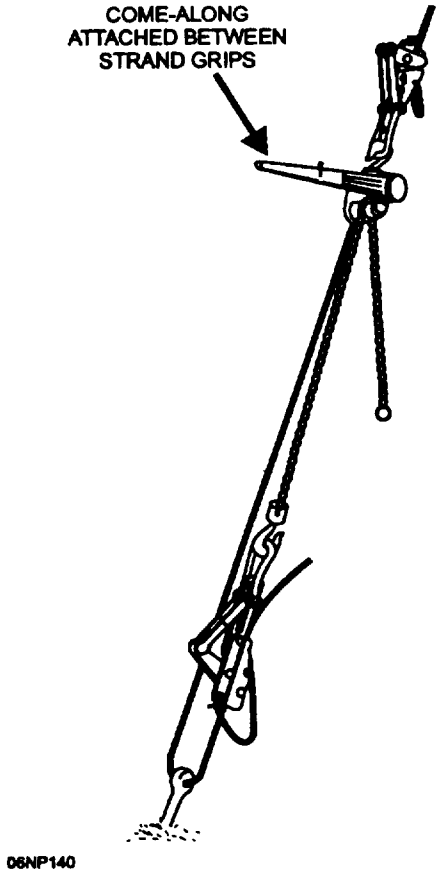


Figure 4-46.—Come-along.

FRAMING POLES

Framing a pole consists of the following actions: determining the face and back of the pole, cutting the roof and gain, and drilling holes for mounting hardware.

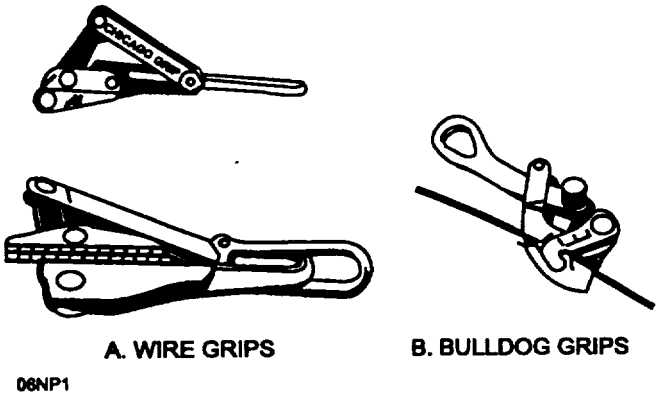


Figure 4-47.—Grips.

Figure 4-48 shows that the face of any pole is on the inside of any curve the pole may have. This allows the wire strain on the crossarm to be against the curve of the pole. This also dictates positioning of the gain on the face of the pole, except for gains on comer poles, when lower crossarms are mounted at a 90-degree angle to the main distribution line.

The roof or top of the pole (fig. 4-48) is cut sloping at a 15-degree angle from the face to the back of the pole; however, on the new pressure-treated poles, roofs are not required.

A gain should be one-half inch deep in the center, slightly concave, and located 12 inches from the top of the pole. The width of the gain should be the height of the crossarm to be used. Spacing of succeeding gains depends on the voltage of the lines to be placed on that level. This information is contained in the project specifications and drawings for any new work for which you are tasked.

To drill holes for mounting crossarms, use a template that can be used to mark the center, or draw two diagonal pencil lines across the gain. The intersection of these two lines determines the center of the gain and the place to drill the hole. The nominal size hole is 1 1/16 inch for a 5/8-inch through bolt.

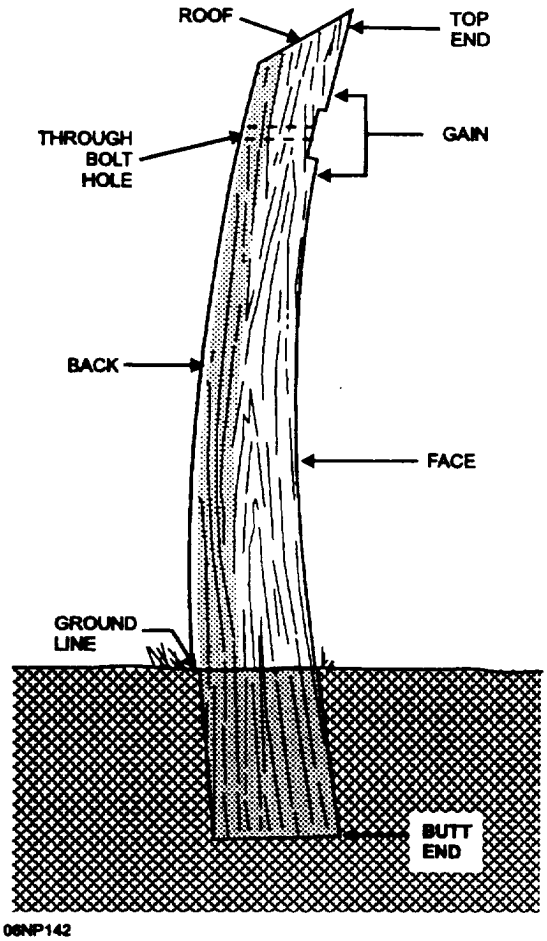


Figure 4-48.—The parts of a pole.

INSTALLING POLES

The depth for a pole hole depends on the length of the pole and the composition of the soil. A hole in firm, rocky terrain does not need to be as deep as a hole in soft soil. Table 4-1 gives recommended depths for poles from 20 to 60 feet long in firm soil and in rock.

A pole set in sandy or swampy soil must be supported by guys or braces, or by cribbing. "Cribbing" means placing some firm material around the part of the pole that is below the ground. One method of cribbing is to sink an open-bottom barrel in the hole, set up the pole in the barrel, and then fill the space around the base of the pole with concrete or small stones after the pole has been plumbed (brought to the vertical). Another method of cribbing is shown in figure 4-49.

There may be a power-driven hole digger available, but in the absence of one of these, the holes must be dug by hand tools (fig. 4-50). You use a "digging bar" to loosen the soil. You can remove about the first 2 feet of depth with a short-handled shovel. Below that, you loosen the earth with an earth auger or long-handled shovel, and haul it up with a long-handled device, called a spoon.

A hole should have a diameter about 6 inches larger than that of the base of the pole to allow room for tamping backfill. It should be a little larger at the bottom to allow for plumbing the pole.

ERECTING POLES

When a earth auger is available, the job of erecting poles is relatively simple. A sling is placed around the approximate midpoint of the pole, and the winch heaves it up, and it is held in place by a pole claw (fig. 4-51).

Table 4-1.—Depth for Setting Poles in Soil or Rock

LENGTH OF POLE (ft)	SETTlNG DEPTH (ft)	
	IN SOIL	IN ROCK
20	5.0	3.0
25	5.5	3.5
30	5.5	4.0
35	6.0	4.0
40	6.0	4.0
45	6.5	4.5
50	7.0	4.5
55	7.5	5.0
60	6.0	5.0

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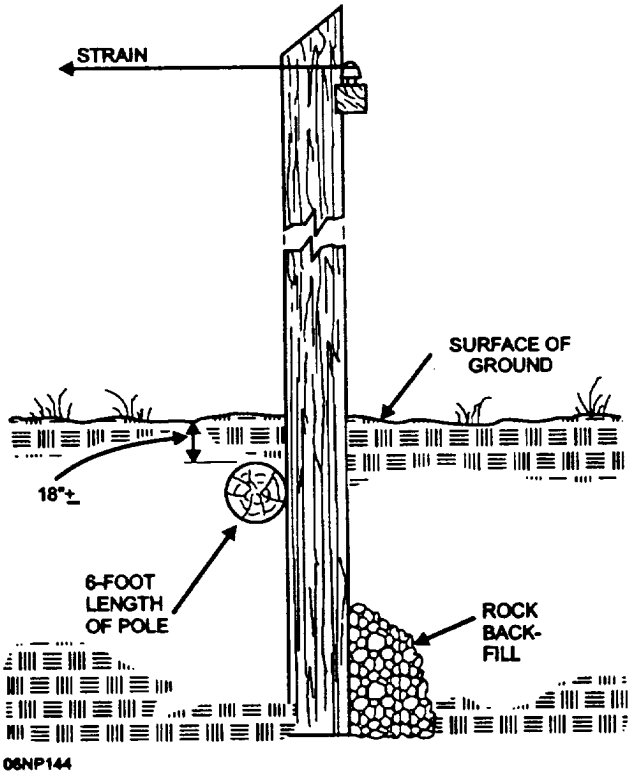


Figure 4-49.—Cribbing a pole with stones and a log.

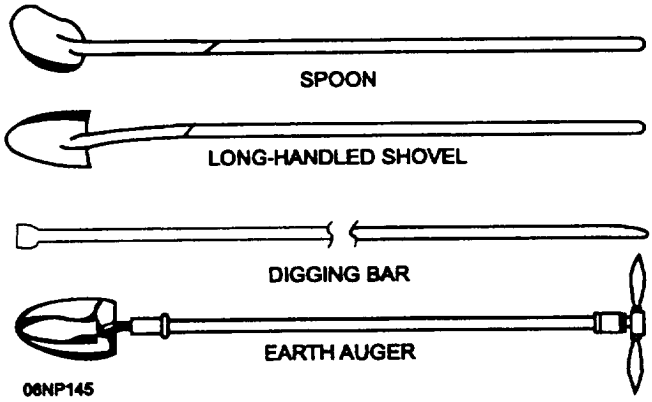


Figure 4-50.—Digging tools.

The truck then proceeds to the hole or is pre-positioned at the hole site, and the base of the pole is guided in as the winch lowers away (fig. 4-52). Since the butt, or base, is heavier than the top end, the pole is raised to an almost vertical position.

In the absence of this equipment, the pole must be "piked up"—meaning that the pole is placed with the base adjacent to the hole and the upper end supported on either a "mule" or a "jenny." A jenny is a wooden support made in the form of an X, and a mule is a wooden support made in the form of a Y. The upper end



Figure 4-51.—Pole positioning before being set.

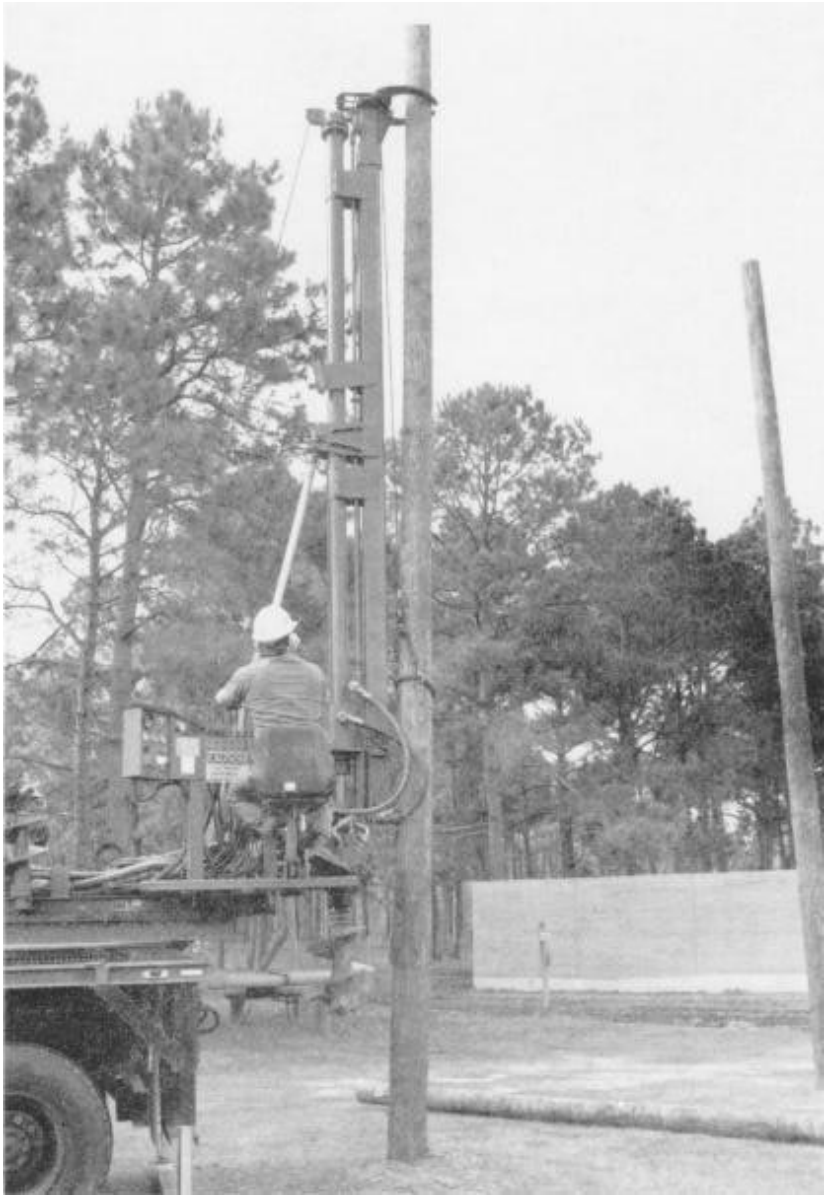


Figure 4-52.—Auger truck setting a pole.

is then "piked" into the air by crew members using pike poles. A cant hook (peavy), pike pole, and pole support (mule) are shown in figure 4-53. Figure 4-54 shows the proper way to position a pole manually for erection.

The procedure for piking up a pole is shown in figure 4-55. The "butt man" holds and guides the butt of the pole with a cant hook (or peavy) (fig. 4-53). This is a handle with a hook designed to grasp the pole when pressure is applied to the handle. As the upper end of the pole is raised, a crew member keeps the jenny or mule in approximate contact by moving it toward the butt. The "butt board" is a length of plank set in the hole and long enough to protrude above the surface. It prevents the

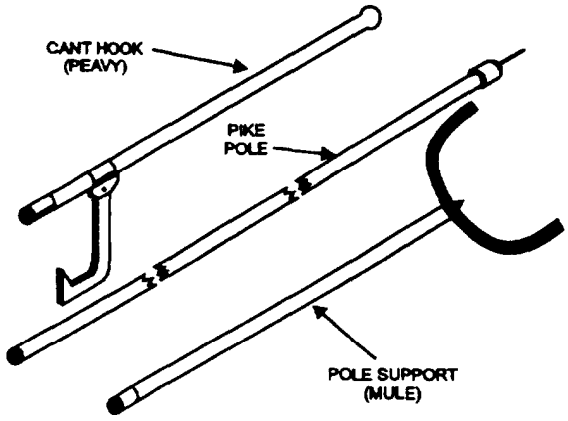


Figure 4-53.—Pole tools.



Figure 4-54.—Manually positioning a pole.

butt of the pole from sliding past the hole and also prevents the butt from caving in the side of the hole. After the pole has reached an upright position, it is "faced"—meaning that it is rotated with the cant hook to bring the crossarm gain to proper position. On a straight line it is the custom to set adjacent poles with crossarms

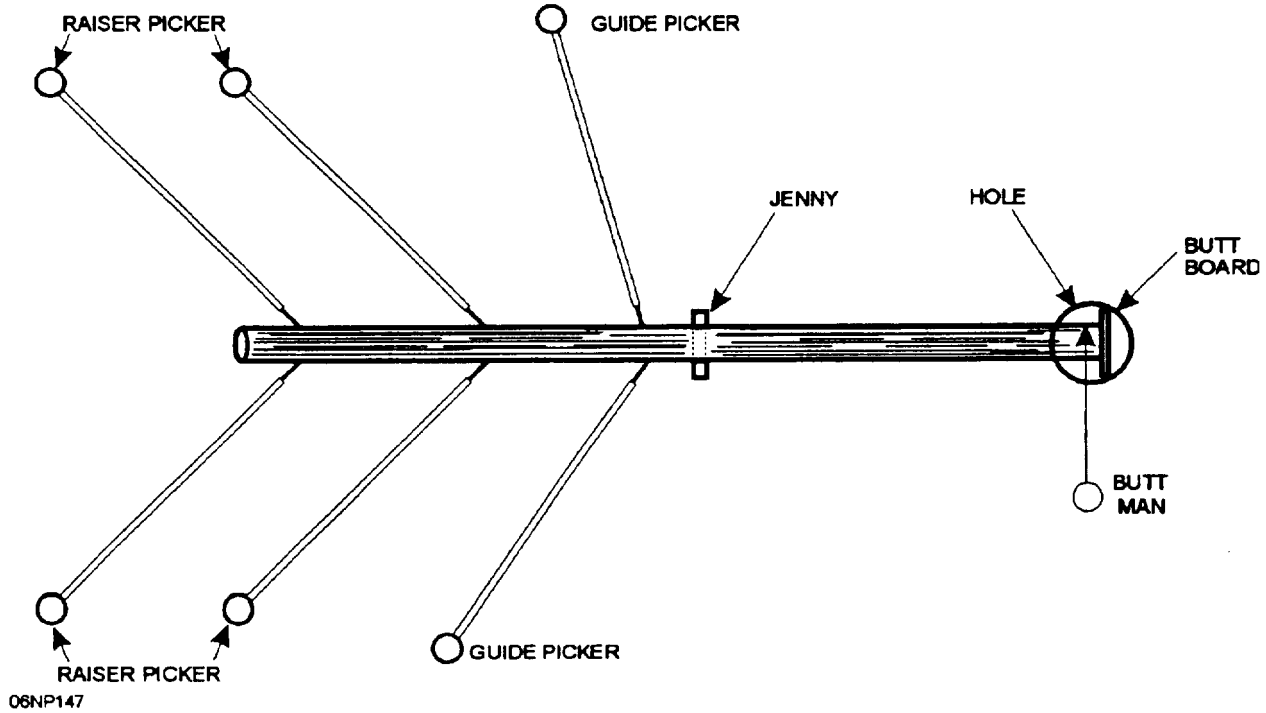


Figure 4-55.—Piking up a pole.

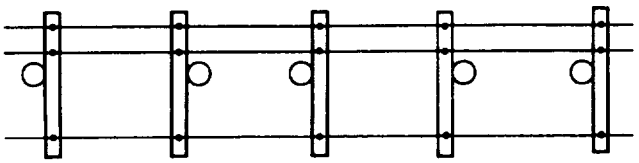


Figure 4-56.—Poles facing in a straight line.

facing in opposite directions, as shown in figure 4-56. This procedure, called facing "gain to gain" or "back to back," provides for maximum strength in the line.

Poles are always faced in the direction of hills, curves, and dead ends, as shown in figure 4-57. This is done to allow the most strain to be placed on the face and against the curve of the poles.

After the pole has been faced, it must be plumbed vertical. This is done by four pikers on four sides of the pole, acting on signals given by one crew member who sights along the line and another who sights from one side. In some cases, a small amount of rake or lean (approximately 12 inches) is left to allow for a wire strain or the normal give of a guy.

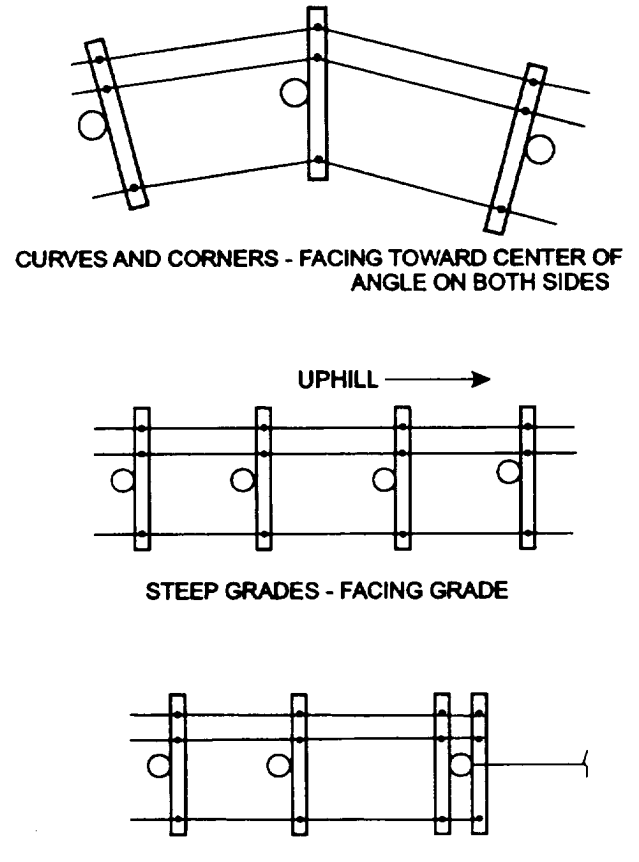


Figure 4-57.—Pole facing.

After the pole has been plumbed, the hole is backfilled and the backfill tamped down firmly. Backfilling is done gradually, in shallow layers, with each layer thoroughly tamped down. Usually two or three crew members tamp, and one shovels. When the hole has been filled to the ground line with tamped backfill, the remaining excavated soil is banked in a mound around the base of the pole to allow for subsequent settling (fig. 4-58).

WARNING

As a pole is being raised, it is safest to assume that at any moment something may slip or break Stand as far away from the pole as possible if you are not in the raising crew.

The pike-pole method of setting poles should not be used unless there are enough crew members to do the work safely. In using pikes the crew must stand far enough apart so that they will not interfere with each other. Never brace a pike pole on your stomach. If the pole should happen to shift your way, you would not be able to get clear. Unmanned pikes alone should not be relied upon to support a pole, while a crew member is on it. Pike-pole tops should be kept covered at all times except when actually in use.

Crew members should not be on poles, while they are being plumbed, canted, or tamped.

INSTALLING GUYS

Guys are assembled using seven-strand galvanized steel guy wire, a strain insulator (of a different design from and not to be confused with the strain insulator used for dead ending a conductor), and three bolt clamps or preformed guy grips. The dimensioning of the guy is determined by the height of the pole, by the amount of strain to be counteracted, and by the climate when the guy is installed. Figure 4-59 shows a typical guy and the method of attaching the come-along for tensioning the guy.

INSTALLING CROSSARMS

As previously discussed in this chapter, crossarms come in various sizes and types, depending on the type of system, size and number of conductors, and voltage of the system.



Figure 4-58.—Tamping and backfilling erected pole.

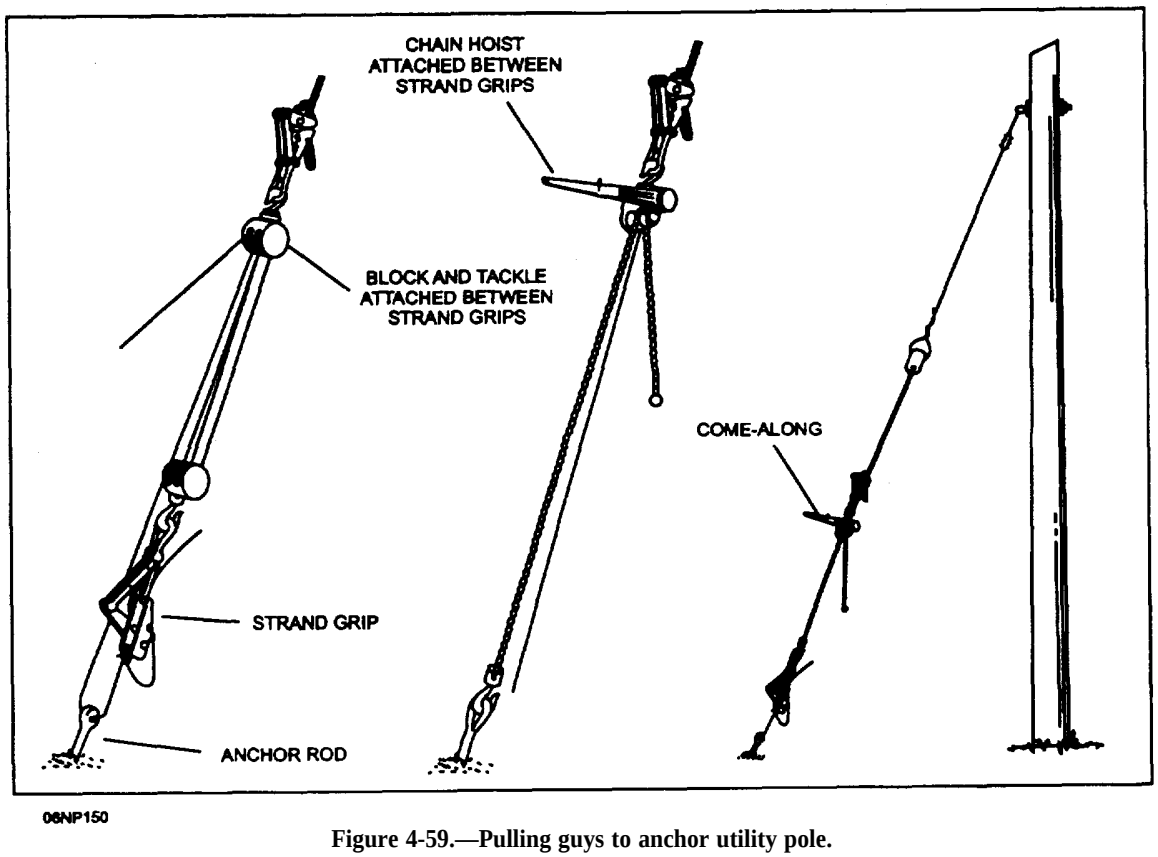


Figure 4-59.—Pulling guys to anchor utility pole.

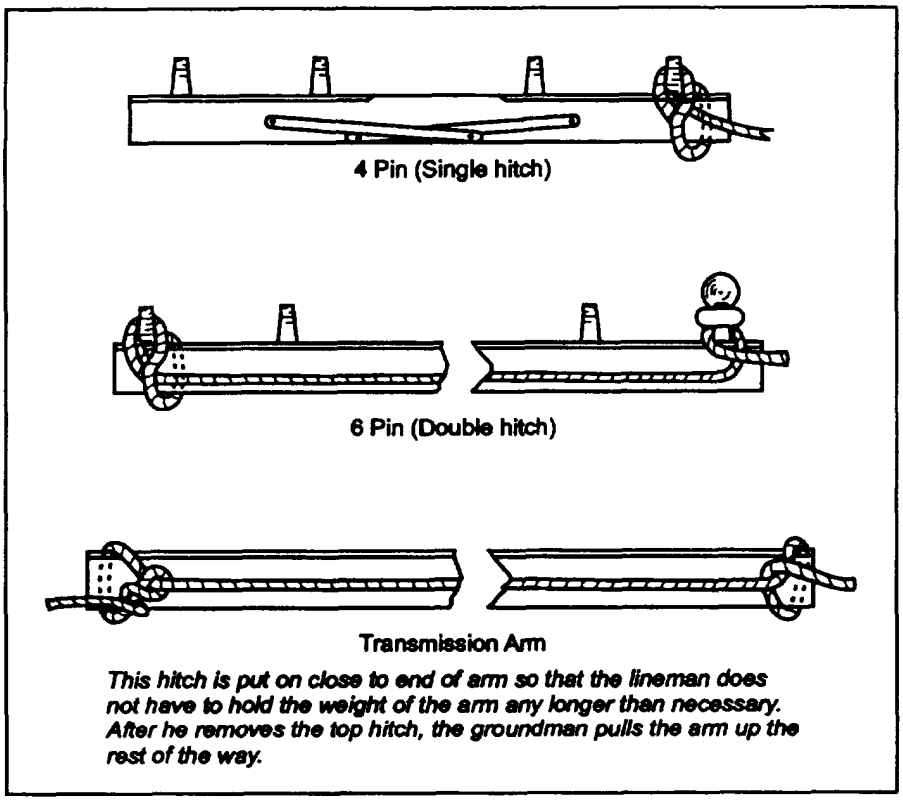


Figure 4-60.—Crossarm, showing proper way to attach a handline.

On most pole-line construction, the installation of hardware and crossarms is accomplished on the ground before setting the pole. This is the easiest and most efficient method; however, sometimes it is necessary to upgrade or build on to an existing system, and then the arm must be installed on a pole that is already standing.

When the crossarm is mounted on the pole before the pole is set, the through bolt is tightened, but the crossarm braces are left hanging loose. Once the pole is set, the crossarm is leveled and the braces are secured to the pole. Finally, the through bolt is drawn completely tight.

When the crossarm is mounted after the pole is set, it is pulled up to a lineman in a working position by a helper on the ground, using a handline attached, as shown in figure 4-60. With the handline attached in this fashion, the lineman can, after he inserts the through bolt, cast off the upper half-hitch, and the helper on the ground can then heave the crossarm level.

Braces are usually fastened to a crossarm with 3/8-inch by 4-inch carriage bolts. Each brace comes down diagonally and is attached to the pole at the lower end with a 1/2-inch lag screw.

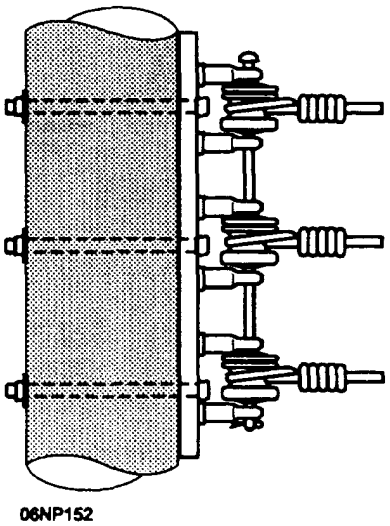


Figure 4-61.—Dead-end secondary rack.

On a straight line without excessive strains, crossarms are used singly-mounted face-to-face or back-to-back, as previously mentioned. At line terminals, corners, angles, or other points of excessive strain, crossarms are doubled. When a power line crosses a railroad or a telephone line, crossarms should also be doubled.

When double arms are used, they are fastened together at the ends with double-arm bolts. One of these is threaded all the way and has two square washers and two nuts on each bolt between the arms. The lineman can adjust the spacing between a pair of crossarms by setting these nuts the desired distance apart on the threaded bolts.

INSTALLING SECONDARY RACKS

Secondary conductors may be strung on crossarms but are usually put on secondary "racks." These racks are made in sizes to accommodate two, three, or four conductors. A secondary rack is mounted on the side of a pole (for a straight run) or on the inside of a pole (for a dead end). A rack is fastened to the pole with lag bolts on a straight line with a through bolt at the top and a lag screw at the bottom, or with through bolts with nuts for a dead end or when a branch line takes off from the main line. A dead-end secondary rack is shown in figure 4-61.

Insulators are held to a rack by a rod passing through the insulators and brackets on the rack, as shown in figure 4-61. On a straight line or inside angle, the conductor is run on the inside of the insulator. On an outside angle, it is run on the outside. The conductor is always placed here with strain against the insulator. Figure 4-62 shows rack arrangements at comers and angles.

INSTALLING CONDUCTORS

There are various ways of stringing conductors. You may place the wire reels on a truck or on a wire trailer and drive along the right-of-way unreeling the

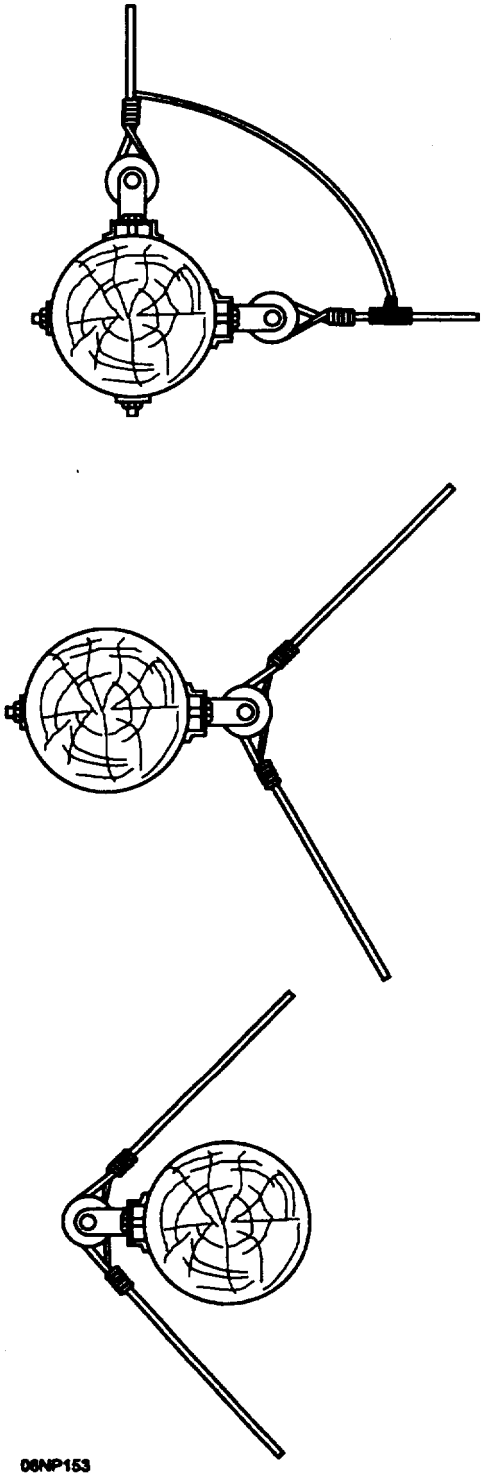
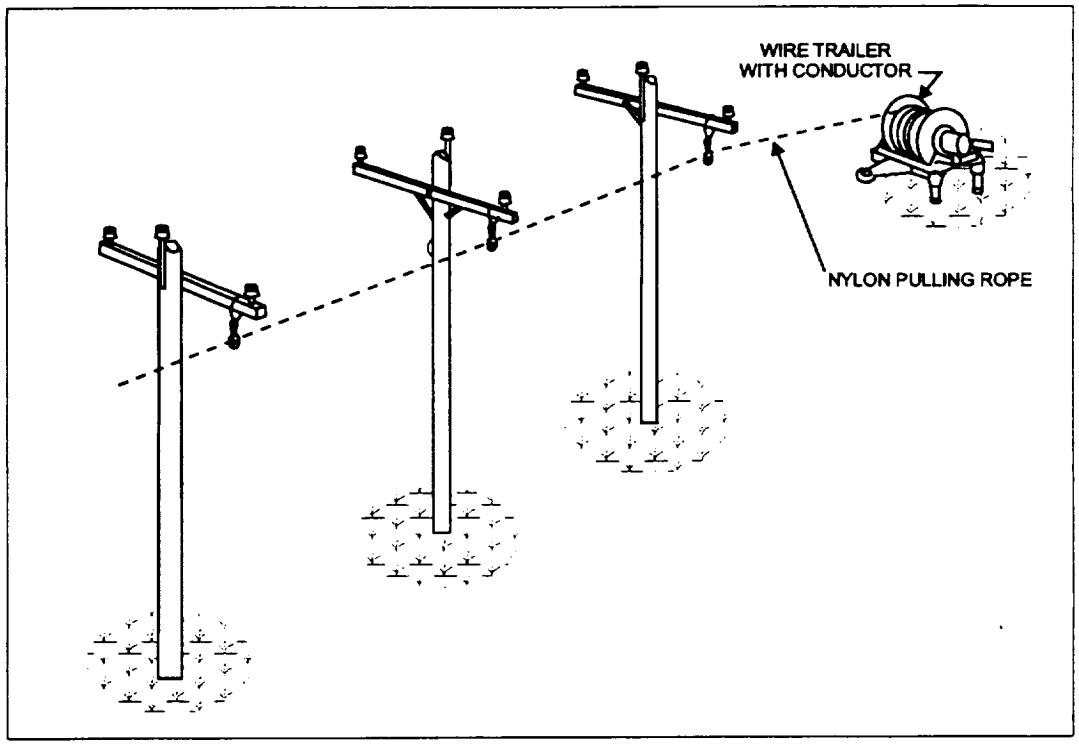


Figure 4-62.—Rack arrangements at corners and angles.



06NP154

Figure 4-63.—Wire trailer with nylon rope used to pull conductor through blocks.

wire, or you may use the running block or over-the-crossarm methods. Figure 4-63 shows the running block method.

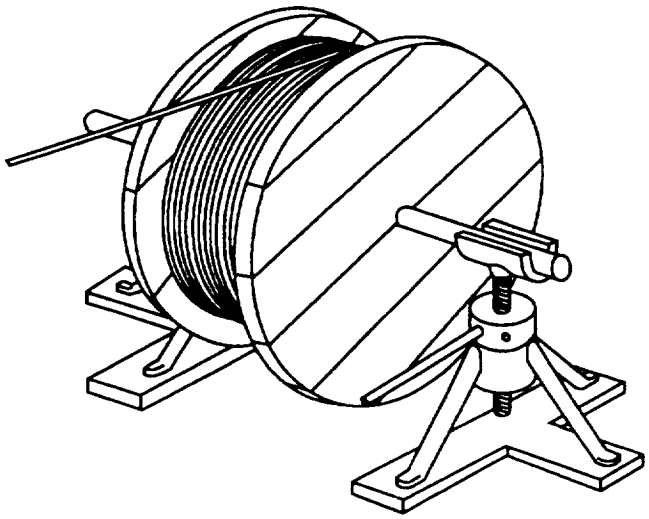
Mounting the Reels

No matter how you string the wire, you will have to mount the reels on some support that allows them to revolve freely. This is usually done by raising a reel on reel jacks, as shown in figure 4-64. A metal rod strong enough to support the reel is put through the hole in the center, and the rod and reel are jacked up on each side with the leg of the T-base away from the reel, as shown. You may have to fasten down the bases of the jacks to keep the strain from upsetting the reel. When you are jacking up, it is necessary only to raise the reel just clear of the deck.

When you are stringing wire in rough terrain, the best method is to anchor a reel to the ground at the end of the line by means of guys run to driven stakes. Then run a rope line over the crossarms or through running blocks mounted on the crossarms for a distance of 1,000 to 1,500 feet. This is accomplished by a lineman climbing each pole and placing the rope in place.

After the rope has been strung over the crossarms, one end is secured to the wires to be pulled, and a couple of turns are taken with the other end around the winch drum on the line truck. The drum is then rotated to haul in the rope and the wires with it. As each wire passes a crossarm, a lineman must climb the pole to set the wire in proper position and guard against twisting.

To keep a paying-out reel from revolving too fast, set a brake or drag against the reel. This can be simply a board, held against the outer edge of the reel by a helper. As a wire or wires are being pulled, enough crew



06NP155

Figure 4-64.—Cable reel on reel jacks.

members must be stationed along the way to establish a chain of signal communication from the head of the line back to the line truck.

Placing the Neutral Conductor

A neutral conductor should always be placed on a center crossarm pin or on a pole-top pin. Butting the neutral on a center pole pin gives the lineman a clear space around the pole to climb through; that is, it ensures that the hot wires are a considerable distance apart.

Pulling In

When the conductors have been hoisted in place on the crossarms and dead-ended on one end, you are ready to start "pulling in"; that is, heaving on the conductors until each has been raised to proper sag. You can do this with a tackle equipped with cable grips like those shown in figure 4-65 or individually, using a cable grip and a come-along.

A cable grip is a clamp device that grips the wire tightly when a strain is applied to the grip.

When you are pulling two or more wires at once, it is best to use the equalizer, as shown in figure 4-65. This device distributes the strain equally on all the wires.

Measuring the Sag

When wires have been pulled to approximately the desired sag, a lineman goes to the center span to measure the sag. Measurement at the center of each span ensures uniformity. Three common ways of measuring sag are by dynamometer, by timing vibration, and by the use of targets.

DYNAMOMETER.—Alever-cam dynamometer is an instrument that is installed in the pulling line and that measures the strain of the pull. It is used in conjunction with a chart that gives the desired pull tension for a given conductor size, span length, and temperature. A traction dynamometer, also installed in the pulling line, provides direct readings on the face of the dial.

TIMING VIBRATION.—The timing-vibration process is done by striking the wire sharply near one of the pole supports and by timing with a stopwatch, the interval that elapses as the impulse from the blow travels to the next pole and returns. This system is not accurate when wind is swinging the line or when the line is being worked on in an adjacent span.

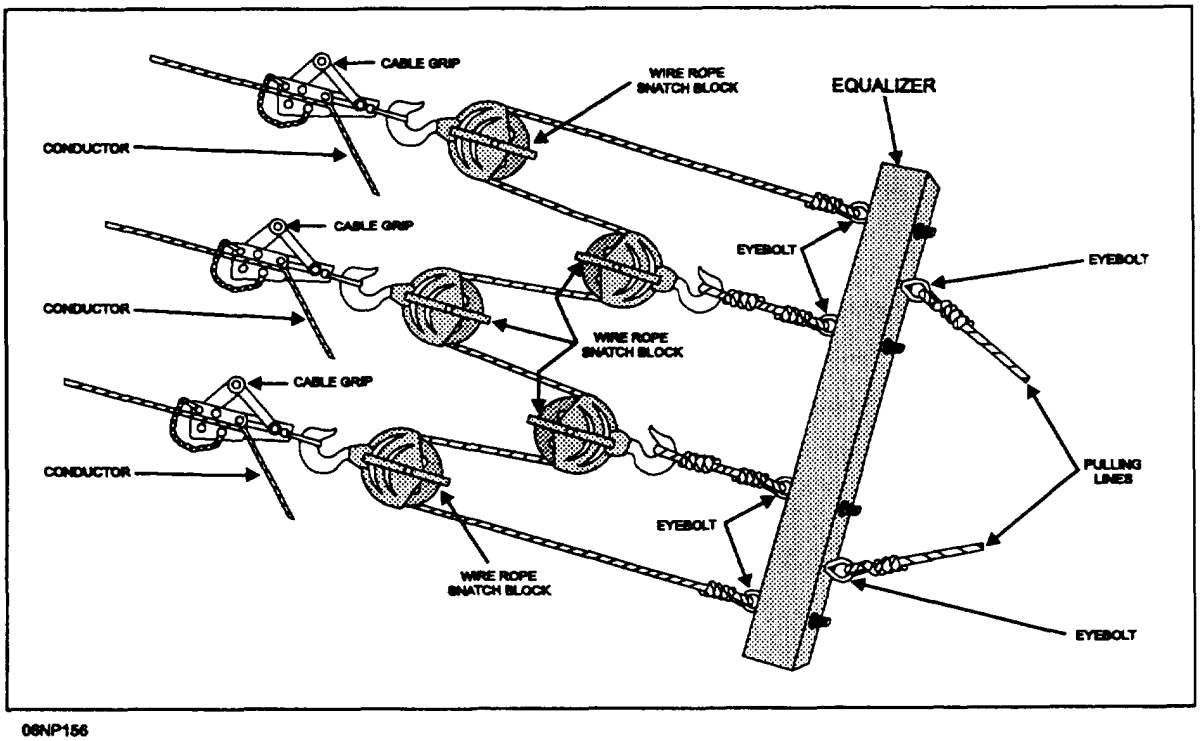
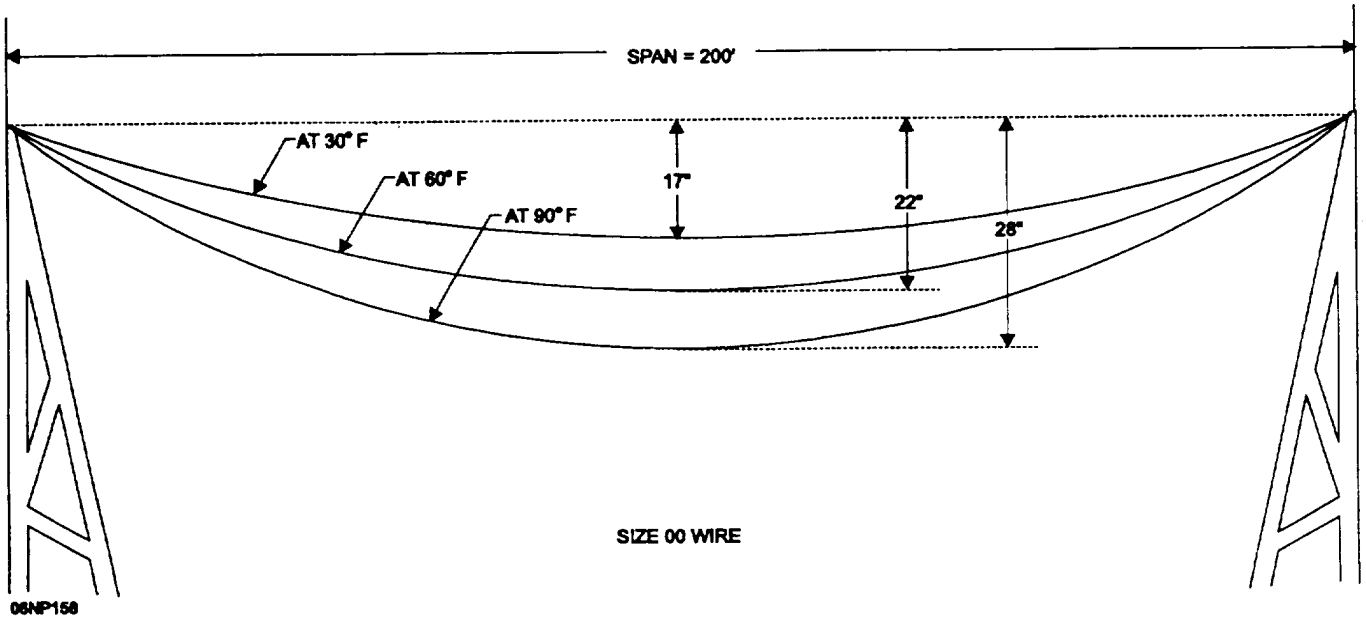


Figure 4-65.—Pulling wires with an equalizer.

Table 4-2.—Sag Variation with Temperature

No. (awg)	Temperature (degrees F)	Sag in inches for span lengths of					
		100 ft	125 ft	150 ft	175 ft	200 ft	250 ft
6	30	5.5	8.5	13	18.5		
	60	8	12	18	24		
	90	12	17	23.5	30		
4	30	5.5	8.5	13	18.5	25	35
	60	8	12	18	24	32	42
	90	12	17	23.5	30	39	50
2	30	5.5	8.5	13	16.5	20	29
	60	8	12	18	22	26	36
	90	12	17	23.5	28	33	44
1	30	5.5	8.5	13	15.5	28.5	24.5
	60	8	12	18	21	24	31
	90	12	17	23.5	28	31	39
0	30	5.5	8.5	13	15.5	18	23.5
	60	8	12	18	20.5	23	29
	90	12	17	23.5	27.5	29.5	36
00	30	5.5	8.5	13	15	17	21
	60	8	12	18	20	22	27
	90	12	17	23.5	26	28	34
0000	30	5.5	8.5	13	14.5	16	19
	60	8	12	18	19	21	24
	90	12	17	23.5	25	27	30

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06NP158

Figure 4-66.—Effect of temperature on sag in 200-foot span of 00 wire.

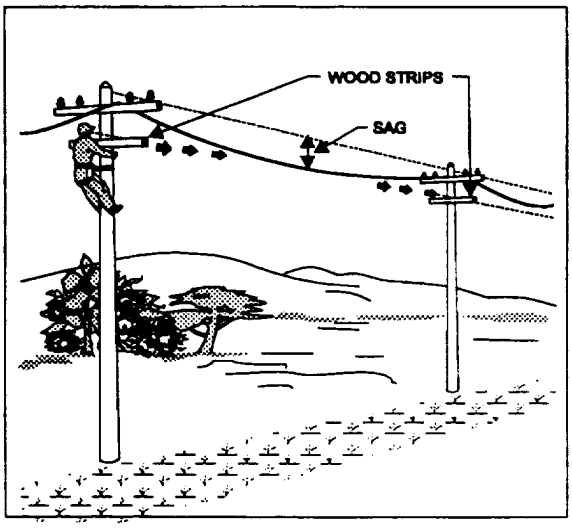


Figure 4-67.—Adjusting sag.

TARGETS.—The target-sighting method is a simple and accurate means for measuring sag. The desired sag is first determined from table 4-2.

Figure 4-66 shows the effect of temperature on the sag in a 200-foot span of 00 wire. You target-measure sag by nailing slat targets, such as a couple of pieces of wood lath, at the point on each pole below the conductor insulator that creates the desired amount of sag. A lineman then sights from one slat to the other, and the conductor is hauled up or lowered until its lowest point is on the line of sight between the slats (fig. 4-67).

After the wires are "sagged in," you allow a rest period of from 1/2 hour to 4 hours (varying according to the length of the pull) to let the wires adjust themselves to the tension in the pull. They will gradually "creep" until tension in all the spans is equalized. After they have crept to the final position, you are ready to "tie in."

TYING IN CONDUCTORS

Tie wire fastens the conductor and insulator together. Conductors can be tied in various ways, but the ties shown in figure 4-68 are the ones most commonly used.

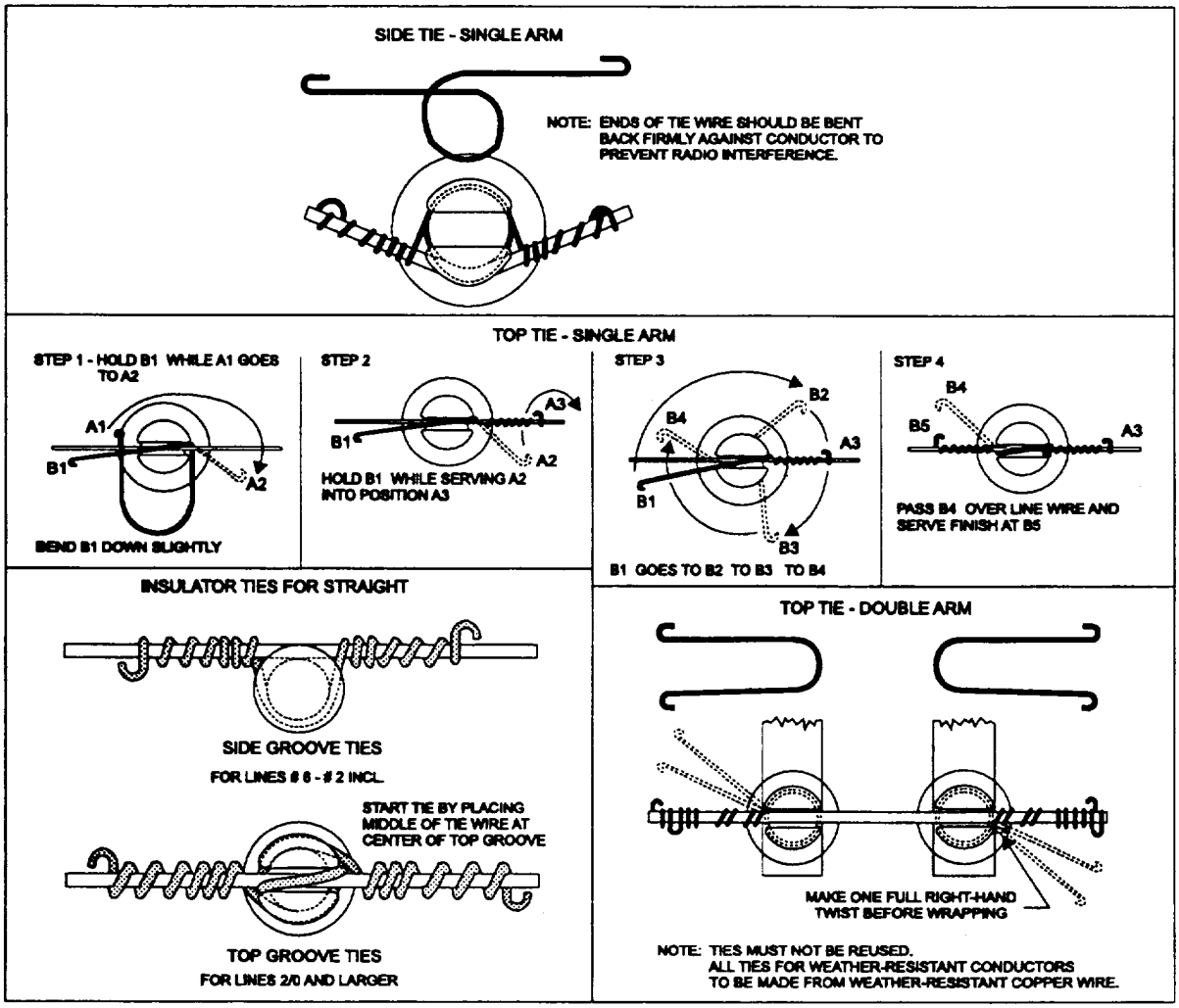


Figure 4-68.—Tying in conductors.

A special reminder—When using an aluminum conductor, you are required to cover it with armor rod at each insulator to provide physical protection against rubbing or pitting caused by the elements. Another important requirement is the use of ACSR-rated dead-end shoes, splice connectors, and all other devices that come in direct contact with an aluminum conductor. This is to prevent electrolysis that occurs from the physical contact of dissimilar metals.

In tying in conductors, observe the following procedures:

Always use new, fully annealed wire for ties. Hard-drawn wire is brittle and cannot be pulled up against the conductor and insulator.

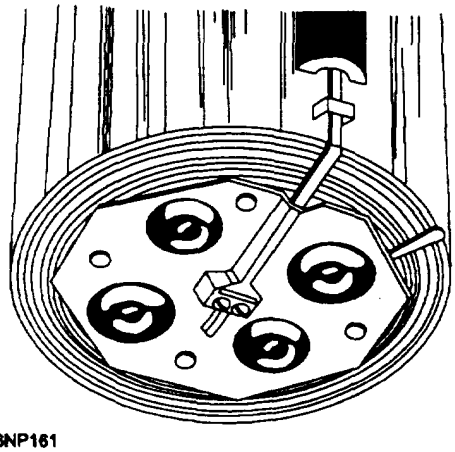
Use the proper size wire. For No. 8 bare, use No. 8 bare. For No. 6 or No. 4 bare, use No. 6 bare. Use No. 4 bare for a No. 2 conductor. Use No. 2 bare wire for No. l/O through 4/0 bare conductor.

Use a piece of tie wire that is long enough to make the complete tie, with enough left over to allow grasping. After the tie is completed, cut off the excess and form a loop, or eye, at the end of any projecting end of the wire.

Make positive contact between the wire and conductor to avoid chafing and to limit possibilities of causing interference with radio communications. Hold the tie wire tight against the insulator as you make your wraps around the insulator and the conductor wire.

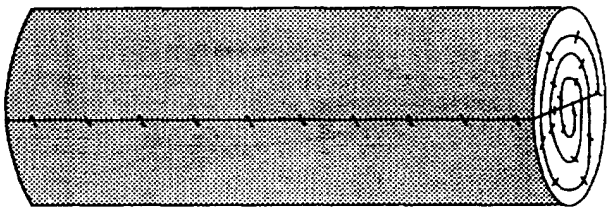
INSTALLING GROUNDS

Grounding in the power distribution system is important. The grounding system protects you and the distribution system when faults occur and aids in the suppression of noise. Grounds are required every quarter mile on a power distribution line and at every pole when equipment, such as transformers, regulators, capacitors, switches, circuit breakers, and lightning arresters, is installed. The maximum resistance of any distribution ground is 25 ohms, but a lower resistance is desired.



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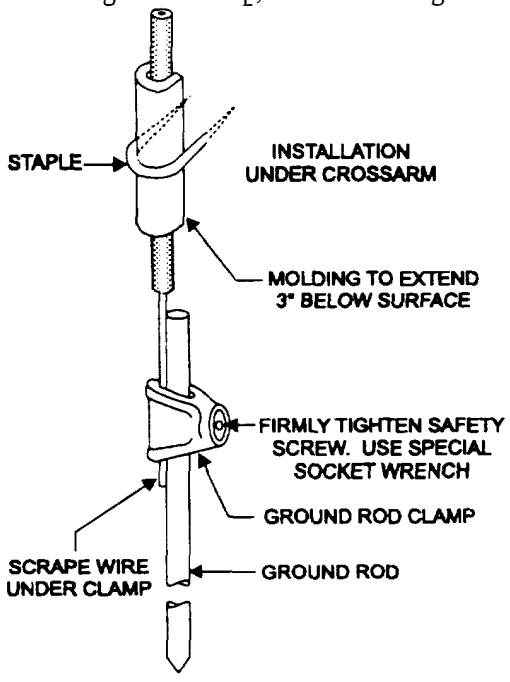
Figure 4-69.—Pole with butt ground plate.



06NP162

Figure 4-70.—Pole butt ground, coiled wire type.

In new construction a butt ground is placed on the pole before the pole is installed. The butt ground can be a manufactured plate, as shown in figure 4-69, or a coil of bare copper wire, as shown in figure 4-70. On existing distribution lines, a ground rod that is 5/8 inch in diameter and 8 feet long is driven at the base of the pole and tied to the pole with a bare copper grounding conductor and a ground clamp, as shown in figure 4-71.



06NP163

Figure 4-71.—Pole ground, ground rod type.

The ground wire on the pole is covered by molding from the level of earth to a height of 8 feet.

On the top of the pole, the grounding conductor is connected to the cases of all installed equipment, lightning arresters, and the primary and secondary neutrals of the distribution system, as shown in figure 4-72.

POLE CLIMBING AND RESCUE PROCEDURES

In line work a requirement is to be able to climb poles. The better you become at climbing poles, the easier your work will be. Yet, no matter how good you become at climbing, the potential for a serious accident always exists when you work around high voltage. In this section you will look at the proper methods of maintaining equipment, climbing poles, and performing emergency rescue from the pole and aerial bucket truck.

POLE CLIMBING

A lineman climbing a pole corresponds to an office worker taking an elevator to the top floor of a building to his or her office. Climbing is not the job, but you must learn to climb and be at ease when you get there.

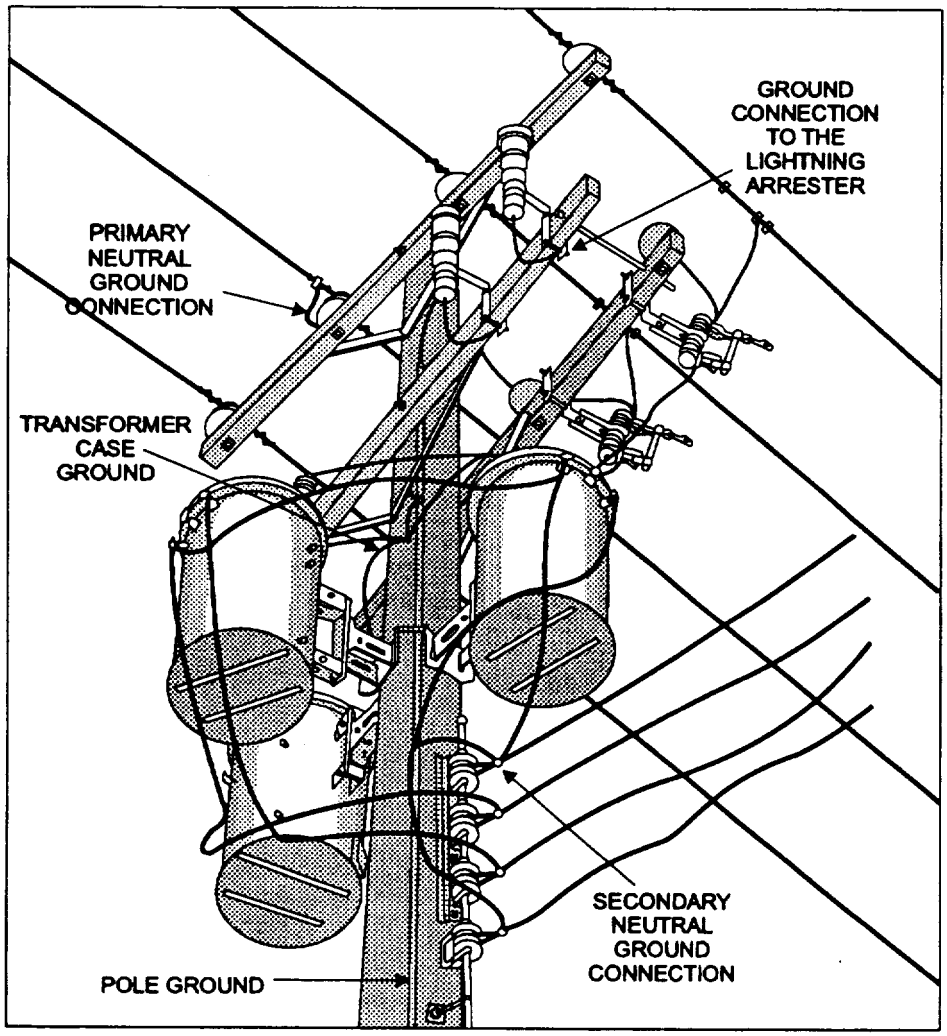


Figure 4-72.—Completely wired installation with wraparound mount showing grounding connections.

To climb a wooden pole or tree, you will use the equipment shown in figure 4-73. On the climber, the stirrup fits under the arch of your foot, and the leg iron runs up the inner side of the calf of your leg. This puts the gaff in a position on the inner side of your foot where you can drive it into the pole or tree as you climb. Two leather straps run through the loop straps and hold the climber tightly against your calf and ankle. The leather pad keeps the upper end of the climber from digging into your leg.

The term *leather* refers not only to treated animal hides but also to neoprene-impregnated nylon products, such as body belts, safety straps, and leg straps. These nonleather items are cleaned with soap and water and are available to the battalions.

The safety strap and body belt, as shown in figure 4-73, are what might be called your extra pair of hands when you work aloft. The safety strap is a leather belt with a tongue type of buckle (keeper snap) at each end. The body belt, strapped around your waist, contains various pockets for small tools. While climbing, you will have the safety strap hanging by both ends from the left ring (called a D ring because of its shape) on the body belt.

The safety strap also has an adjustable buckle that permits varying the length to suit the lineman and circumference of the pole.

Care of Climbing Equipment

To a lineman the term *burning a pole* means the highly unpleasant experience of sliding all the way, or a good part of the way, down a pole as a result of defective equipment or some error in climbing techniques made on the way up. The burning you receive does not need to be explained in detail, and besides burning, you may get many splinters. However, climbers, body belt, and safety strap should keep you up where you belong—if you use them properly and take proper care of them.

The body belt and safety strap require continuous inspection. Look for the following:

- Loose or broken rivets
- Cracks, cuts, nicks, or tears in leather
- Broken or otherwise defective buckles
- Defects in safety-belt snap hooks and body-belt D rings



Figure 4-73.—Pole climbing equipment.

- Worn leather
- Enlarged tongue holes for belt buckles

If you discover any of these defects, turn in the equipment and replace it.

You must periodically perform maintenance work on the leather parts of your climbing equipment. Cleaning comes first. Use a damp sponge and a mild soap. Work up a thick, creamy lather. Then wash the soap off and wipe the belt with a dry cloth.

Next, to make the genuine leather soft and pliable, lather well with saddle soap. Work the lather into all parts; then place the belt in the shade to dry. After the lather has nearly dried, rub down the leather with a soft cloth.

Both belts and safety straps, made of genuine leather, require oiling about every 6 months. Be sure the leather is clean before applying oil. Use about 2 teaspoonfuls of neat's-foot oil, working the oil in gradually. Place the belt in a shady place and allow it to dry for 24 hours. Then rub it down with a soft cloth.

Always, before you climb a pole or tree, inspect the climbers for the following defects:

- Broken or loose straps
- Stirrup worn to a thickness of one-eighth inch or less
- Length of pole gaff of less than one-fourth inch as measured along the inner surface
- Length of tree gaff of less than 5 1/2 inches as measured along the outer surface and of less than 3 1/2 inches along the inner surface
- Difference in gaff lengths of more than one-eighth inch

If you find any of these defects, turn in your climbers for a new pair.

Climber's Gauge

To minimize certain dangers that can occur from neglect of the climbers, make sure you check your gaffs frequently, using a climber's gauge (fig. 4-74). This gauge is used to check the dimensions of the gaffs. These must be within certain tolerances or the climber will "cut out" or lose contact with a pole or tree.

Measurements of the length, width, and thickness of the gaffs are made as follows (fig. 4-75):

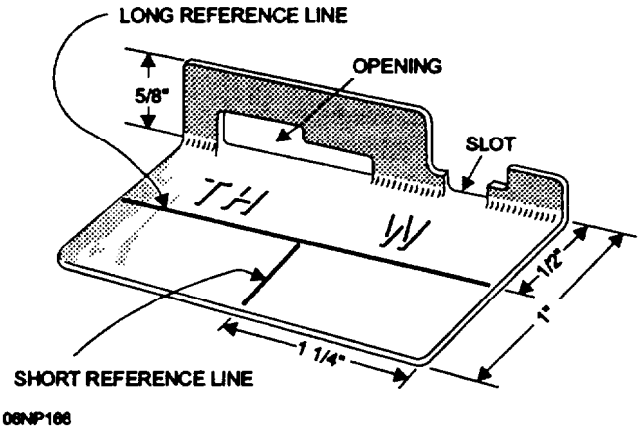


Figure 4-74.—Climber's gauge.

LENGTH. Place the lined face of the gauge against the inner surface of the gaff, with the short edge of the gauge held tightly against the crotch (fig. 4-75, view A). The crotch is the point where the gaff joins the leg iron of the climber. If the point of the gaff extends to or beyond the short reference line, the length of the gaff is satisfactory.

WIDTH. Insert the gaff as far as possible through the small slot marked "W," with the inner surface of the gaff resting against the lined face of the gauge (fig. 4-75, view B). If the point of the gaff does not extend beyond the long reference line, the width of this section of the gaff is satisfactory. Insert the gaff as far as possible

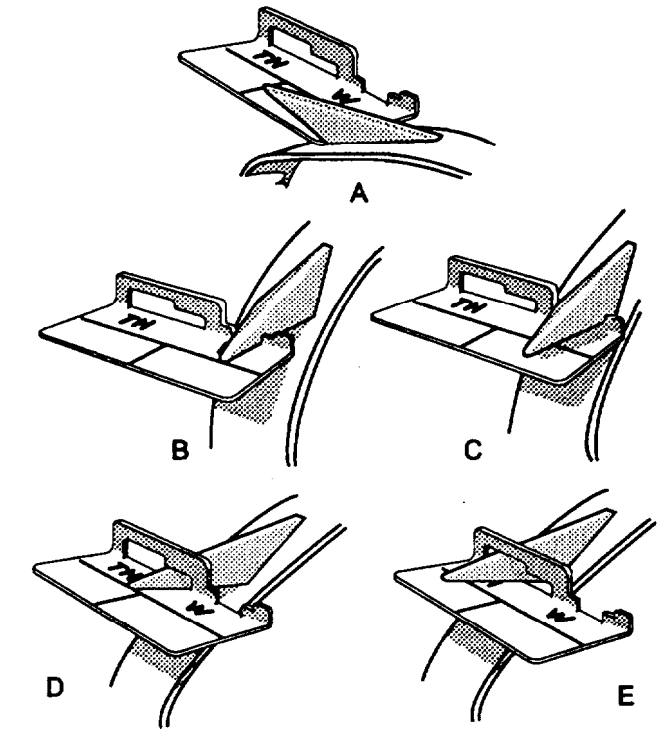


Figure 4-75.—Use of climber's gauge.

through the large slot marked "W," with the inner surface of the gaff toward the lined face of the gauge (fig. 4-75, view C). If the point of the gaff does not extend beyond the far edge of the gauge, the width of this section of the gaff is satisfactory.

THICKNESS. Insert the gaff as far as possible through the small opening marked "TH," with the inner surface of the gaff resting against the lined face of the gauge (fig. 4-75, view D). If the point of the gaff does not extend beyond the reference line, the thickness of this section of the gaff is satisfactory. Insert the gaff as far as possible through the large opening marked "TH," with the inner surface of the gaff resting against the lined face of the gauge (fig. 4-75, view E). If the point of the gaff does not extend beyond the far edge of the gauge, the thickness of this section of the gaff is satisfactory.

Sharpen dull gaffs by taking long strokes with a file from the heel to the point of the gaff, removing only enough material to make a good point. NEVER USE A GRINDSTONE OR EMERY WHEEL TO SHARPEN GAFFS, since the metal may become overheated and lose its strength (temper). Never sharpen the gaff to a needlepoint (fig. 4-76) since it would sink too deeply into the pole and make climbing difficult. Always leave a shoulder about one-eighth inch back from the point.

Remember that climbers are for use on poles ONLY. Do not wear them while working on the ground, and do not use the gaffs for such irregular procedures as the opening of cans.

Going Up

Before you start to climb a pole, there are a number of preliminary steps that you should take. First, of course, make the preclimb inspection of equipment previously described AND PUT ON YOUR HARD HAT. Then inspect the pole to determine the best side on which to start. This is usually the back, or high side.

Get against the pole and grasp each side of it with your hands—not that you will hand support your weight in climbing, but simply because you will use your hands to help in balancing yourself on the climbers (fig. 4-77).

To learn pole climbing, you must practice actual pole climbing. Some pointers that will help you become proficient in pole climbing in minimum time are as follows:

Raise your right leg about 8 inches off the ground and sink the gaff on that leg into the pole. Do not jab the gaff in the wood. Allow your weight to sink it in. Now, swing yourself up off the ground and lock your right leg in a stiff-legged position so that all your weight is supported on that leg.

At the next step, raise your left foot about 8 inches and sink the gaff on that foot into the wood. Then swing up onto the left leg, stiff-legged, and take the next step similarly with the right foot. Continue this stepping up and locking stiff-legged until you reach working position. Keep the upper-part of your body away from the pole (fig. 4-78); if you were to "hug" the pole, you would tend to throw the gaffs out of the wood.

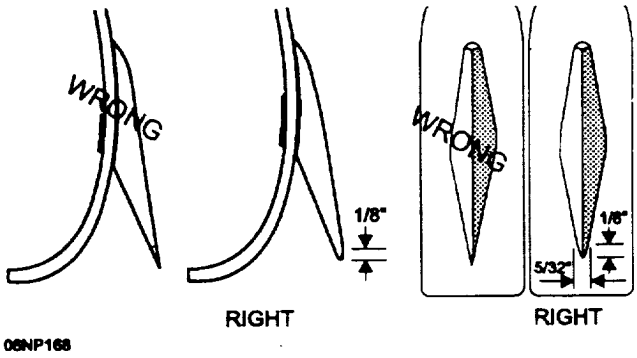


Figure 4-76.—Sharpening the gaffs.

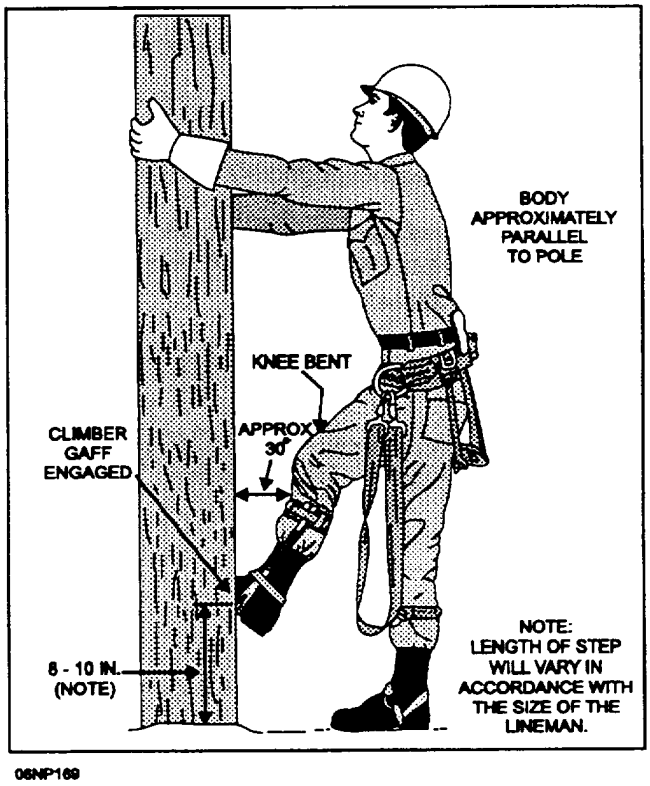


Figure 4-77.—Starting to climb a pole.

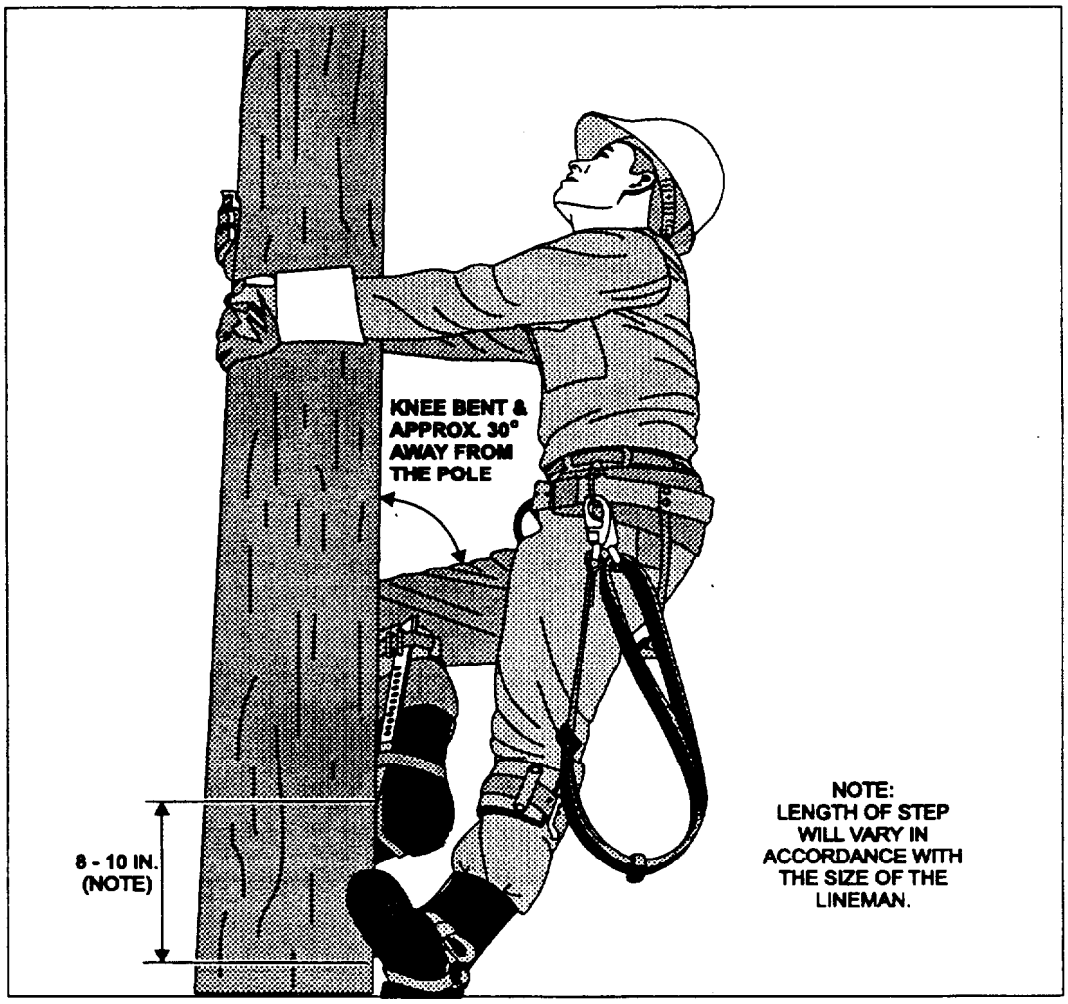


Figure 4-78.—Continuing the climb.

When you reach the working position, proceed immediately with great care to attach the safety strap. You should place your feet so that most of the weight is on the right foot, with the right knee locked. The left foot should be slightly above the right foot and the left leg should be slightly bent.

Crook your right arm around the pole. Use your left hand to unsnap one end of the safety strap from the left D-ring on the body belt. Holding the end of the safety strap in your left hand, pass it around the back of the pole. Transfer the end of the safety strap from the left hand to the right hand; at the same time, crook your left arm around the pole to hold yourself in position. Then swing the end of the safety strap quickly around with your right hand and snap it onto the right D-ring on the body belt.

WARNING

Visually check to ensure that the snap hook on the safety strap is hooked on the D-ring and that the keepers on the snap hooks on both ends of the strap are facing away from your body. When you are sure the strap is secure, you may slowly lean back against the safety strap, as shown in figure 4-79.

Coming Down

Before starting down the pole, you must release the body belt. Crook your left arm around the pole, and unhook the safety strap from the right D-ring with the right hand. Pass the end of the safety strap to the left hand, crook your right arm around the pole, and snap the end of the safety strap to the left D-ring.

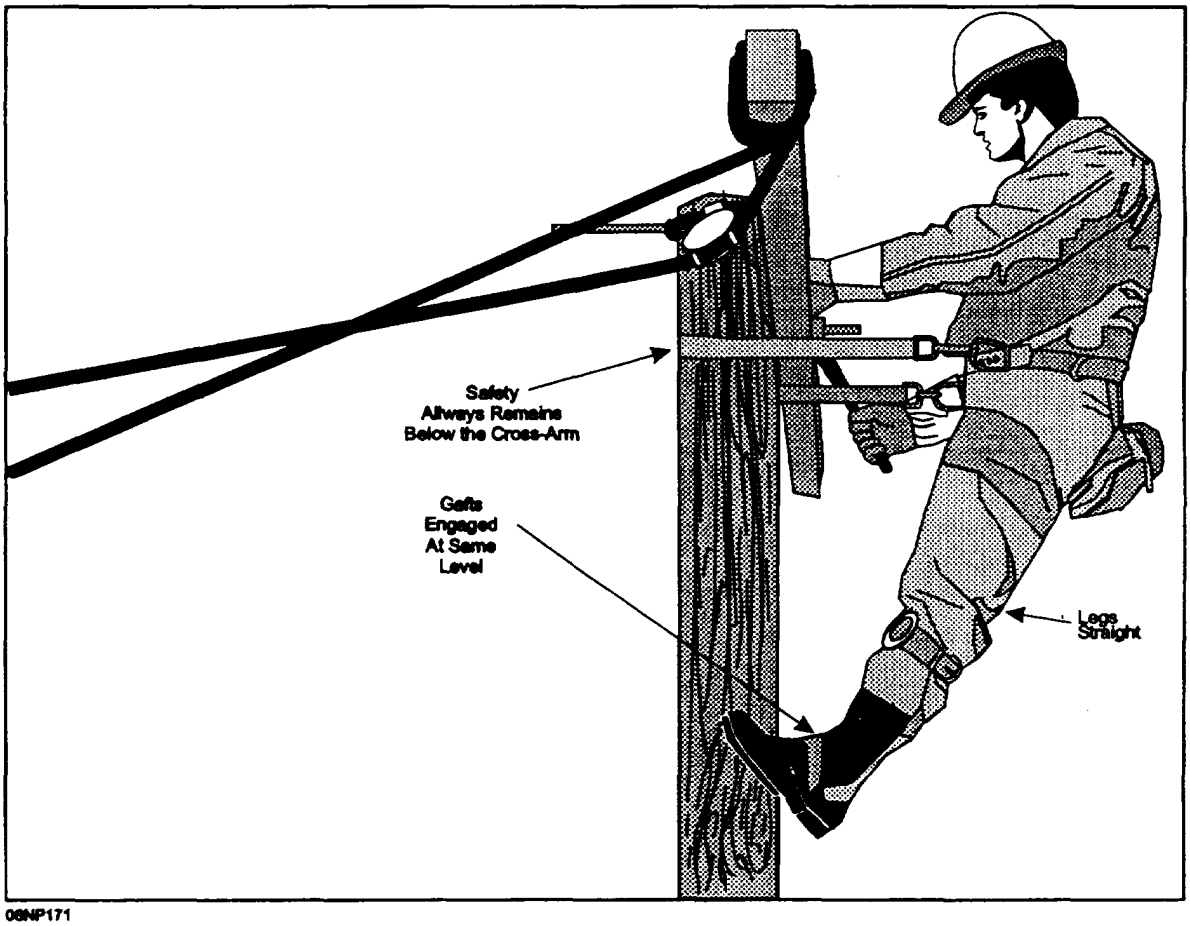


Figure 4-79.—Working position.

You are now ready to descend. Break out the left gaff by swinging the left knee out from the side of the pole. Step down with the left foot to a point about 12 inches below the right; stiff-leg the left leg, and bring your weight on it to sink the gaff. Then break out the right gaff by swinging the right knee away from the pole (fig. 4-80) and proceed as formerly with the left leg. Continue this stepping-down process until you have reached the ground.

Safety in Pole Climbing

Never climb an erected pole until it has been plumbed, backfilled, and tamped. Before going aloft on an old pole, perform a butt rot test on the pole to assure yourself that the pole is strong enough to withstand your weight, and then carefully perform the previously described inspection of the body belt, safety strap, climbers, and other equipment.

The body belt contains pockets for small tools. Keeping the tools in these pockets is important. Never use the center loop in the body belt for carrying a tool, however. In case of a fall, the tool may injure your tailbone.

If you try to climb with tools in your hands, your own balance on the pole will be unsafe, and you could drop tools on someone below.

The safety strap is used to secure you to the pole, leaving your hands free to work. As you go up, the safety strap is always fastened to a single D-ring on the body belt. For a right-handed person, it is carried on the left D-ring.

Never use an improvised safety strap, or one that has been lengthened by the addition of rope or wire. Never attach the strap to pins or to crossarm braces. Never put the safety strap around the pole above the highest crossarm if the length of the pole above the crossarm is short. The strap should never be less than 1 foot below the top of the pole.

Never wear climbers except for climbing. Be careful not to gaff yourself or anybody else.

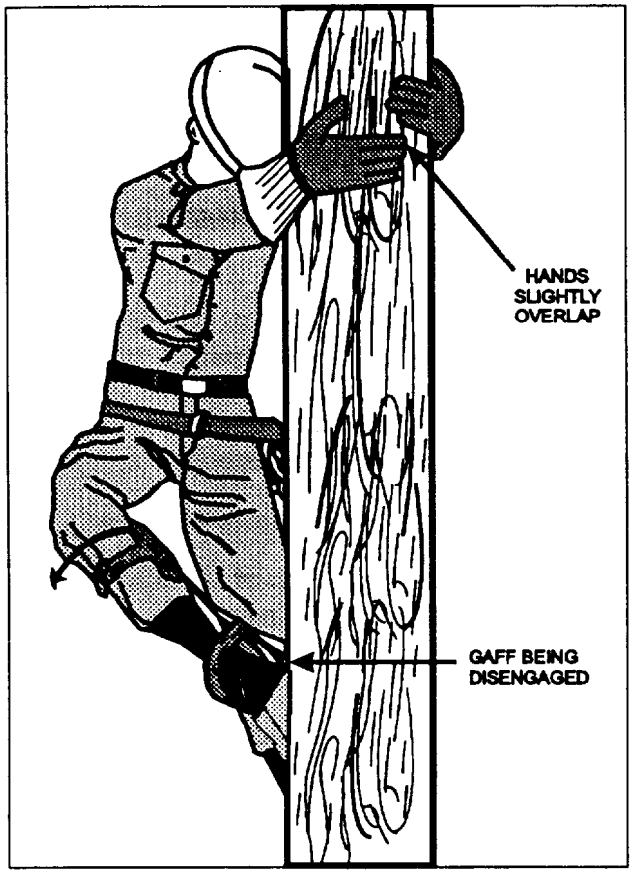


Figure 4-80.—Descending.

Some precautions to keep constantly in mind are as follows:

- NEVER carry tools or other objects in your hand when climbing.
- NEVER trust pins,crossarmbraces,orguywires as supports.
- If you are working with another person on the same pole and he or she goes up first, wait until he or she is strapped in the working position before you start up.
- Do not depend on the snapping sound when you snap the safety strap to a D-ring. Look down to ensure that the snap is hooked on the ring.
- If the top crossarm is near the top of the pole, do not pass the strap around the short length of the pole protruding above the crossarm.
- Ensure that keepers on the snap hooks on the safety strap are facing away from the body.

Protective Clothing and Equipment

A lineman should always wear gloves or gauntlets when tending a reel for stringing conductors. Never work with the gauntlets of the gloves turned down

Do not wear hobnailed shoes or shoes with metal plates. When trimming trees for pole lines, wear rubbers or rubber-soled shoes for climbing. Always test the safety strap and body belt before using them. Never wear a strap with stitching across it or one mended with tape. Make all the safety checks of climbing equipment every time you prepare to go aloft.

POLE-TOP RESCUE

When a crew member working aloft is shocked into unconsciousness, there are several ways of performing pole-top resuscitation, depending on the prevailing circumstances.

There are some basic steps that you must take when accomplishing a pole-top rescue. First, you need to evaluate the situation; second, you should provide for YOUR safety; third, you have to climb to position where you can attempt the rescue; and fourth, you need to determine the seriousness of the victim's condition and take the necessary action to accomplish the rescue.

EVALUATE THE SITUATION. Call out to the victim, "Hey! Do You Need Any Help", "Are You O.K.?" If there is no response or if the victim seems stunned or dazed, prepare to do a rescue. At this point, TIME IS EXTREMELY IMPORTANT! While calling to the victim, look at the surroundings. Look for things such as the pole or crossarm being split, cracked or on fire. If the victim is in contact with an energized conductor you will need to clear him or her using rubber goods or hot stick. When evaluating the scene look at the whole scene and not just the victim.

WARNING

To ensure your personal safety, you need to wear rubber gloves or sleeves and take enough other equipment to secure your position

PROVIDE FOR PERSONAL PROTECTION. Consider turning off the electricity, but don't waste time looking for a switch, the rescue is more important. Your safety is very important to the rescue mission Without you, there will be no rescue. This means personal climbing equipment and rubber goods are in serviceable condition. Hot line tools are ready in case needed and

physical condition of the pole has been surveyed. Plan your route to the victim now. To be on the safe side assume the pole is energized; unless confirmed de-energized. Leap onto the pole. No part of your body should touch the pole and the earth at the same time. This prevents your body from providing an alternate path for the electricity. Remember, don't take chances and become a victim also.

CLIMB TO RESCUE POSITION. Lay out the rescue rope and attach one end to a loop of your body belt. While climbing to the rescue position, be sure to climb carefully and belt in at a safe position. Clear the victim from energized conductors using rubber goods or hot sticks, then reposition yourself and determine the victim's condition. Slightly above and to one side is normally best for checking and working with the victim.

A safe and easy method used to lower the victim to the ground is shown in figure 4-81 and requires a pulley line or a handline attached to a crossarm and tied off around the victim's chest. The knot should be in front of the victim, close to one armpit. lie three half-hitches, and snug the knot so that the rope rides high on the victim's chest Take up the slack, cut the victim's safety strap, and slowly lower him or her to the ground.

MAINTENANCE OF POWER DISTRIBUTION SYSTEMS

The elements, accidents, and willful vandalism are the causes of most damage to power distribution equipment. To repair these damages, the lineman requires experience, a total commitment to safety, and the knowledge to accomplish repairs to the system as quickly and economically as possible.

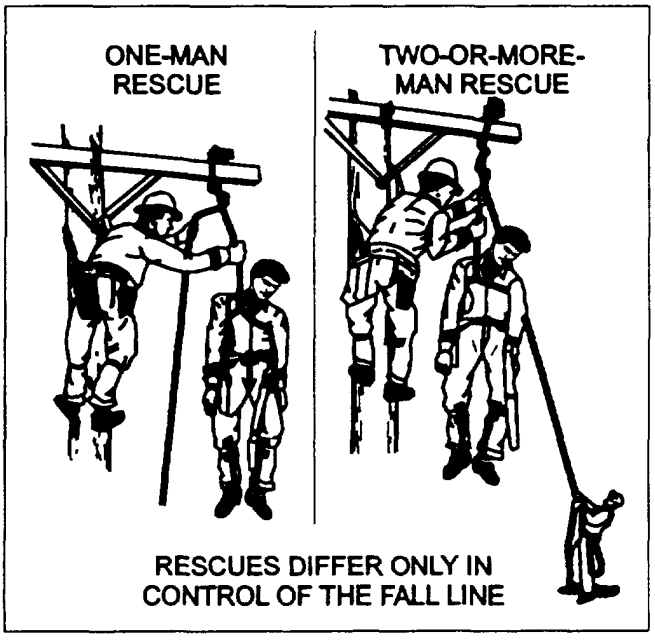


Figure 4-81.—Pole-top rescue.

MAINTENANCE OF POLES, TIMBERS, AND CROSSARMS

The maintenance required on the poles, timbers, and crossarms in a power distribution system is minimal. Normally, this equipment lasts for a period of 20 years or more. The following problems may occur, however, and create a need for maintenance action:

- A pole can settle and require straightening.
- Wood can shrink and cause all hardware to become loose and require tightening.

WOOD POLE MAINTENANCE

Wood poles are treated with preservatives to prevent decay, but small organisms, insects, and fungi all contribute to the breakdown of the wood preservatives. The life of a pole can be extended by inspections and treatment, when necessary, to stop pole decay.

The inspection would normally include sounding the pole by hitting it with a hammer from belowground level to approximately 6 feet above ground to determine obvious defects. Also the pole is bored to determine the presence of internal voids. Poles with internal decay can be treated with insecticides. External decay is removed, and the area is treated with preservatives and wrapped with a moisture-proof barrier. Poles weakened excessively by internal or external decay must be reinforced or replaced.

MAINTENANCE OF HARDWARE, CONDUCTORS, ACCESSORIES, AND GUYS

Other items that may require maintenance are the hardware, conductors, accessories, and guys.

- Over time, guys stretch and require re-tensioning.
- Insulators get dirty and require cleaning, especially around the sea where there is salt in the air.
- Connections become loose with age and must be re-torqued to prevent hot spots.

- In time, conductors stretch and require re-sagging.
- Insulators crack and require replacement.

OPERATOR MAINTENANCE RESPONSIBILITY

Operators must keep the vehicle or assigned equipment clean and in serviceable condition and must perform daily operator's maintenance. Equipment must be inspected daily and any defects noted to be corrected before a serious breakdown or mishap occurs. The NCF equipment is scheduled for preventive maintenance every 40 workdays. No piece of equipment can be expected to operate for 40 days without daily operator care. Many units of equipment have hourly and daily lubrication points. This lubrication is the responsibility of the operator. Operators must ensure that equipment is maintained as outlined in the operator’s manuals. These manuals can be obtained from the CM shop library.

MAINTENANCE AND TESTING OF AERIAL EQUIPMENT WITH HYDRAULIC BOOM

Operation of aerial equipment starts in the same way as other pieces of equipment. The operator must have a valid license, and a thorough prestart inspection must be performed. Maintenance and lubrication must be performed according to the manufacturers' recommendations and guidelines. Daily operator checks, made before placing the equipment in service and again when securing the equipment, will be kept on file for a minimum of 60 days. If the operator detects any condition that would indicate the equipment to be unsafe or unreliable for use, the equipment must be removed from service.

A **condition inspection,** an **electrical insulation test,** and a **load test** are to be performed annually. The certifying official of the designated activity is responsible for the certification of these inspections and tests. A copy of the certification must be posted on the equipment in full view of the operator. The original certification form is to be filed in the equipment history record file.

CHAPTER 5

INTERIOR WIRING

At any Navy or advanced base, the electrical system consists of three parts: the power plant that supplies the electrical power, the distribution system that carries the electrical current from the generating station to the various buildings, and the interior wiring systems that feed the electrical power to the appliances and equipment within a building.

As defined here, interior wiring begins at the point where the distribution systems service leads are connected to the wiring from within the building and extends through each circuit of the interior wiring of the building to the last fixture installation.

In this chapter, we will discuss your responsibilities in meeting various code and specification requirements and a variety of techniques for installing, repairing, and maintaining interior wiring systems.

STANDARDS

The National Electrical Code© (NEC©) is prepared and published every 3 years by the National Fire Protection Association (NFPA). You should use the latest publication and volume reference. The NEC© is an accepted guide for the safe installation of electrical conductors and equipment. Its purpose is to safeguard personnel and buildings and their contents from hazards arising from the use of electricity. NAVFACENGCOM recognizes the NEC© and uses it as its minimum standard.

How does the NEC© minimize the dangers mentioned above? Briefly, the NEC© provides the following:

- Various methods of wiring and descriptions of materials

Techniques for wiring designs and protection

- Requirements of general and special equipment
- Special conditions and occupancy information
- A variety of tables and examples for calculations

The NEC© is a wealth of information that provides CEs with a strict to-be-observed guide that experience has shown minimizes electrical hazards to personnel and buildings and their contents.

Now, we are going to distinguish between three important electrical terms. As a CE, you will need to know the difference between the terms grounded, grounded conductor, and grounding conductor. Grounded, as defined by the NEC©, means connected to the earth or to some other conducting body that serves in place of the earth. A grounded conductor is a circuit conductor that is intentionally grounded. A grounding conductor is a conductor used in connecting equipment in the circuit of a wiring system to a grounding electrode or electrodes. As a CE, you should make it a point to learn the difference between these terms. You will see them and hear them discussed throughout your career. Use the NEC©, study it, and learn it. A working familiarity with this reference will prove useful to you, and, as you advance in rate, teach your junior personnel the importance of this valuable guide.

SERVICE ENTRANCE AND DISTRIBUTION PANELS

The starting point for interior wiring is the service entrance. It is connected to the service drop. The service entrance is made up of several components, but before we get into the specifics concerning the service entrance, let us look briefly at the wiring system used to supply a building.

The types of electrical systems that are to be installed are determined mostly by what the building is to be used for and the type of equipment that is to be used. Generally speaking, electrical loads are divided into four categories: two-wire, single-phase; three-wire, single-phase; three-wire, three-phase; and four-wire, three-phase.

WIRING SYSTEMS

The simplest wiring system is a two-wire, single-phase type, as shown in figure 5-1. This system is used

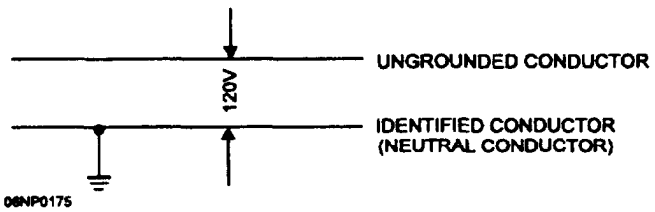


Figure 5-1.—Two-wire, single-phase system.

in small buildings where the primary requirement is lighting. It can also be used to operate 120-volt appliances and motors. The two-wire system consists of one ungrounded, insulated conductor and one identified (grounded) conductor, which is called the neutral. This system is limited to the operation of 120-volt equipment and relatively light loads of 50 amperes or less. Larger loads can be better served by another type of wiring system. The two-wire system requires the use of an equipment-grounding conductor that may be a separate conductor, conduit, or other recognized means of grounding.

Figure 5-2 shows the three-wire, single-phase wiring system, used both for lighting and power. This system, commonly known as "220," "110," (single phase), uses two ungrounded conductors and a neutral conductor, which is grounded. It provides 110 volts between each ungrounded conductor and the neutral. It also provides 220 volts between the two ungrounded conductors. This system is used for lighting and power loads, such as air conditioners and heating equipment. The three-wire, single-phase system provides up to twice the power that is available from a two-wire system with conductors of the same size provided that the load is balanced between the two ungrounded conductors. The 110-three-wire, 220 volts is the most common system used in residences today. This system also requires the use of an equipment-grounding conductor.

A second type of three-wire system is the three-wire, three-phase system shown in figure 5-3. This system is used to furnish power, usually 220 volts, to installed equipment. If some lighting is needed, 220-volt fixtures and bulbs can be installed, but be aware that there are certain restrictions placed on lighting circuits exceeding 120 volts. When substantial amounts of power are required, higher voltages, such as 480 volts ac, maybe provided with this type of system.

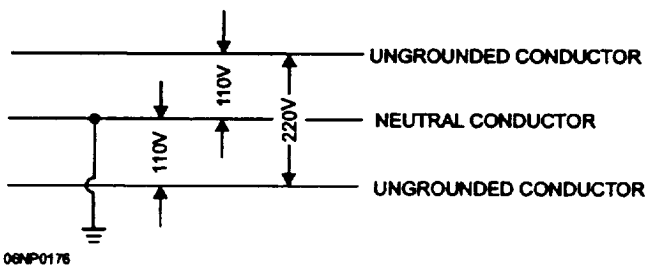


Figure 5-2.—Three-wire, single-phase system.

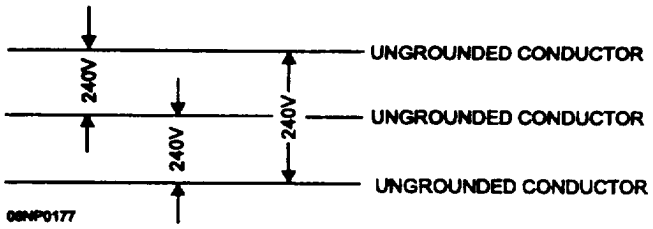


Figure 5-3.—Three-wire, three-phase system.

The last type of wiring system in common use is the four-wire, three-phase system (fig. 5-4). This system has three ungrounded phase conductors plus a grounded neutral. This system is a combination of light and power and offers quite a cost reduction over a three-wire, single-phase system for the same amount of power. The usual voltages are 120/208 or 120/240 VAC, depending on the type of transformer connections used.

SERVICE ENTRANCE

The service entrance serves to bring power from the service drop to the panelboard inside the building. One of the components of the service entrance is the conductors through which the current flows. The conductors may consist of individual wires run through a protective raceway, such as rigid metal conduit, electrical metallic tubing, or rigid nonmetallic conduit. The raceway provides the conductors with protection from both physical and weather damage. Power may also be brought into the building by means of service entrance cable. This cable does not need raceway protection unless it is likely to be physically damaged by abrasions or by being struck by passing equipment.

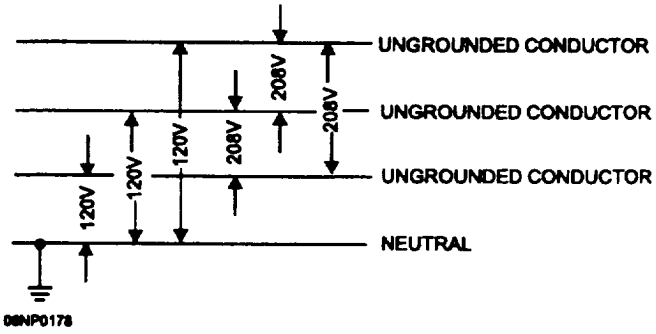


Figure 5-4.—Four-wire, three-phase system.

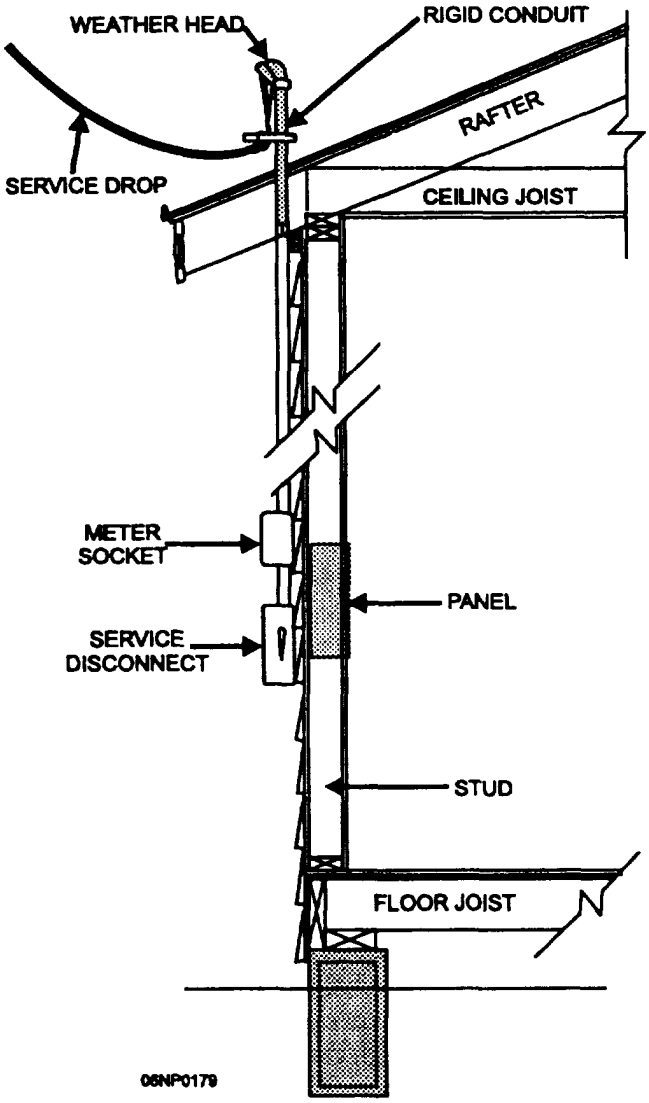


Figure 5-5.—Service mast service entrance.

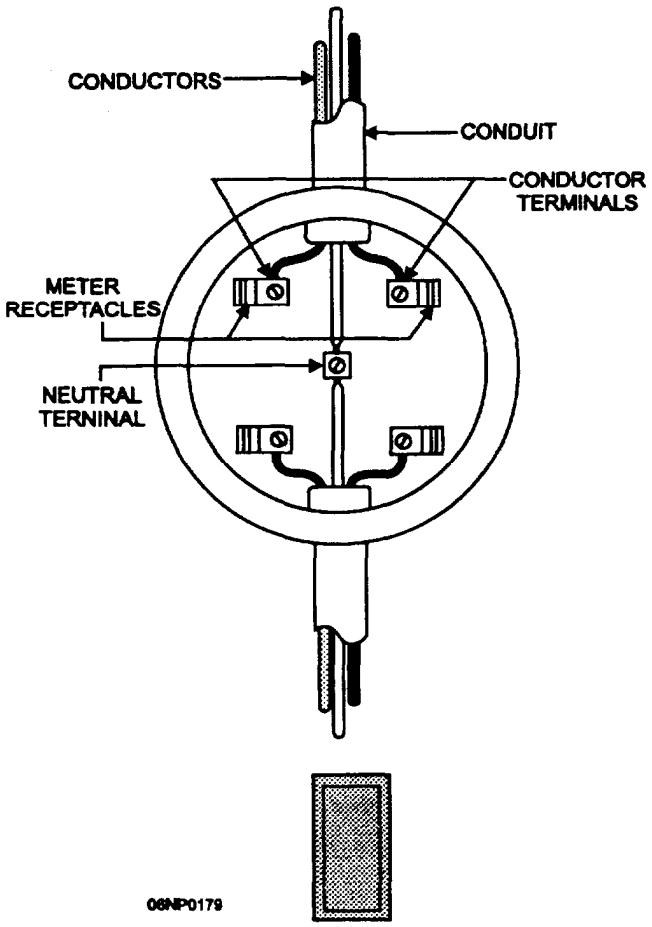


Figure 5-6.—Meter socket and wiring.

A weather head, also called a service head, as shown in figure 5-5, is used with a raceway to provide an exit for the conductors from the raceway. The weather head is designed to prevent the entrance of rain into the raceway. The conductor holes in the service head are designed to reduce abrasion to the insulation. Power delivered to the building may need to be measured to determine how much power is used. When this measurement is necessary, a watt-hour meter socket (fig. 5-6) is installed in the service entrance circuit so that a wattmeter may be included to record power consumption. Article 230 of the NEC© covers the service conductors and equipment for control and protection of services and their installation requirements.

SERVICE DISCONNECTS

The service entrance must provide a means of disconnecting the service entrance conductors from the interior building circuits. The service disconnecting means will be installed at a readily accessible location either outside of a building or structure, or inside nearest the point of entrance of the service conductors. A service disconnect, or main switch, can be used to turn off all interior power in case of a fire or other emergency conditions. A disconnect switch is also useful when work is to be performed on the panelboard or work is done on two or more circuits at the same time. Overcurrent protective devices are required for the service conductors in conjunction with the service disconnects.

Several types of service entrance disconnects are permitted. One of these is in the form of a knife-blade switch with one, two, or three blades, as needed, to open

the circuit. Figure 5-7 shows a two-pole knife-blade disconnect. As you can see, this switch has two fuses directly beneath the movable blades. Another type of disconnect is installed as a fuse block. The fuse block contains a fuse for each ungrounded conductor. Removal of the fuse block has the same effect as opening a switch to interrupt current flow. A third method of providing for service disconnect and overcurrent protection is the use of circuit breakers. These may be installed as a multiple assembly with a single-switch handle. The service disconnect must be permanently marked to identify it as a service disconnecting means. The grounded conductor is not normally attached to the disconnect switch, but when it is, the switch must be in the form of a circuit breaker, and all the ungrounded conductors must open simultaneously with the grounded conductor. Regardless of whether it is switched, the grounded conductor has to be fixed so it can be disconnected. A terminal or bus bar to which all grounded conductors can be attached by means of pressure connectors meets this requirement.

The service entrance must be grounded to a low-resistance ground (refer to section 250 of the NEC©). Normally, a ground rod is driven into the ground for this purpose, but a metal underground water pipe in direct contact with the earth for 10 feet or more and electrically continuous to the points of connection of the grounding electrode conductor and the bonding conductors may be used. Another way is to use the nearest available effectively grounded structural metal member of the building for grounding. Once a suitable grounding electrode is identified, the grounded or neutral conductor must be attached to it. The grounding electrode conductor is installed as a continuous conductor from the neutral bus bar to the grounding electrode. Small grounding conductors are enclosed in a protective metal covering that should be electrically continuous from the panelboard cabinet to the grounding electrode. Metal raceways, meter sockets, panelboard cabinets, and the grounding electrode conductor enclosure must all be electrically bonded together and to the grounding electrode conductor so as to be electrically continuous. This arrangement results in all metal parts and enclosures in the service entrance and the grounded conductor being at the same potential electrically.

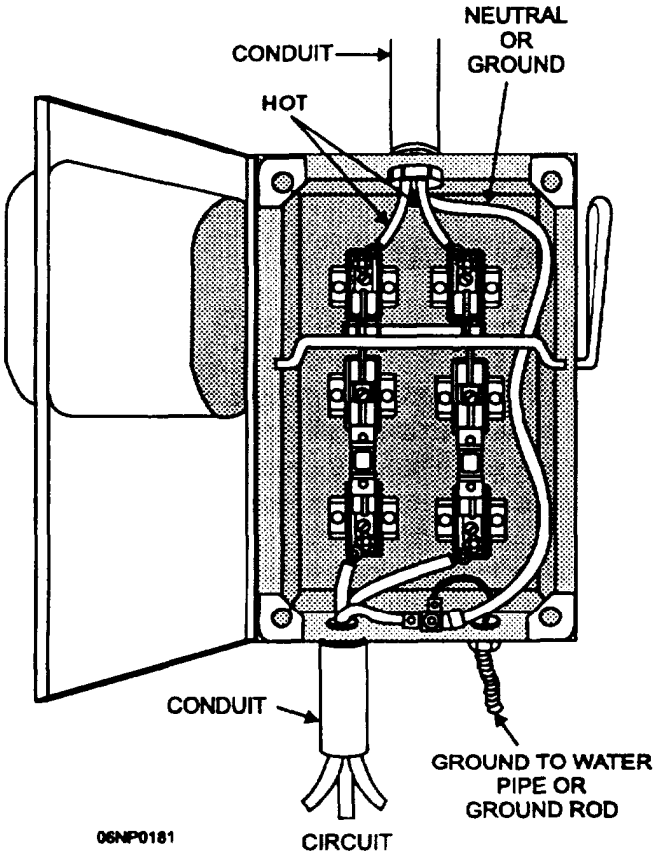


Figure 5-7.—Service entrance disconnect and overcurrent protection.

INTERIOR WIRING SYSTEMS

Every interior wiring job you will be assigned will have its own particulars, depending upon what type of building or structure you are assigned to wire. Some of these particulars are whether to use rigid, flexible, or thin-wall conduits. The type of conductors you will use, whether single or a cable with multiconductors, such as Romex or flexible cord. These particulars, as mentioned above, depend on what type of job you are assigned, temporary or hard-wired, block or drywall construction. Use this information provided here to become familiar with installation requirements. Learn to use the proper cable, conductors, and conduit in the correct place. Make sure you are familiar with the various methods of bending, joining, and installing the various materials, and learn to select the proper fittings and accessories that you will need to install those materials. As you are referred to the NEC© throughout the chapter, look up the articles indicated This action will help you get acquainted with the NEC©. A good CE takes pride in doing a neat, safe, and proper job.

CONDUCTORS AND CABLE SYSTEMS

Electrical conductors generally consist of drawn copper or aluminum formed into a wire. They provide paths for the flow of electric current and usually have insulating material encasing the metal. The insulation material is provided to minimize short circuits and to protect personnel. Atmospheric conditions, voltage

Table 5-1.—Percentage of Current-Carrying Capacity of Conductors

NUMBER OF CONDUCTORS	PERCENT OF NORMAL CURRENT-CARRYING CAPACITY
4 through 6	80
7 through 24	70
25 through 42	60
43 and above	50

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requirements, and environmental and operating temperatures are factors considered in the selection of the type of insulating material for a particular job.

Single Conductors

A conductor may consist of a single, solid wire or a combination of a number of solid wires (stranded) that are not insulated from each other and share in carrying the total current.

A stranded conductor has the advantage of being more flexible than a solid conductor, thus making it more adaptable for pulling through bends in the conduit.

Conductors vary in diameter. wire manufacturers have established a numerical system called the American Wire Gauge (AWG) standard. Table 8 of the NEC© shows how this numerical system eliminates the necessity for cumbersome, circular mil or fractional inch diameters in the description of wire sizes. Notice that the wire gauge numbers increase from 4/0 through 18 as the diameter of the wire decreases.

Size, Number, and Ampacity

The wire size most frequently used for interior wiring is No. 12 AWG, used as a solid or stranded copper conductor. Table 310-17, column 2, of the NEC© shows the allowable ampacity of a single conductor in free air. No. 12 AWG (for types FEPW, RH, RHW, THW, THWN, XHHW, and ZW insulation) to be 35 amperes. However, the minute that same conductor is not alone in free air and is placed in a raceway, cable, or direct burial, you see, by referring to table 310-16, NEC©, that its ampacity is reduced to 25 amperes, provided that not more than three conductors are in the raceway or cable. Table 5-1 of this training manual indicates the reduced ampacities for a variety of numbers of conductors in such a situation, according to the NEC©.

Suppose now that you have four to six No. 12 AWG wires in a conduit. The allowable current-carrying capacity would be only 80 percent of the normal, or 20 amperes. To ensure a current-carrying capacity of 25 amperes, you would have to use No. 10 wire that has a normal current-carrying capacity of 35 amperes, 80 percent of which is 28 amperes.

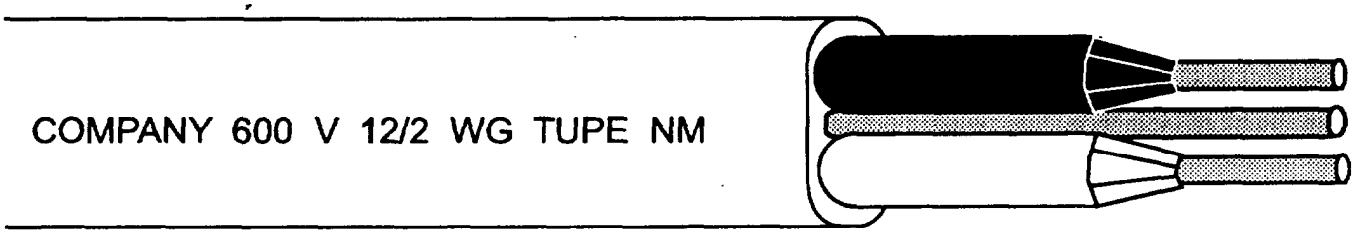
Cables

A cable is an assembly of two or more conductors insulated from each other with an additional insulating or protective shield formed or wound around the group of conductors.

Nonmetallic Sheathed Cable

Nonmetallic sheathed cable is more commonly called nonmetallic cable, NM cable, or Romex. Nonmetallic cable consists of two or three insulated conductors in an outer sheath. It may have an added insulated or bare conductor to be used as an equipment ground. The outer sheath is made of a moisture-resistant, flame-retardant, nonmetallic material either of thermoplastic or treated braid.

Nonmetallic cable has copper, aluminum, or copper-clad aluminum conductors. Copper conductors used in cable range in size from No. 14 to No. 2 AWG. The size of aluminum conductors is from No. 12 to No. 2 AWG. Specific descriptive information must be marked on the exterior of nonmetallic cable, repeating at intervals of at least every 24 inches. The information required to be shown includes the manufacturer's name or trademark, maximum working voltage, wire size, and cable type. Most cable is also marked to show the number of conductors and whether it has a ground, as shown in figure 5-8. The ground wire is used to ensure



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Figure 5-8.—Markings on nonmetallic cable.

the grounding of all metal boxes in the circuit, and it also furnishes the ground for the grounded type of convenience outlets.

Nonmetallic cable comes in two types: NM and NMC. Type NM cable has a flame-retardant and moisture-resistant cover. Type NMC cable is corrosion-resistant. Its covering is flame-retardant, moisture-resistant, fungus-resistant, and corrosion-resistant. Refer to the NEC©, Articles 336, for Types NM and NMC uses permitted and not permitted.

In naval installations, Romex is used primarily for temporary work, such as on Quonset huts. Civilian contractors, however, use it extensively for residential wiring. All connections in Romex must be at the junction or outlet boxes. Saddle, straight clamps, or cable connectors must be used for securing the cable to the boxes. In installations where Romex is permitted, the ground wire is fastened securely to create a good mechanical and electrical ground. When a bend is made in Romex, the radius of the bend should be not less than five times the diameter of the cable.

BOX SELECTION

There is no firm requirement that a certain type of box be installed for a specific purpose. The usual practice is to install octagonal boxes for lighting outlets and to install rectangular and square boxes for switches and receptacle outlets. Round boxes are normally installed overhead for lighting purposes especially where the fixture canopy must cover the box. However, when the need arises because of inside space requirements, wall-surfacing materials used, number of electrical devices to be mounted, or the availability of boxes, almost any box can be used for any purpose.

The size and number of conductors to be installed in a box have a definite impact on the selection of a box. Each conductor in a box must have some free air space to prevent a buildup of heat. As a result, the more conductors, or the larger their size, the bigger the box must be in which they are installed. The cubic inch capacity of a box is determined by its length, width, and depth. An increase in one or more of these dimensions increases box capacity. When gangable boxes are assembled together, box volume is the total of all sections assembled together. Also, when a raised cover or a box extension with volume markings is added to a box, as shown in figure 5-9, its capacity is added to the volume.

The box to be mounted in each location is selected after the number and size of conductors it will contain

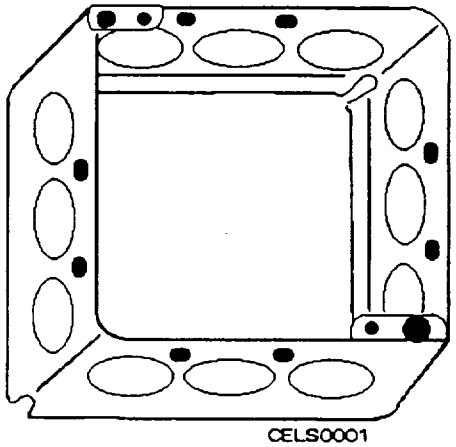


Figure 5-9.—Extension ring.

are known In many cases, the usual box for the intended purpose is not adequate. To ensure proper air space for a conductor in a box, consult the table 370-16(a) for metal boxes in the NEC©. This table lists dimensions for common boxes, their cubic inch capacity, and the maximum permitted number of conductors in wire sizes No. 14 through No. 6. The number of conductors listed does not make allowance for fixture studs, cable clamps, grounding conductors, switches, or receptacles, or straps for mounting these devices. One conductor must be deducted from those listed when the box contains one or more fixture studs or cable clamps. Each strap containing one or more devices requires deduction of one conductor.

Also, one conductor is deducted for one or more grounding conductors that enter the box. A conductor that runs through the box is counted as one conductor. Each conductor that terminates in the box counts as one. Fixture wires and conductors that do not leave the box, such as an internal grounding wire, are not counted.

Let us use an example to see how the table works. Two receptacle outlets are to be installed using No. 12 nonmetallic cable. One of the outlets is to be installed as an extension to the other. Device boxes with cable clamps are to be used if possible. The first step is to determine the number of conductors that will be wired through the box. Two conductors plus a grounding conductor enter this box. Also, if a second outlet is to be connected to this one, then two conductors plus a grounding conductor must leave the box. If the preceding rules are followed, we have four conductors plus one for the grounding conductors, the equivalent of one conductor for the cable clamps, and the equivalent of one conductor for the receptacle outlet. This method gives us an equivalent of seven conductors. In looking

at the table for metal boxes in the NEC©, we do not find a listing given for seven No. 12 conductors in a device box. There are a couple of listings for eight conductors; one indicates a device box 3 by 2 by 3 1/2 inches is required. Since there will be an equivalent of just five conductors in the device box for the second outlet, the table shows a 3 by 2 by 2 1/2-inch box to be adequate.

The table does not cover all the requirements for conductor space in boxes. Boxes of 100 cubic inches or less, not covered by the table, and nonmetallic boxes are marked with their cubic inch capacity. When these boxes are used or when conductors of different sizes are installed in the same box, the number of conductors allowed in a box is based on the free air space requirement for each conductor. The free air space needed is given in table 370-16(b) in the NEC©. According to the table, the volume of space needed in cubic inches per conductor is 2 for No. 14, .2 1/4 for No. 12, 2 1/2 for No. 10, and so on. As an example, if a box is to contain four No. 10 conductors and two No. 12 conductors, multiply 4 times 2 1/2 and 2 times 2 1/4. This equals 14 1/2 cubic inches, the minimum sized box that can be installed.

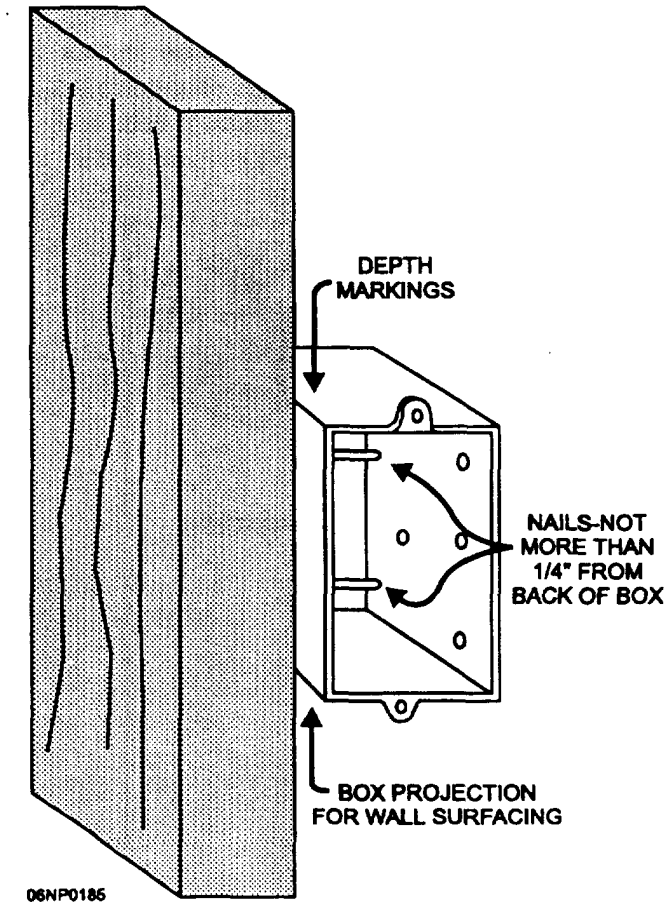


Figure 5-10.—Box installed with nails.

Outlet and junction boxes are installed in a number of ways in either new construction or an old building. Article 370 of the NEC© gives the installation rules for outlet, switch, and junction boxes. In most cases, boxes in new construction are fastened with nails or screws. Usually, nails are preferred because they are cheaper and quicker to use. Unless the box has a bracket on it, the side of the box must be removed to use screws for mounting. Some of the newer box mounting brackets have prepunched and preformed devices that are driven into wood framing to support the box in the place of nails.

Nail Through Box Mounting

One of the simpler boxes to mount is a device box. Boxes without brackets are mounted by putting two sixteen penny nails (3 1/2 inches long) through the holes in both sides of the box and then driving them into the wood framing member (stud). Nails that pass through the inside of a box must not be more than a quarter inch from the bottom (or back) of the box, as shown in figure 5-10. Also, note the markings on the side of the box. These are depth markings which let you easily install the box to project the proper distance from the edge of the stud to offset the thickness of the wall material that will be installed. Another way to mount device boxes with sixteen penny nails is shown in figure 5-11. In this case, the nails are outside the box, eliminating the possibility of wiring interference inside. The extension of the box sides, as is done here to provide for nailing, is often referred to as an S bracket mount. The bracket is made so that the nails can be driven in straight or on a slant, depending on whichever is easier. Being able to drive the nails at a slant is especially useful when the stud spacing is less than normal. The notches on the front outer ends of the bracket serve as a depth guide for mounting, the same as the markings mentioned before.

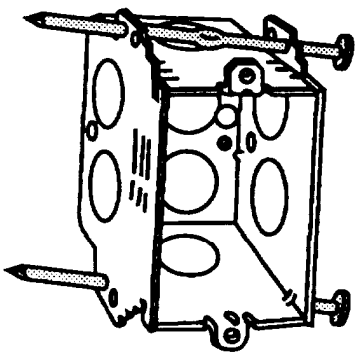


Figure 5-11.—S bracket box.

Many boxes come with attached brackets of various designs. Several of these brackets are shown in figure 5-12. The D bracket illustration is the simplest one of the group and is simply an extended box side. It is nailed or screwed to the stud. It also has notches to serve as an installation guide. The next bracket is the A bracket. As you can see, it is a straight bracket with a turned over upper edge that fits over the edge (face) of the stud. When nailed from both the front and side, this bracket makes an extremely strong mounting. The A brackets come attached to the boxes at varying distances from their edges to allow for use with different thicknesses of wall material.

The B bracket is made to fasten the box to the face of the stud. It has a couple of spurs that, when driven into the stud, hold the box in place while it is being nailed. The bracket may be attached to the box so it projects slightly above the edge, as shown in the illustration. This bracket prevents the device cover and its holding screws from causing a bulge when sheetrock is used for the wall surface. B brackets on device boxes are located at various depths to coincide with the thickness of the finished wall. Some B brackets are about twice as long as the one shown. These brackets are suitable for mounting on doorway framing studs to place switches and their cover plates beyond the edge of the door trim. This same bracket may be attached to the end of a device box for the horizontal mounting of a switch or receptacle. The J bracket is used the same as any other bracket that is fastened directly to the side of a stud. The holes are slotted to permit the box to be toenailed. The bracket is flush with the edge of the box and has gauging notches for positioning. This bracket has a knockout that allows installation of conduit through the stud into the box. The FA bracket is similar to the D bracket, except the bracket is welded to the side of the box. It also has a positioning spur to assist in holding the box in place while it is being nailed The bracket is offset from the edge of the box one-half inch or five-eighths inch to allow for the wall material thickness. The FH bracket is similar to the FA bracket, except it has two barbed hooks that drive into the face of the stud. The bracket is welded flush on square boxes and offset one-half inch on device boxes. Driving the barbed hooks into the stud face and nailing the side make a very rigid mount. The W bracket is fastened to both the face and side of the stud to provide a rigid mount. Since it stands the box off to the side of the stud, it is used to provide clearance between switches and switch plates and doorway trim, as does the long B bracket.

Box Mounting on Metal Framing

Much modem construction makes use of metal framing members. The ones you are concerned with mostly are the studs and the doorframes. Boxes can be attached with sheet metal screws or machine bolts and nuts. However, special attaching devices are available. A special anchor, as shown in figure 5-13, provides a

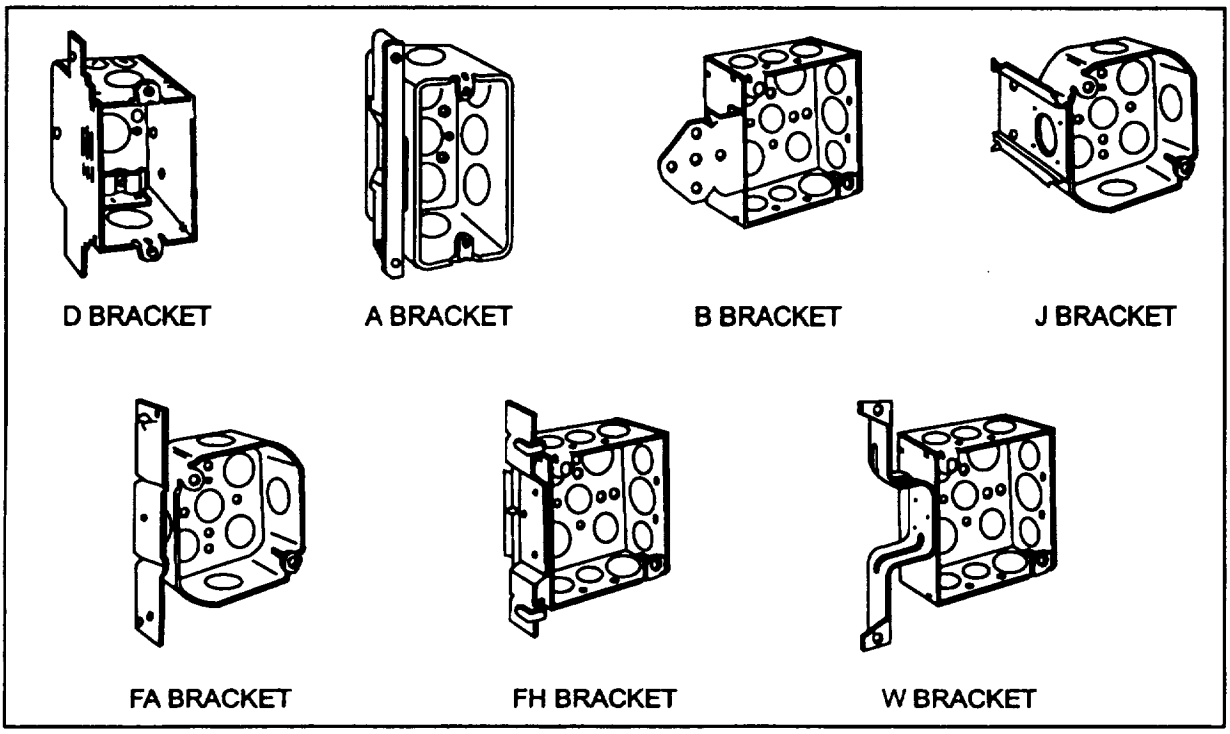


Figure 5-12.—Assorted box mounting brackets.

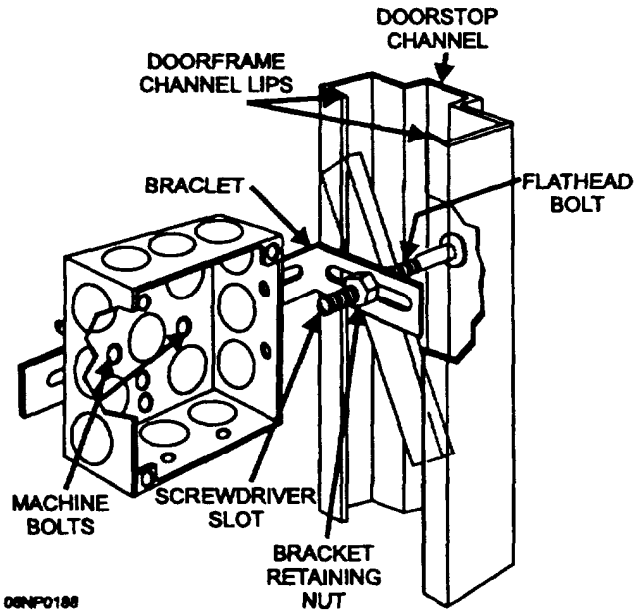


Figure 5-13.—Box mounting on metal doorframe.

quick, simple method of installing a box on the doorframe. This anchor allows the box to be adjusted in all directions; that is, toward or away from the frame, the depth from the outside wall surface, and up or down as needed. The nut on the bolt shown in the figure holds the bracket to the anchor and must be loose while the anchor is installed. The anchor itself consists of a flathead bolt with a screwdriver slot and a threaded channel. The channel comes in two sizes; one for narrow doorframes not over 4 inches wide and a second for doorframes up to 7 inches wide. The anchor is set in place by inserting it in the frame channel with the flathead of the bolt toward the doorstop channel and the threaded channel under the lips of the doorframe. The anchor is locked in place by inserting a screwdriver in the slot of the bolt and turning it clockwise until tight. As you can see in the figure, the bracket is adjustable and is held in position by the tightened nut on the bolt. The box is adjustable toward or away from the doorframe and is attached to the bracket with two machine bolts and nuts.

Metal spring clips provide a quick and easy way of mounting boxes onto metal studs. The same clip will work on studs of more than one design and size, such as 1 5/8- to 3 5/8-inch C channel studs and the truss type of studs. They are designed to mount square boxes with cover plates and to permit device boxes to be flush-mounted with various thicknesses of wall surfacing. A metal spring clip is shown at the left in figure 5-14. To mount a box, tap the clip over the open edge of the box. Then tip the box so the upper prong slips behind the face of the stud, as you can see at the right in figure 5-14. Press the lower prong back with your thumb until it slips

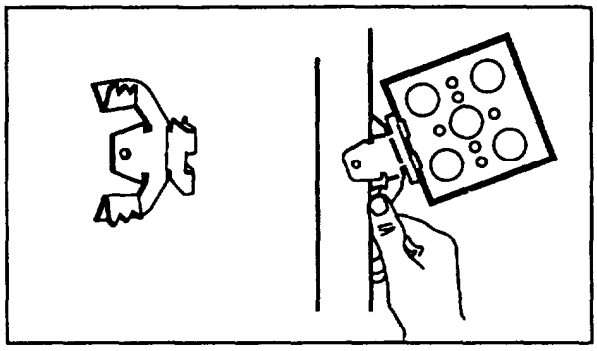


Figure 5-14.—Box mounting on metal stud with spring clip.

behind the stud face and locks the box in place. The box can be moved easily up or down on the stud by releasing the spring tension. Boxes can also be attached to metal framing members with sheet metal screws or machine bolts and nuts.

Box Mounting Between Framing

At times, boxes must be mounted between the building or wall supports instead of directly on them. This positioning is particularly true of ceiling lights where the joists do not coincide with the spot at which the light is to be placed. In such cases, boxes must be mounted on a separate support attached to the structure. These supports may be purchased in the form of bar hangers or metal straps, or they may be constructed from metal straps or wooden strips. Figure 5-15 shows

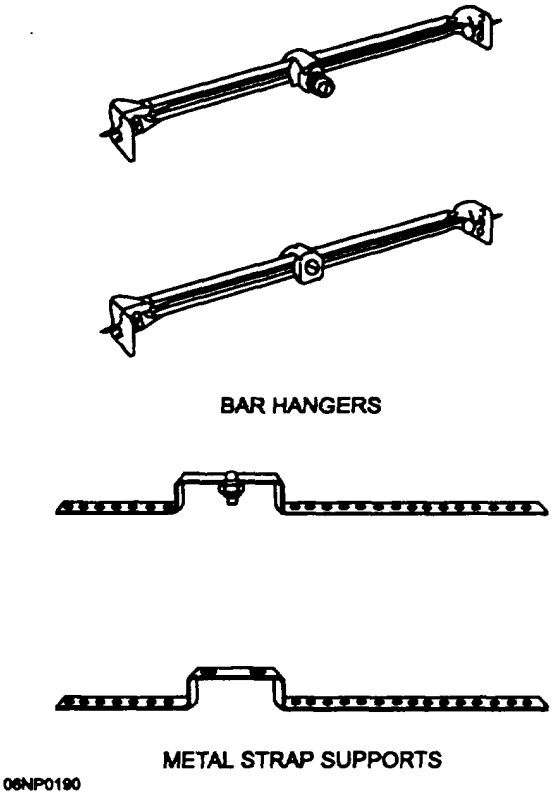
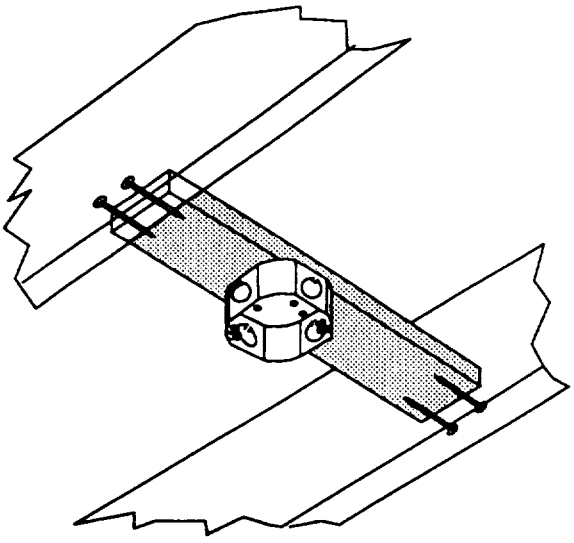


Figure 5-15.—Box supports.

two typical bar hangers and two metal strap supports. You can see that one of the bar hangers includes a fixture stud that also serves to support the box when it is installed through the knockout in the box bottom. The other bar hanger supports the box by means of a clamp installed through the bottom knockout. Bar hangers with boxes already attached are available. Bar hangers come in different lengths with each having a range of adjustment to fit spaces of varying widths. Bar hangers are fastened in place by nails driven into the side of the joist or stud. Sheet metal screws or machine bolts and nuts are substituted for nails when metal framing is involved. Metal straps may have fixture studs or may have slotted mounting holes so the box may be attached with machine bolts and nuts. Strap supports come in different lengths with several nail holes in each end to fit various width spaces. Strap supports are nailed to the face of the joist or stud They have different offsets to fit different box depths or installation needs.

Metal strap supports can be made similar to the manufactured one shown in the lower part of figure 5-15. Hole locations should be determined and holes drilled as needed for the specific installation being made. Wood supports can be made in a number of ways. About the simplest form is shown in figure 5-16. It consists of a piece of 1- by 4-inch lumber cut to length to fit between the joists and nailed in place. You need to allow for the depth of the box plus the thickness of the ceiling material when positioning the board for nailing. In some cases, two 1 by 4s may be nailed up with the wide dimension perpendicular to the joist or stud faces and the box mounted between them. Sometimes the ends of the 1- by 4- by 4-inch support is nailed to 1- by 4- by 4-inch blocks which, in turn, are nailed to the joists.



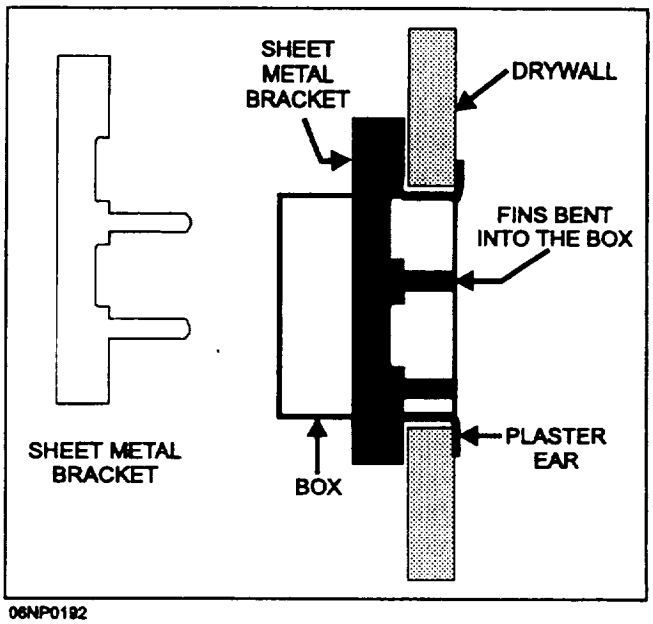
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Figure 5-16.—Woodbox support

Box Mounting in Existing Structures

A completely different method of box mounting is required when a concealed extension is to be made to an existing circuit or when a new concealed circuit is to be added in an existing structure. The procedures discussed here pertain to mounting boxes in hollow walls; that is, walls, such as sheetrock or plaster on studs. Boxes must be equipped with plaster ears to assist in anchoring them in place. One method of hollow wall mounting is shown in figure 5-17. This method uses two sheet metal brackets to hold the box in place. The first step for this type of mounting is to locate and cut the mounting hole. After the hole is cut, hold the box in place in the hole with the plaster ears against the wall. Slip a bracket with the fins pointing out, long end first, between the box and the wall. Slide the bracket up until the short end clears the hole. Rush the short end into the hole and slide the bracket downward to center the fins with the box. Bend the fins tightly over the box edge and down against the inside. Repeat these steps for the second bracket. The box should now be held firmly in place.

A second method of mounting a box in a hollow wall makes use of clamping devices attached to the box sides, as shown in figure 5-18. These boxes usually come with a stiff paper template to outline the hole that must be cut into the wall. If you do not have a template, put the box against the wall and draw around it. Be sure you do not include the plaster ears in your drawing. Cut the hole as indicated, Slip the box into the hole and tighten the clamping screws until the box is firmly anchored. One variation of this method works quite



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Figure 5-17.—Bracket support of box in hollow wall.

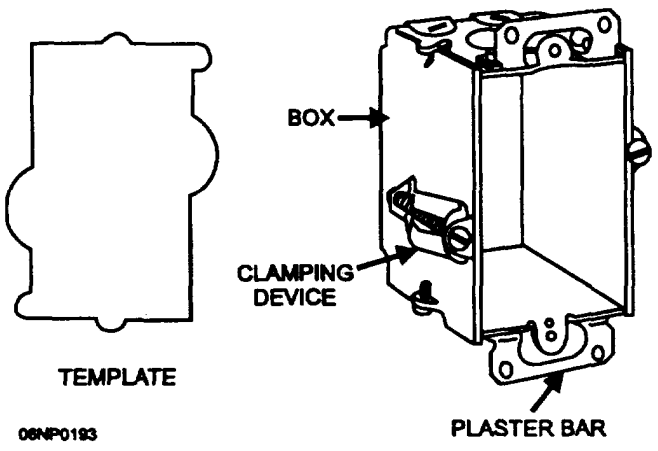


Figure 5-18.—Box with hollow wall clamps.

well with a lath and plaster wall. On the side of the box are cleats that unfold when the screws are tightened and clamp behind the lath. In this way, they support the ends that were cut when the hole was made.

A third means of fastening a box in a hollow wall uses a support that is added to the box through the knockout in the back. The application of this support is shown in figure 5-19. After the knockout is removed, assemble the support to the box by inserting the bolt with the retaining washer through the knockout hole. Thread the bolt into the support Rush the box into the prepared hole and press on the bolt head until the ends of the support spring clear on the inside. lighten the bolt with a screwdriver until the box is held securely in place.

Box Mounting Height and Location

There are no specific requirements for mounting boxes at a certain height. Mounting may be at any convenient height that meets the need for which the box is being installed. All boxes for the same purpose should be mounted at the same height. In some extreme cases, receptacle outlet boxes have been mounted in the wall parallel to the floor and just high enough to permit the cover plate to be installed. This type of installation requires that an allowance be made for the base finishing material as well as for the wall material when box depth is set. Receptacles set against the floor are hard to use and are hazardous in places where floors are mopped.

Heights for receptacle outlets and switches are usually given in the plans. The measurement may be from either the subfloor or the finished floor and may be to the bottom of the box; the center of the box, which is probably the most common; or the top of the box. The most popular height for receptacle outlet boxes in the living areas of a house is 12 inches from the floor line to the center of the box. Many electricians mark their hammer handles to use as a guide for installing outlet

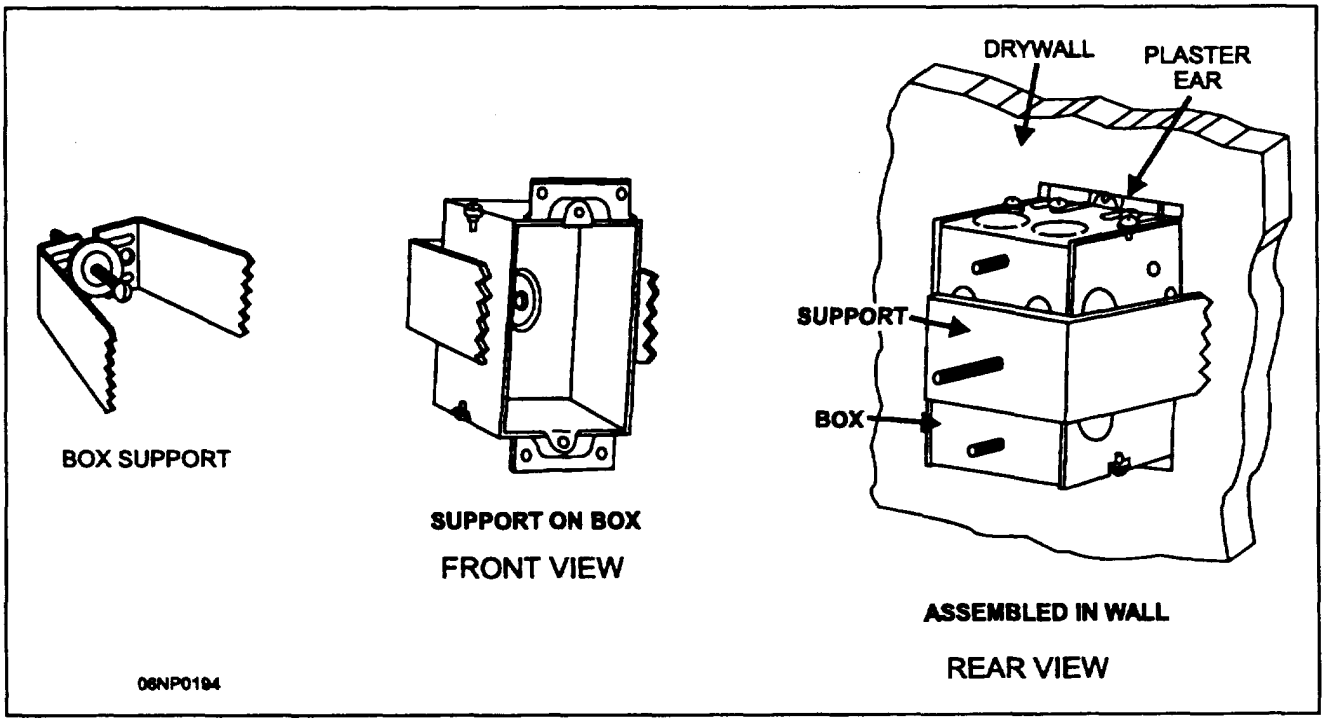


Figure 5-19.—Box support for hollow wall.

boxes at the proper height, as shown in figure 5-20. Any number of other guides, such as a rule or a notched stick, can be used.

It is a fairly common practice to mark the exact location of each wall-mounted box on the studs throughout the building before mounting begins. A lumber crayon, carpenter's pencil, or felt-tip pen that makes an easily seen mark should be used. An arrowhead, like that shown in figure 5-20, is used to show where the center of the box is to be placed. The arrowhead also points to the side of the stud where the box will be put. As an added convenience, symbols may be marked near the arrow to indicate the types of device to be installed. Some examples might be XX for a duplex outlet, SS for two single-pole switches, S3 for a three-way switch, or XR for a range outlet.

Switch boxes and outlet boxes for laundry and utility rooms and garages are normally set 4 feet above the floor. This height is often increased 4 to 6 inches when some type of wainscoting or paneling 4 feet high is to be included as part of the wall. Boxes for outlets over counter tops are usually installed about 18 inches above the counter top (see NEC Article 210-52(c)(5)). This measurement can vary a few inches up or down, depending on the height of the backsplash panel. Installing boxes without considering the splash panel could cause you to have boxes that overlap different wall surface levels.

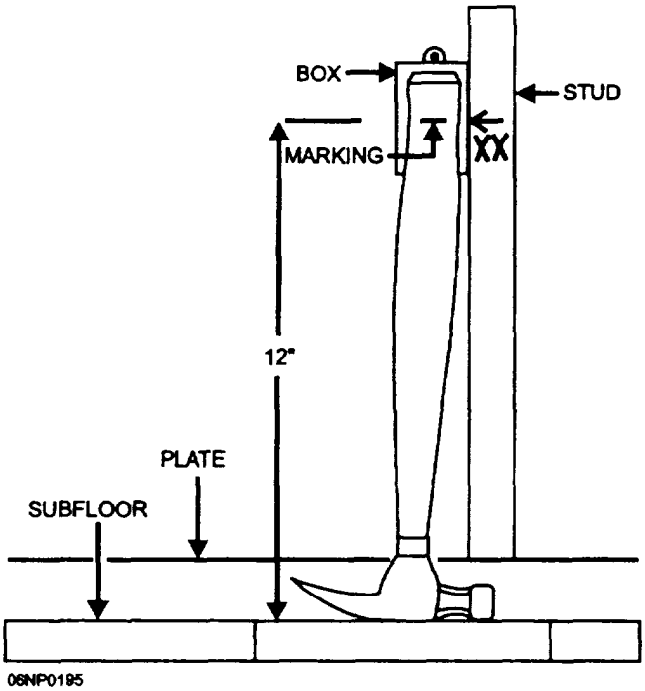


Figure 5-20.—Measuring box mounting height.

Ceiling boxes are located by a completely different method of measurement. Most rooms have at least one ceiling light located in the center of the room. A number of ways can be used to find the spot to mount this light box. One way is to use a rule or tape to find the halfway point across one dimension of the room and mark it, as shown in figure 5-21, view A. Make a second measurement across the same room dimension and mark the halfway point. Connect the two marks. Measure the other room dimension to find the center and mark it on the preceding line. This point is the place for the ceiling light box. Figure 5-21, view B, shows another way to spot the ceiling box. Run diagonals with string from opposite comers of the room. The point where the diagonals cross is the room center. Sometimes the position of the box is laid out on the subfloor. The point is then transferred to the ceiling by use of a plumb bob (a pointed weight on a string). When the plumb bob is suspended by a string held at the level of the ceiling joists with the point of the weight over the desired location, the top of the string will be at the spot where the box is to be mounted.

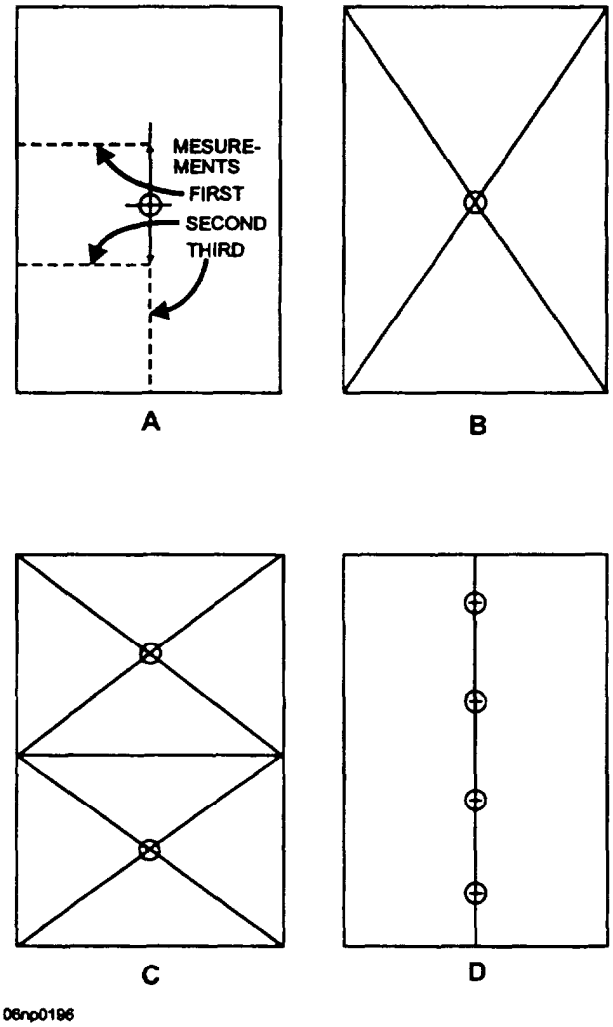


Figure 5-21.—Location of ceiling lights.

Many rooms require multiple ceiling lights. If only two lights are involved, measure half the length of the room and then run diagonals for each half, as shown in figure 5-21, view C. This measurement procedure gives you the location for each light. A room that is to be lit with a row of lights will have them installed along the center line. The lights should be spaced so that the lighting is as uniform as possible. You can determine the spacing by dividing the length of the room by the number of lights. This figure is the space that is to be left between any two adjacent lights. The light at each end of the row is placed at half the preceding distance from the wall. This spacing is shown in figure 5-21, view D. If you take another look at view C, you will see that the space from the end walls to the lights is also half that of the space between the lights.

INSTALLATION OF NONMETALLIC CABLE

Installation of electrical circuits with nonmetallic cable is fairly simple. It is usually done in two stages. The two stages are called roughing in and finish work. Roughing in is the work done before the walls and ceilings are put in place, and finish work is just what it implies, the finishing up. You splice wires as needed and install the receptacle outlets, switches, and lighting fixtures.

ROUGHING IN

The main objectives in roughing in are to get circuits routed properly, to reduce the chance of damage to the cable during installation, and to reduce the chance of damage while the structure is being finished or during later modifications. You should refer to Article 300 NEC© for wiring methods.

When roughing in your circuits, study your electrical blueprints. They will show the general location of the outlets and switches and how the cable is to be routed. The exact spot where each outlet and switch are to be put is determined by the requirements of the NEC© and the experience of you, the electrician, unless specific directions are given.

A straight line is the shortest distance between two points. This principle is used a great deal of the time by electricians when they are routing cables. Cable is run from box to box by the shortest route unless there is a good reason not to do this. Such routing does not always look neat, but it keeps the cost of material and labor down, and since most wiring is concealed, it is not often seen.

Cable must be fastened in place to support it and to prevent strain at boxes and connections. Cable must be anchored within 12 inches of a box, cabinet, or fitting and at points no more than 4 1/2 feet apart between boxes. NM cable is usually attached to wooden framing studs by staples (fig. 5-22). Care must be taken not to drive the staples in tight enough to damage the cable. Another method for securing Romex is by the use of straps. Figure 5-23 shows four types of straps that may be used to secure cables.

Concealed cable is installed either through holes bored in wooden framing studs or into notches cut in their edges. Holes can be bored with various sixes of bits, depending upon the size of hole needed. The holes should be drilled in the center of framing studs in a straight line and at the least possible angle either

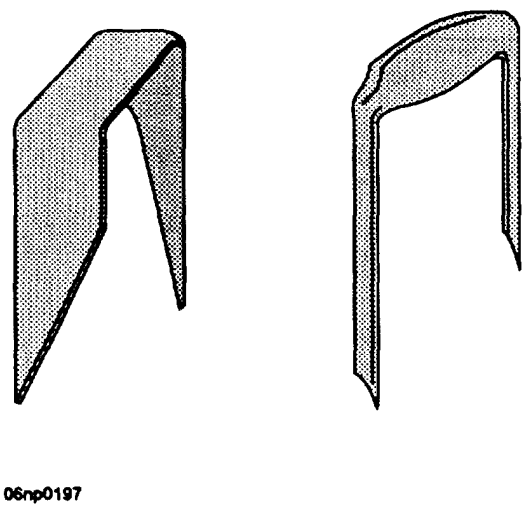


Figure 5-22.—Nonmetallic cable staples.

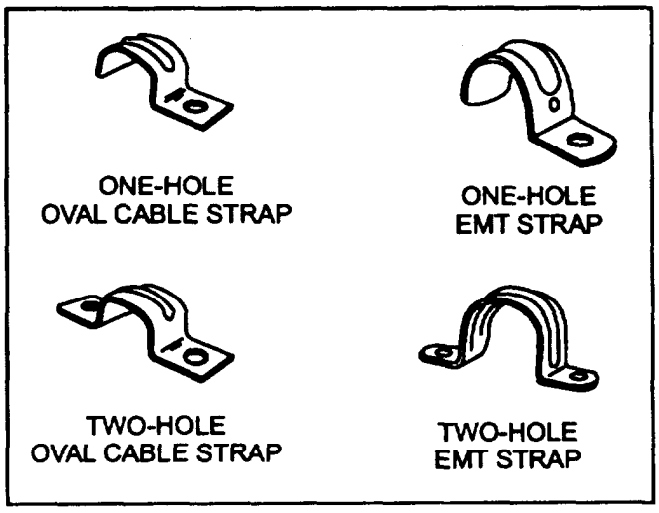


Figure 5-23.—Straps for fastening cable.

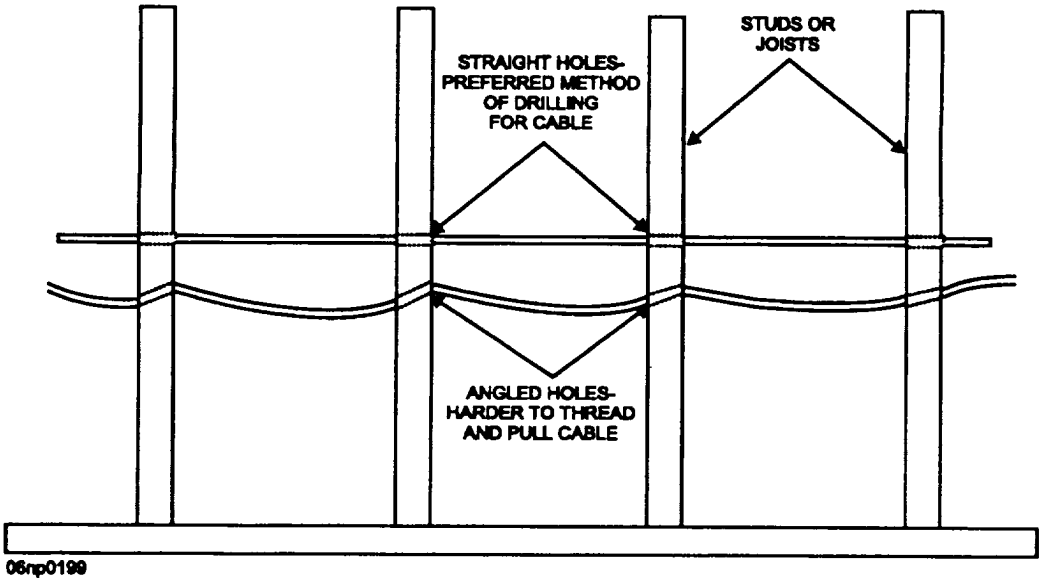


Figure 5-24.—Drilling holes for nonmetallic cable.

vertically or horizontally, as shown in figure 5-24. Holes that are drilled in a crooked line or at much of an angle to the line of pull, as shown at the bottom of figure 5-24, make it harder to thread the cable through the holes and pull it into position.

Cable can be placed into notches cut in the edge of the framing members and studs, as shown in figure 5-25, if the notches will not weaken the building structure. The notches should be as small as possible. Their depth must not exceed one fifth of the width of the wood. Cable placed in notches or through studs is protected from nails and screws by a thin metal plate at least one-sixteenth inch thick, according to the NEC©, Article 300-4, like those in figure 5-25.

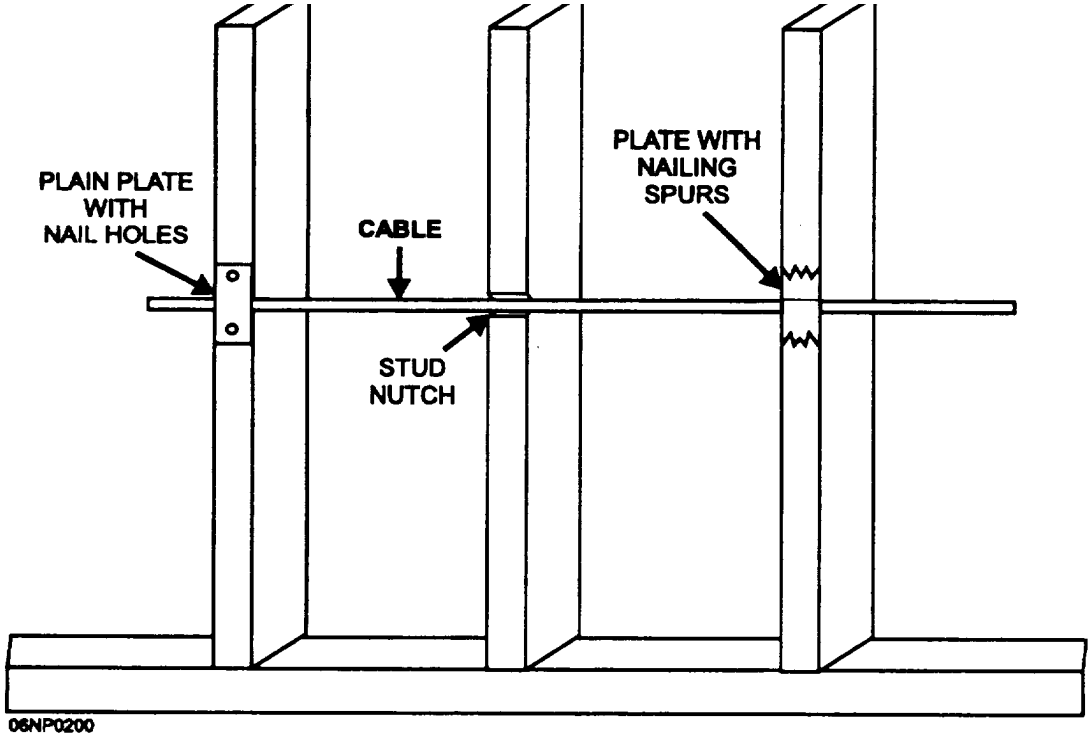
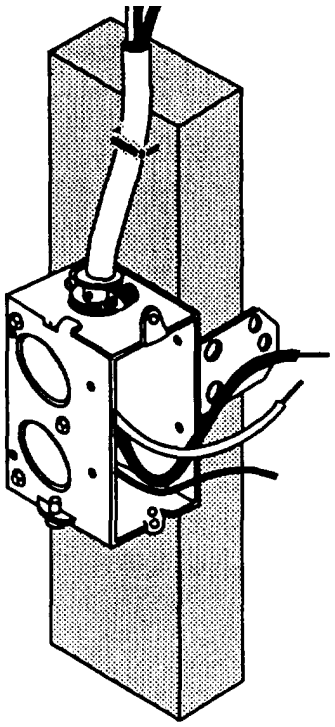


Figure 5-25.—Nonmetallic able installed in notches.

Cable is installed through metal framing members in about the same way as it is in wooden ones. Either holes or slots are used and they must be cut, punched, or drilled at the factory or in the field. Normally, holes in metal members must have bushings or grommets inserted securely to prevent damage to the cable covering. If holes or slots have been formed so that no metal edge can cut or tear the cable insulation, bushings or grommets are not needed. Use good judgment when deciding whether or not grommets are required. A steel sleeve, plate, or clip must be installed for protection wherever a cable might be punctured or cut by a nail or screw.

The first step in wiring a building after the distribution panel or panels have been installed is, in most cases, to mark the location of the outlet boxes. Then mount the boxes in place unless the mounting of a box might interfere with hole boring or cable anchoring. Once the boxes are in place, make the needed holes or notches for the installation of the cable. Install the cable by starting at the free end. Strip, as a minimum, 6 inches of the outside covering from the cable end. If the box has cable clamps, remove one of the knockouts and insert the stripped cable end through the hole under the clamp until one-fourth inch of the cable cover extends beyond the clamp. Tighten the clamp to hold the cable firmly in place, but be careful not to overtighten as this procedure could cause a short. This procedure will give you conductor ends 6 inches long in the box, as shown in figure 5-26. You need these ends so you can make splices or attach devices or fixtures easily. Remember to anchor the cable within 12 inches of the box, as shown in figure 5-26.



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Figure 5-26.—Cable termination at box.

Boxes without cable clamps require a little different procedure. After stripping the cable end, remove one of the box knockouts. Then install a cable connector, similar to the ones in figure 5-27, in the knockout hole. Install the locknut so that it points inward to dig firmly into the metal box as shown in figure 5-27. Put the cable end through the connector to expose one-fourth inch of the outer cover, and then fasten it in place, as shown in figure 5-25.

After the free end of the cable is in the box, work the cable back toward the other box. Run the cable along the framing members, fastening it at points no more than 4 1/2 feet apart. When you get to the other box, cut the cable to length, allowing for 6 inches of free conductor in the box. Strip the outside covering, insert the cable end, fasten it to the box, and anchor it within 12 inches of the box. To help avoid damage to the wires as wall coverings are being placed and other construction is being done, make sure you tuck back the wires into the outlet box.

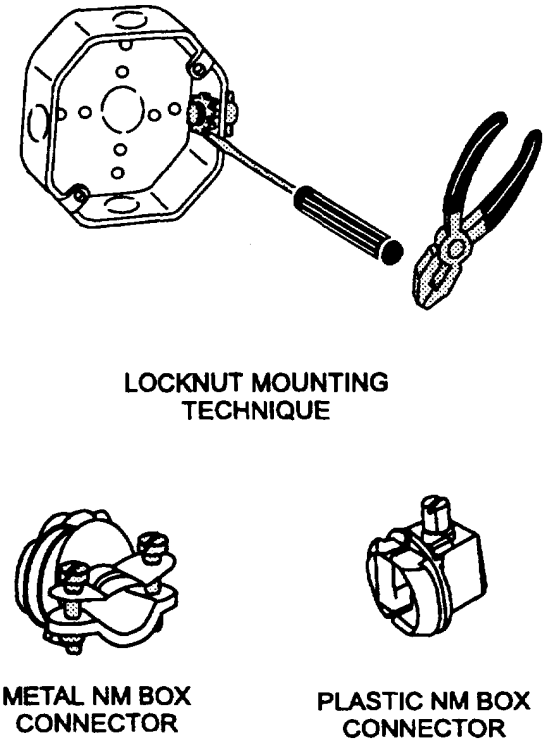


Figure 5-27.—Nonmetallic cable box connectors and mounting techniques.

Look at figure 5-28. As you can see, most of these cables are run through holes in the framing members. When holes are involved, you must plan ahead for easiest installation and the least waste. You would find it to be a little easier to run the cable between the two duplex receptacle boxes in the figure if you put a carton of cable near the box on the right and thread it through the holes to the box on the left. For the circuits that run from the left duplex receptacle box and the switch box to the ceiling outlet, the carton of cable should be placed under the boxes. Then you thread the cable up through the holes to the ceiling outlet. From these examples, you can see that you need to look at what is involved before you start to run the cable for a circuit. After you have completed the roughing-in phase of a project, your job comes to a halt for a time. In most cases, you should not start the finish work until the walls and ceilings are completed; after which you can splice wires as needed and install the receptacles, outlets, switches, lighting fixtures, and covers.

FINISH WORK

Once you begin the finish work, the first thing you need to do is to make all ground connections. Equipment grounding is the grounding of all exposed noncurrent-carrying metal parts of an electrical system to the earth. Grounding is done to protect anyone who might come in contact with these parts from being shocked and also to protect equipment from damage. Grounding is accomplished when all noncurrent-carrying parts are connected to a grounding conductor (or grounding has been achieved by other means, as approved by the NEC©), and the grounding conductor has been connected to earth at the service equipment or panelboard, as shown in figure 5-29. The equipment

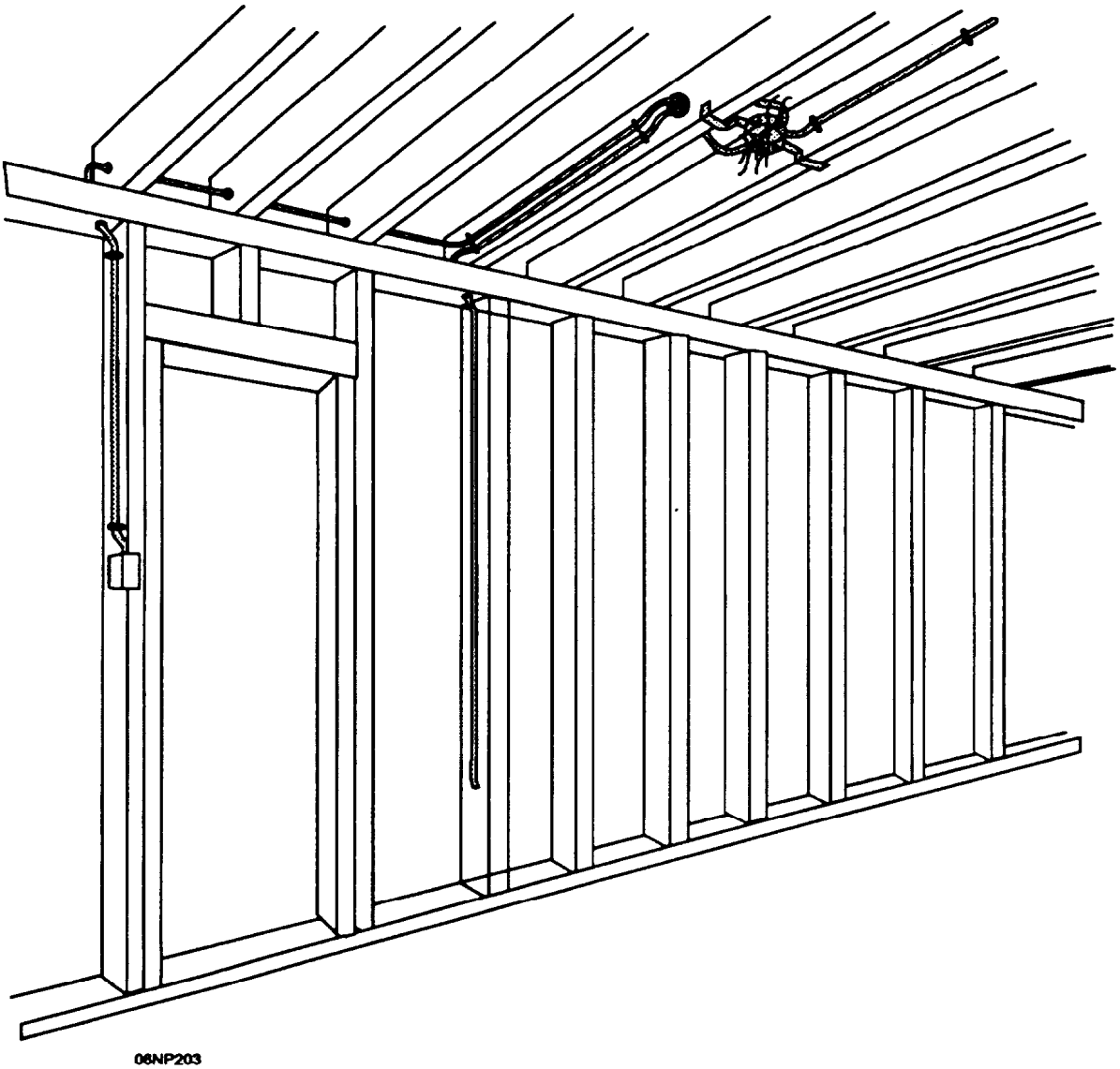


Figure 5-28.—Nonmetallic cable installation.

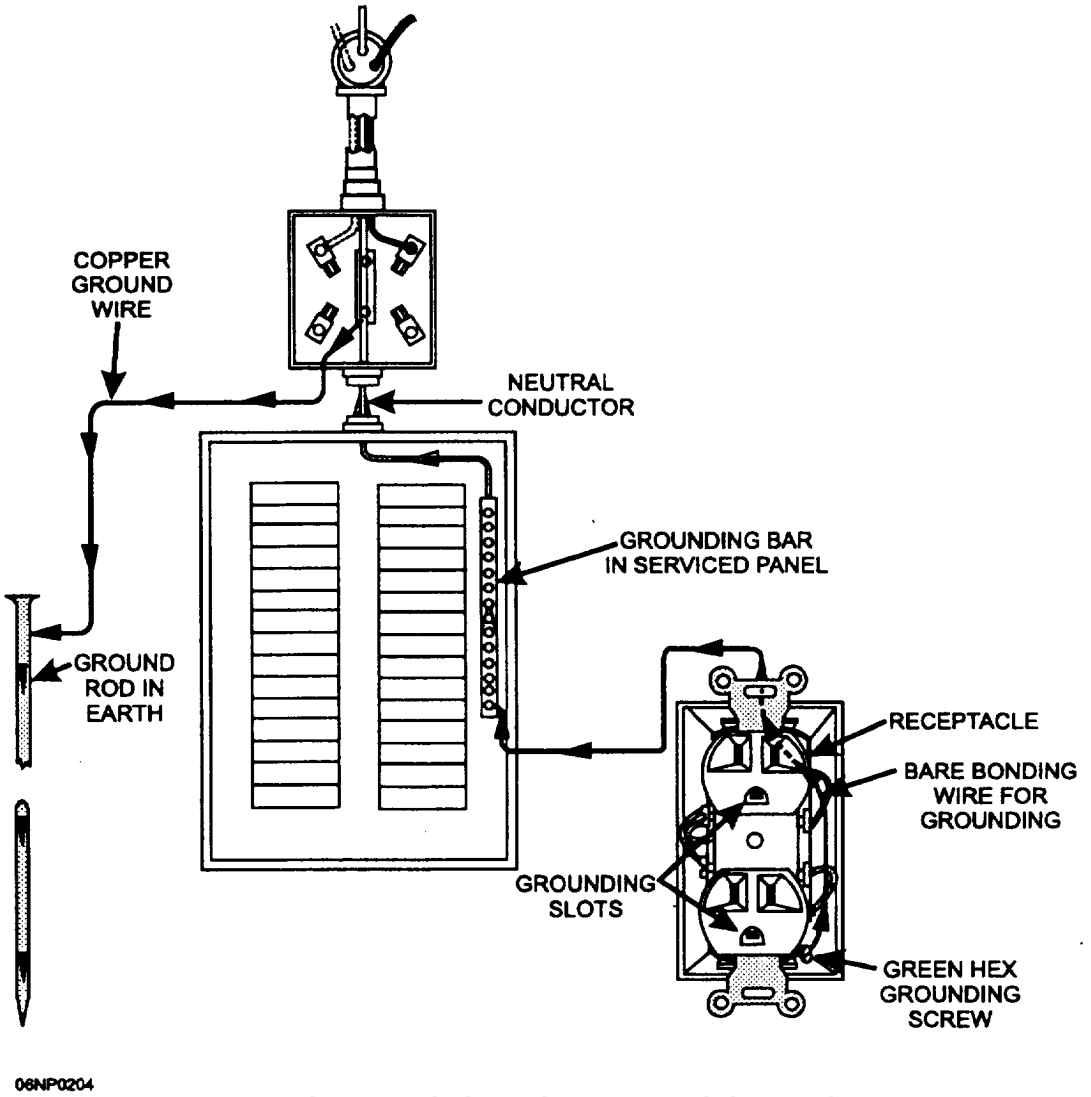


Figure 5-29.—Duplex receptacle electrical connection with the grounding system.

ground does not normally carry current. The only time it does is when there is a fault in the circuit. At all outlet boxes that require grounding according to the NEC©, the equipment-grounding conductor must be fastened to the box with either a grounding clip or a grounding screw, as shown in figure 5-30.

When we speak of installing a device, we should be aware that, according to the NEC©, a device is the part of an electrical system that is intended to carry, but not use, electrical energy; for example, switches and receptacles are devices. The grounded duplex receptacle comes equipped with a green hex-head screw to be used for connecting the ground wire. When more than one receptacle is connected in a circuit, the NEC© requires that these receptacles be connected to the grounding wire in such a way that the continuity of the circuit equipment ground is not broken if the receptacle is removed This grounding method is accomplished as

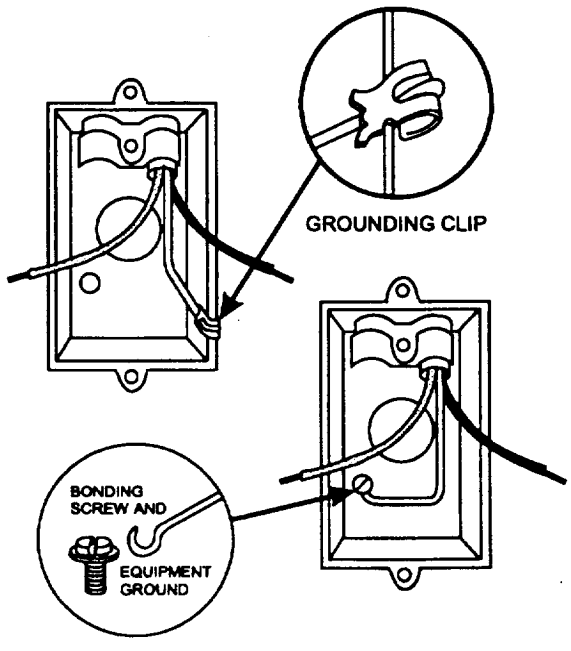


Figure 5-30.—Grounding clip and grounding screw.

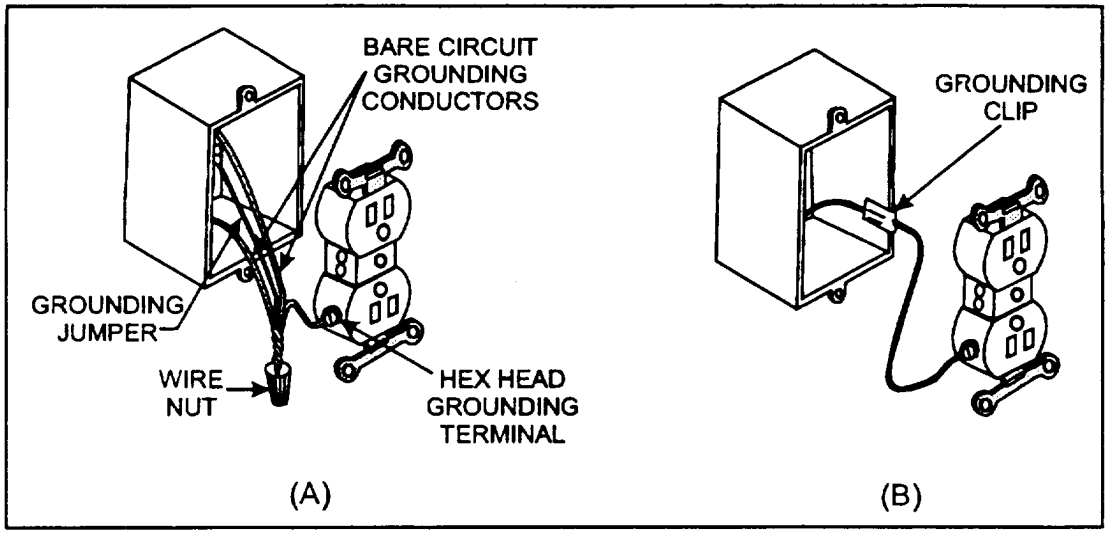


Figure 5-31.—Grounding methods: (A) More than one receptacle in line and (B) a single receptacle in a circuit.

shown in figure 5-31, view A. Figure 5-31, view B, shows an example of how you can ground a single receptacle in a circuit using a grounding clip. Grounding the receptacle in this way bonds the box, grounding wire, and receptacle, and precludes use of an additional jumper wire.

Now that we have made the ground connections, the next step of the finish work is to make terminal connections. Properly made terminal connections are important for several reasons. The operation of the circuit, prevention of tire, and safety of personnel all depend on good electrical connections. Electrical connections must be electrically and mechanically secure. There are two ways to make connections to devices: with or without using a terminal loop. The method of using the terminal loop and screw is shown in figure 5-32. Some receptacles and switches are made so that they can be wired from the back without using a terminal loop. This method is shown in figure 5-33. Now that you have made your terminal connections, you install the device into its box and secure it with the screws provided. The next step is to install the receptacle cover plates. Cover plates will be installed plumb, will completely cover the opening, and will be seated against the mounting surface.

When installing switches for interior wiring, you use single-pole, three-way, or four-way toggle switches. Most of the switches you use will be single-pole, but occasionally you will have to install a three-way system, and on rare occasions, a four-way system. Still another system of switching, called the low-voltage system, is coming into use.

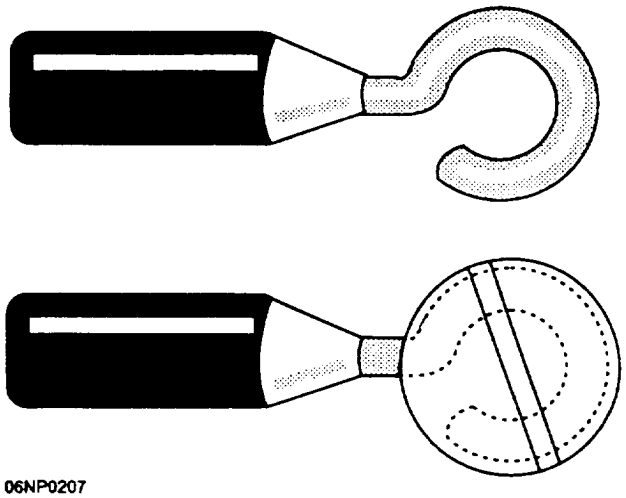


Figure 5-32.—Wire terminal loop.

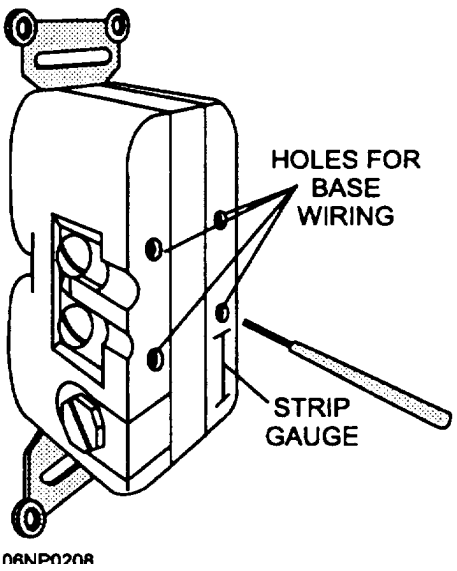


Figure 5-33.—Back-wired receptacle.

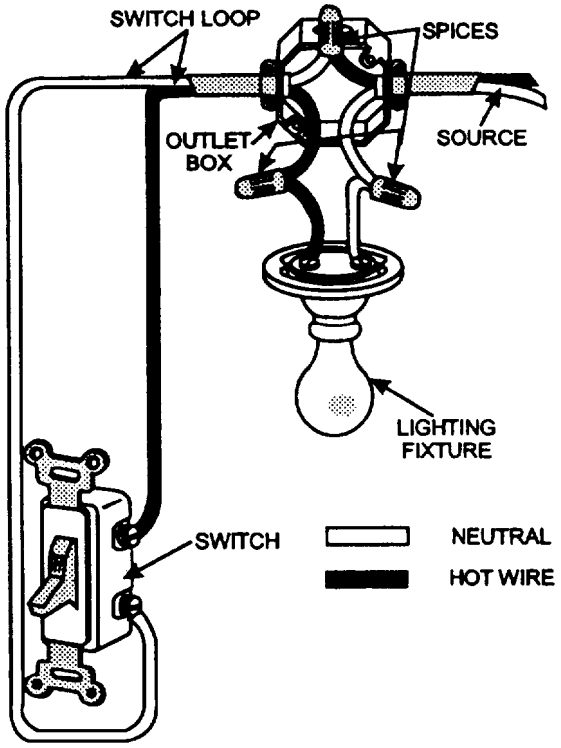


Figure 5-34.—Single-pole switch circuit.

A single-pole switch is a one-blade, on-and-off switch that may be installed singly or in multiples of two or more in the same metal box. In wiring a single-pole switch, a general rule is a neutral conductor (white wire) should not be switched or used as one leg in a switch loop. This rule is easily followed in conduit systems but does not apply to armored and nonmetallic sheathed cable. Article 200-7 of the NEC© contains the exception to this rule. Figure 5-34 shows a single-pole switch circuit using nonmetallic sheathed cable.

In a three-way switch circuit, you may turn a light on or off from either of two positions. The typical situation is one in which one switch is at the head of a stairway and the other at the foot. Figure 5-35 shows how the circuit functions.

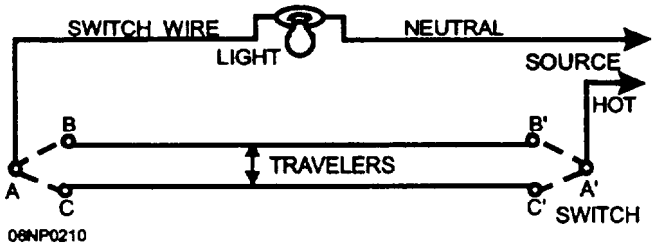


Figure 5-35.—Three-way switch circuit.

Terminals A and A' are the common terminals, and switch operation connects them either to B or C and B' or C', respectively. Either switch will operate to close or open the circuit, turning the lights on or off.

By tracing the circuit in figure 5-35 from the source, you can see that the hot wire goes to the first switch, through the closed switch blade to the other switch by way of the traveler, and through the closed switch blade to the other switch by way of the traveler, and through this switch to the light. If the position of either of the switches is changed, the circuit is broken.

One or more four-way switches may be used with two three-way switches to provide control of a lamp from three or more different points. A four-way switch is an extension of a three-way circuit by the addition of a four-way switch in series with the two traveler wires. Figure 5-36, view A, shows how a four-way switch is used in combination with two three-way switches to control a lamp from three locations. By tracing this circuit from the source, you observe the hot wire connected to Switch C passing through Position 1, which is closed. The hot wire continues to Point 4 on the four-way switch (B). At this time the toggle on Switch B is in the UP position, and contact is made from Point 4 to Point 3. The hot wire continues on through the traveler to Switch A, and through Position 2 (which is closed) to the light.

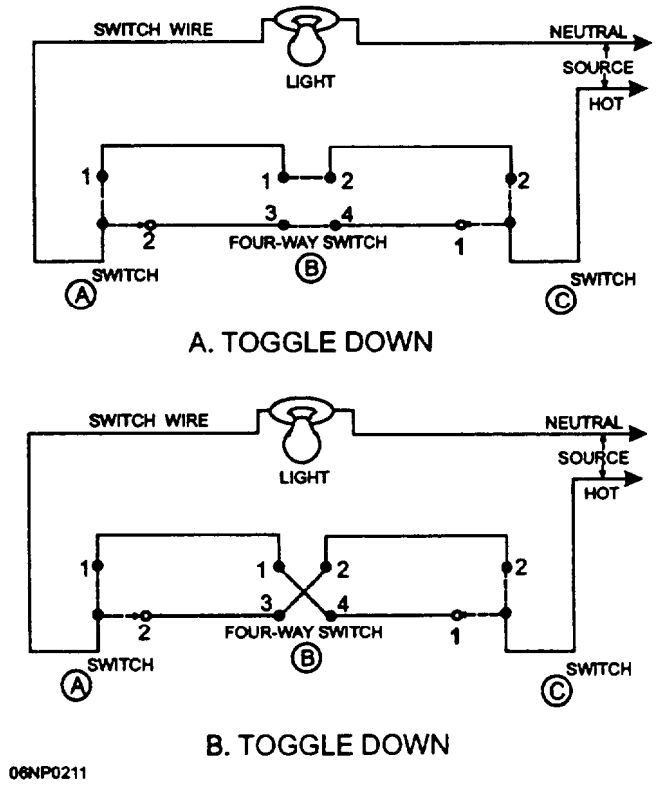


Figure 5-36.—Four-way switch circuit.

Suppose, now, that you want to turn the light off at the four-way switch (B). By putting the toggle in the OFF (down) position, you change the switch blades from Points 1 to 2 and 3 to 4 to Points 1 to 4 and 2 to 3. (See fig. 5-36, view B.) If you now retrace the circuit from Switch B to Switch A, you will find that it goes from Point 4 to Point 1 on Switch B and through the traveler to Switch A to Point 1 where the circuit is broken by the blade being in the open position.

Note that three- and four-way switches may be used as single-pole switches, and four-way switches may be used as three-way switches. However, three- and four-way switches are usually larger than single-pole switches and take up more box room. The size of a switch depends on its ampacity (rated maximum amperage). The ampacity and maximum allowable voltage are stamped on the switch and must be considered when you order equipment for the job.

REMOTE CONTROL WIRING

Remote control wiring provides a method of controlling standard voltage devices through the use of low voltage. They consists of relays, low-voltage switches, and transformers. A low-voltage conductor cable is used instead of conduit or Romex. Low-voltage wire is available as three, four, and multiple conductor cables. Multiple conductors are color coded to identify them. Roughing in a remote control wiring system uses many of the wiring techniques used with nonmetallic cables.

Remote control relays have two coils (on or off) with a common center tap. The use of two coils allows the relay plunger to be moved positively in either direction without the use of springs. When a push button (switch) is turned ON, current will pass through the ON coil and cause the movable core to shift into the ON position. The contacts are closed in the load circuit and the light goes on. The same happens when the OFF button is depressed. The current is passed through the OFF coil and the core moves. The contacts open and power to the light is turned off. The relay will maintain this position until the push button again energizes the ON coil. These relays are capable of controlling 20 amperes of lighting or inductive loads at 110 or 277 volts ac. Relays can be mounted individually in junction boxes as shown in fig, 5-37, or several may be mounted in a centrally located cabinet.

Transformers in a remote control system reduce 120-volt line voltage to 24 volts to provide power in the switching/relay circuit. Wherever transformers are located, they must be accessible and they must be kept

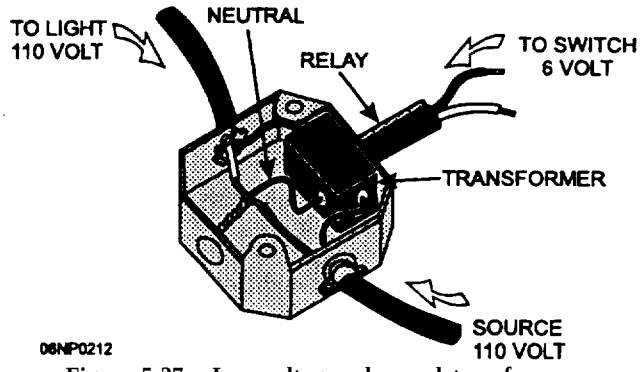


Figure 5-37.—Low-voltage relay and transformer.

from excessive heat. They are sized according to the number of relays they will power.

In the low-voltage system, as many switches as are required can be installed for any given light, or a master switch can be installed to turn on as many as eight lights simultaneously. There is no necessity for three-way or four-way switches because the switches are connected in parallel.

CONDUIT SYSTEMS

As a CE, you will be called upon to install all types of wiring systems. Unlike the electricians in civilian life who often specialize in the installation of specific types, you have to be able to install any type. In most locations you will have to install wiring systems that require the added protection provided by conduit. Conduits are of various types, such as rigid, flexible, intermediate metal, PVC, and electrical metallic tubing (thin-wall or EMT). As you read this section, you should become familiar with the different ways of bending, cutting, and threading; the fittings used; and the different locations where they may be used.

CUTTING AND THREADING

The use of rigid conduit involves a good deal of cutting and threading of lengths. It is best to cut with a hacksaw or special conduit cutter. An ordinary

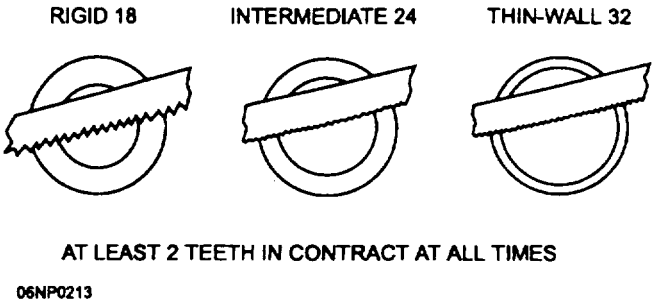


Figure 5-38.—Hacksaw blades, teeth per inch, for different types of conduit.

revolving wheel pipe cutter leaves a heavy inside ridge that is difficult to remove and may damage the passing through of conductors. Always ensure that you make a cut at right angles to the axis of the pipe (fig. 5-38).

Thin-wall conduit (EMT) and polyvinyl chloride (PVC) should be cut with a hacksaw because pipe cutters may flatten the end of the pipe. The pipe cutters also leave a ridge on the inside of the pipe that is hard to remove. There are tubing cutters made specifically for cutting EMT or PVC, but you need to be sure you have the right cutter for the job. When you are cutting conduit, use a vise to stabilize the conduit.

Flexible conduit and tubing should also be cut with a hacksaw. Because of its spiral construction, flex should be cut at an angle so that only one ribbon is cut all the way through. A slight reverse twist will separate the two ends (fig. 5-39).

Cutting any type of conduit leaves a sharp edge or burr on the inside of the pipe that must be removed by reaming. Reaming can be done with several tools. To ream rigid and intermediate conduit, you should use a pipe reamer. A rat-tailed file does a good job on any type of conduit. To ream EMT that has been cut with a hacksaw, you should use the heads of a pair of pliers, such as needle nose or side-cutting pliers, and they will do the job. The important thing is to remove any edges, or burrs, in the pipe that might cut the insulation when the conductors are pulled into the conduit.

The next step is cutting the thread on the end that was cut off. For the smaller pipe you use a ratchet type of die that turns directly with the handle. On larger pipe you use a die with a mechanical advantage; that is, you use a die that makes only a part of a revolution when the handle makes a complete revolution. Hand-held portable electric and shop type of threading machines are also available.

A conduit-threading die, like a plumber's die, makes a tapered thread, so that a coupling starts rather loosely but binds hard as it is set up. This tight connection serves two purposes: it makes a watertight joint and it makes a good electrical connection for a continuous ground throughout the length of the conduit.

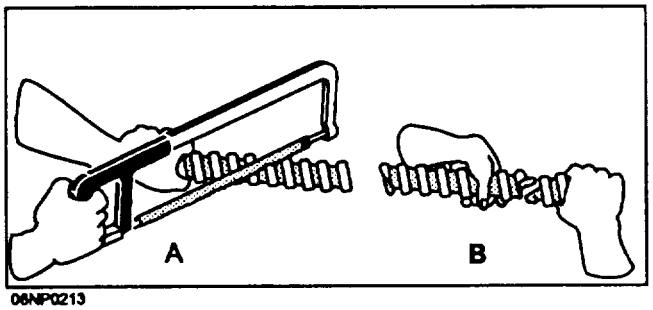


Figure 5-39.—Cutting flexible conduit.

Rigid polyvinyl chloride (PVC) conduit has been developed by many manufacturers. Some of the advantages of PVC conduit are the light handling weight, high corrosion resistance, ease of installation, leakproof joints, and easy wire pulling (because of the mirror-like walls). Refer to Article 347 of the NEC© for installation requirements.

Permanent joints are made quickly in PVC conduit by cutting the conduit with a handsaw or hacksaw and removing the burrs with a pocketknife. When joining PVC conduit, always follow the manufacturers' instructions listed on the cement can for best results. A variety of threaded PVC fittings are available from manufacturers. Their use is covered in Article 370 of the NEC©. The preferred method of installation is by the solvent-welding technique because the joints are waterproof and vapor-proof.

CONDUIT BENDING

The NEC© Article 346 through 348 applies to electrical conduits. It states that the "bends in conduits will be made so that the tubing will not be injured and that the internal diameter of the conduit will not be effectively reduced." In addition, the NEC© has a table that indicates the minimum radius acceptable for various sizes of conduit. It also states that "a run of electrical conduit between outlet and outlet, between fitting and fitting, or between outlet and fitting, will not contain more than the equivalent of 4 quarter bends (360 degrees total) including those bends located immediately at the outlet or fitting."

When installing conduit, you will need to make bends to go over or around obstacles. Bends of various shapes will be needed, such as right-angle or 90-degree bends, offsets, and saddles. These bends must be made without reducing the inside diameter of the conduit in the bend. You will make most of these bends on the job as part of the installation procedure. They are called field bends. Factory-made bends may be used instead of field bends; however, they will cause you more cutting and threading, and they increase the cost of the job.

Most of the field bends will be done with manual benders or a hot box heater in the case of rigid nonmetallic conduit. Manual benders used to bend rigid conduit and EMT are of two types. These are the rigid

bender, called a hickey (fig. 5-40), and the one-shot bender (fig. 5-41). The one-shot bender is normally made for EMT, but some are made to be used for both EMT and rigid. The one-shot bender was given this name because a full 90-degree bend can be made with a single motion. Conduit sizes up to 1-inch rigid or 1 1/4-inch EMT can be bent without much trouble with manual benders. Larger sizes are bent with mechanical or hydraulic benders. Hydraulic benders will be discussed at the second-class level.

Rigid Nonmetallic Conduit

Although a complete line of factory elbows (90, 45, or 30 degree) are available, bending PVC conduit (1/2 through 2 inch) is accomplished easily with the use of a PVC hot box. A PVC hot box is nothing more than a heater, enclosed by metal having a mirror finish on the inside with openings on each end. To bend PVC conduit, place the conduit inside the hot box, turn the switch on, rotate the conduit until it becomes flexible, remove the conduit, and bend it to the desired shape.

WARNING

The hot box is a heater. If you leave the conduit in long enough, it will BURN. You should use gloves when bending PVC.

Electrical Metallic Tubing (EMT)

Conduit bending is a precise art form. You will use degrees, angles, measurements and prefigured deductions for radiuses and shrinkage. Combine all these calculations correctly and you will get a finished product that is not only functional but pleasing to the eye, and something to be proud of.

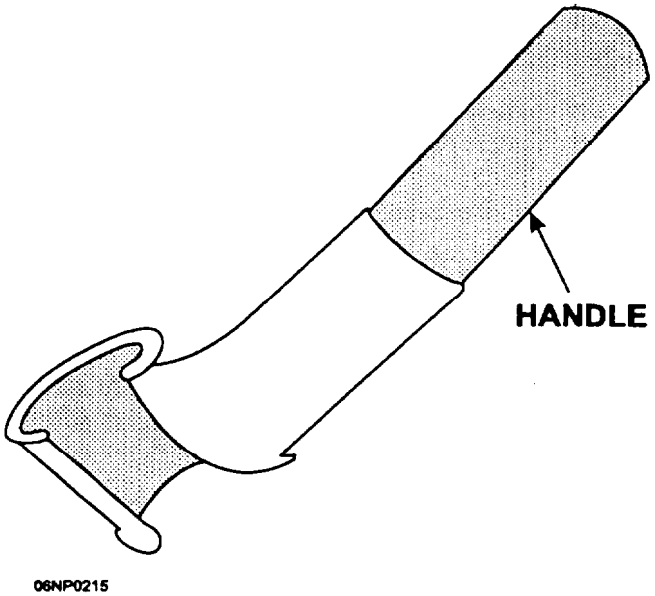


Figure 5-40.—Hickey.

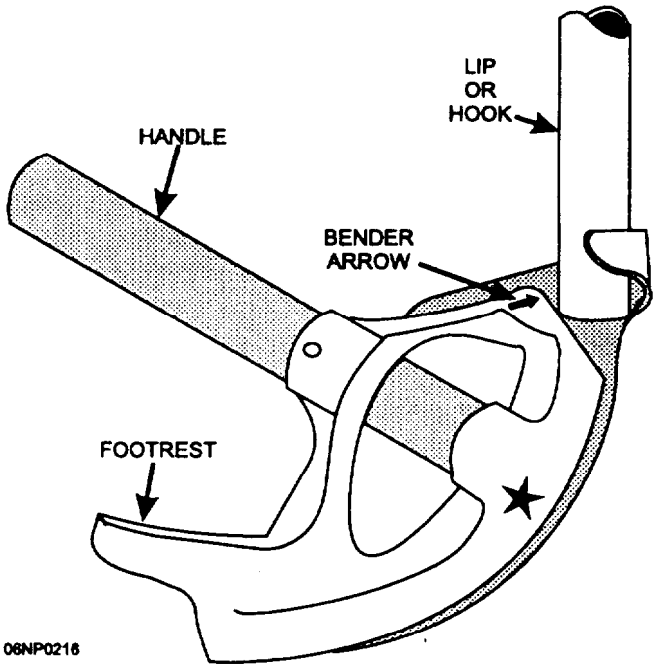


Figure 5-41.—One-shot hender.

90 DEGREE BENDS.—One of the most common bends you will make in the field is the right-angle bend, more commonly called a 90-degree bend, or just a 90. Anyone can make a 90 in a stick of conduit and then cut it off to make it fit the situation, but this practice wastes time and material. The secret is to bend the conduit in the right place so that you do not have to cut it. To accomplish this, there are some things you have to know. First, you need to know the distance from the end of the conduit to the back of the 90. This distance is called the stub-up. Second, the radius of the bend takes up a part of the stub-up. This part is called the take-up. The amount of take-up depends on the type and size of conduit you are bending. (See table 5-2.)

Table 5-2.—Conduit Take-up

AMOUNT OF TAKE-UP FOR 90° BENDS (ONE-shot Benders)	
SIZE AND TYPE OF CONDUIT	TAKE-UP
1/2" EMT	5"
3/4" EMT OR 1/2" RIGID*	6 "
1" EMT OR 3/4 RIGID*	8 "
1 1/4" EMT OR 1" RIGID*	11"
*IMC AND RIGID WILL BE THE SAME	

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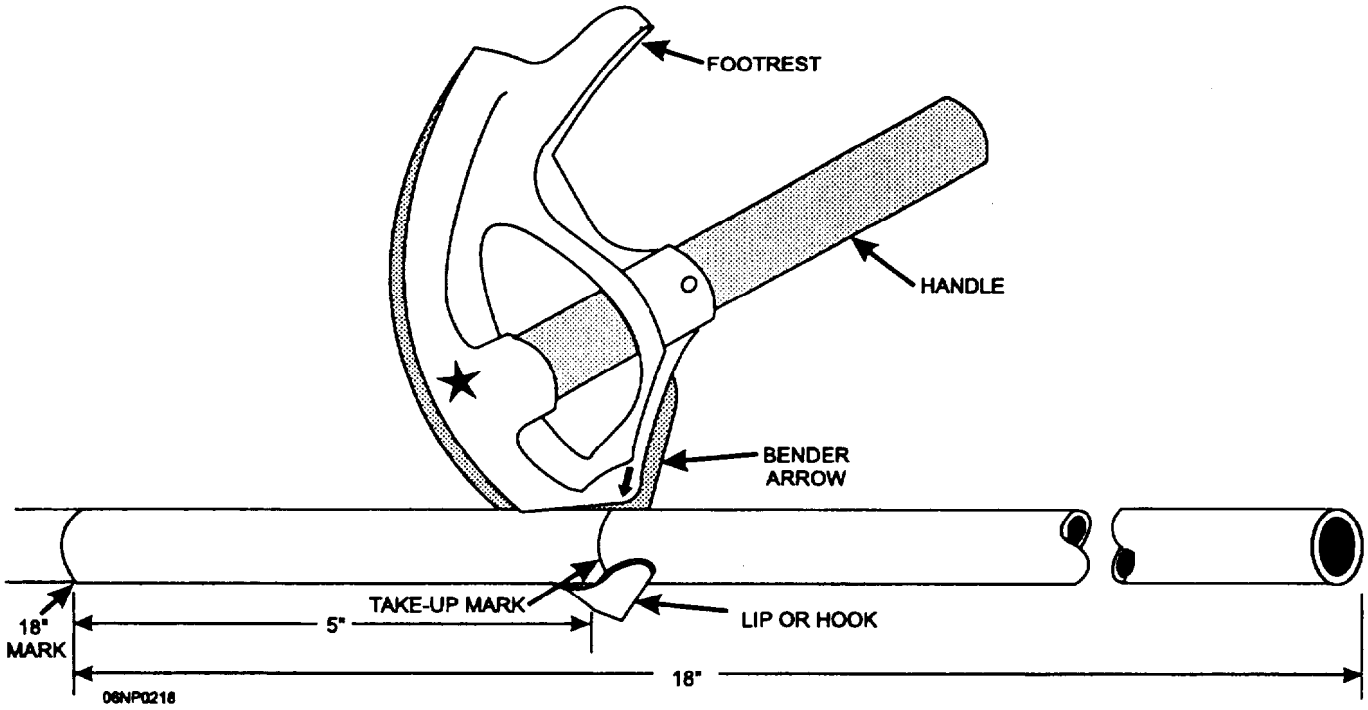


Figure 5-42.—Alignment of arrow and take-up mark for bending a 90.

Now, let us see how a 90 is made to fit a specific situation. Suppose you are going to run the conduit from the top of a panel to the ceiling and then horizontally along the ceiling, using 1/2-inch EMT and a one-shot bender. The first step will be to measure from the top of the panel to the ceiling. This measurement will give you the stub length. Assume the length is 18 inches. Measure 18 inches from the end of the conduit and make a mark at that point. Next, look at table 5-2 and find the take-up for 1/2-inch EMT. The take-up is 5 inches. Now, measure 5 inches back toward the end of the conduit from your first mark and make a second mark. This measurement gives you the take-up. Place the conduit on the floor with the stub in front of you. Align the bender arrow with the take-up mark, as shown in figure 5-42. Put one foot on the footrest and hold the handle with both hands. Apply pressure on the footrest as you pull the handle until the handle is at about a 30-degree angle with the floor, as shown in figure 5-43. You should now have a 90-degree bend with an 18-inch stub. Remember: Heavy foot pressure is critical to keep the EMT in the bender groove and prevent kinked conduit. To check that the bend will fit the situation we started with, you can place it next to anything that you know is a right angle and measure from the floor to the end of the stub. If the bend is not a full 90, place the bender back on the conduit, and pull more bend. If it is more than a 90, place the handle of the bender over the end of the stub, place one foot on the conduit on the floor, and spring the stub back.

BACK-TO-BACK BENDS.—The back-to-back bend is actually two adjacent 90s made in the same piece of conduit. You make the first 90 with the amount

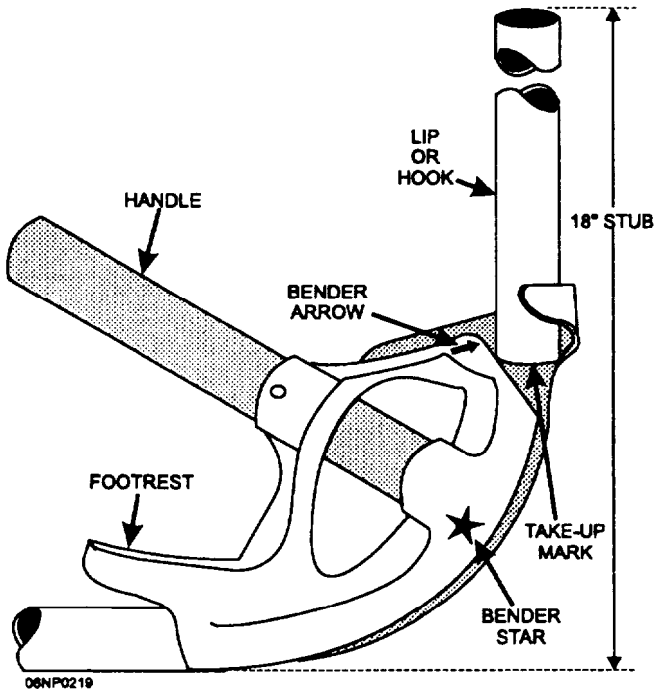


Figure 5-43.—Right-angle bend, 90.

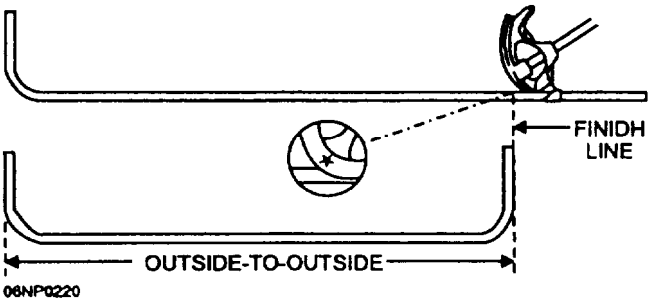


Figure 5-44.—Using the star for back-to-back bend.

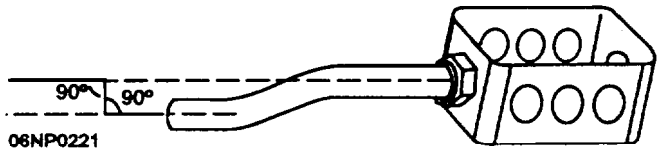


Figure 5-45.—Box offset.

of stub you need, as described previously. To determine where to place the next stub, you first need an outside-to-outside measurement. This measurement is the distance from the back of the first bend to the point where you want the back of the second bend.

Two methods are used for making the second bend. The first is to subtract the take-up, use the arrow on the bender, and pull the bend in the same direction as you did the first bend. The second method, and probably the easiest, is to turn the bender around, line up the star on the bender with your outside-to-outside measurement, and pull the bend in the opposite direction, as shown in figure 5-44.

Table 5-3.—Offset Bending Formula

FORMULAAND CONSTANT MULTIPLIER FOR DETERMINING DISTANCE BETWEEN BENDS WHEN BENDING OFFSETS		
FORMULA **OFFSET DEPTH X CONSTANT MULTIPLIER = DISTANCE BETWEEN BENDS**		
ANGLE OF BENDS	CONSTANT MULTIPLIER	SHRINKAGE
22 1/2°x 22 1/2°	2.6	3/16” PER INCH
30° x 30°	2.0	1/4” PER INCH
45° x 45°	1.5	3/8" PER INCH
60° x 60°	1.2	1/2” PER INCH

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OFFSET BENDS.—An offset bend is two equal bends in opposite directions. It is used to avoid contacting a part of the structure or to bring the conduit out from the structure to match a knockout in a box or panel. The angle of the bend in an offset depends on several things; how much offset is needed, how much room there is where the offset is going to be placed, and the type of obstacle you are avoiding. Figure 5-45 shows a box offset into a handy box. There is no way to mark the conduit for a box offset. The amount of bend and the distance between bends are estimated. The key to making good box offsets is practice.

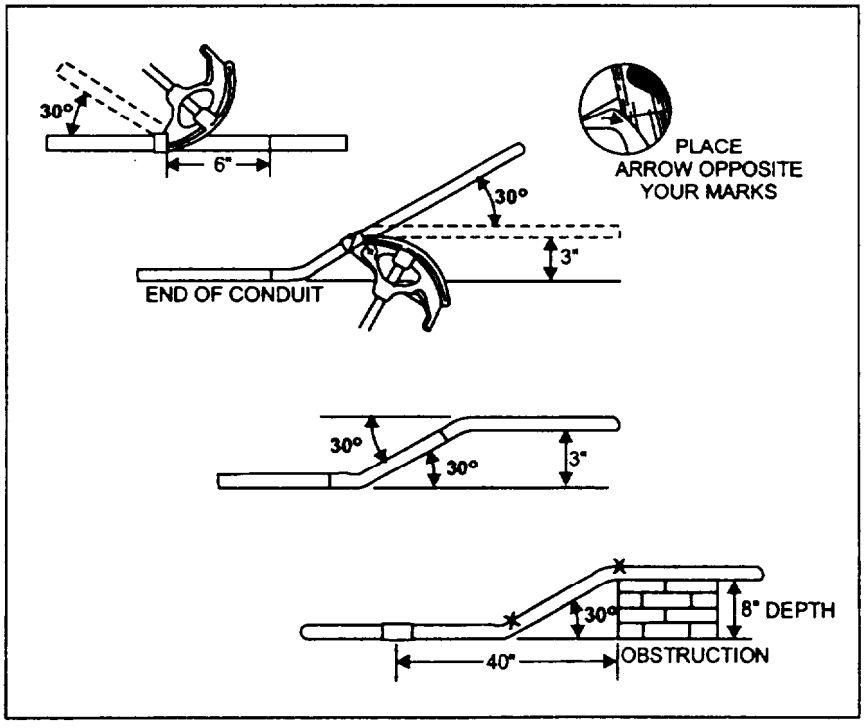


Figure 5-46.—Bending an offset.

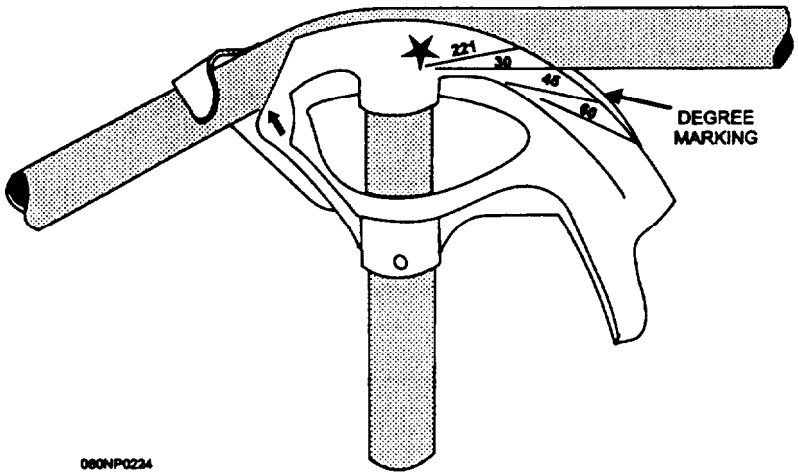


Figure 5-47.—Bender degree markings.

To make accurate offsets of 2 inches or more in depth, you can mark a predetermined distance on the conduit. The distance between the bends depends on the depth of the offset and the amount of bend that you are going to use. Table 5-3 shows the formula to use to find the distance to be marked on the conduit. It also shows the constant multiplier that must be used in the formula for the angle of bends you intend to use and the shrinkage per inch.

Let us use an example to see how the formula works. Suppose you need to avoid a part of a obstruction that requires an 8-inch offset, you are going to use 30-degree bends, and you are 40 inches from the obstruction. Table 5-3 shows that the constant multiplier for 30-degree bends is 2 and the shrinkage of one-fourth inch equals 2 inches for a total of 42 inches. Using the formula, multiply the depth of the offset (8 inches) times the constant multiplier (2), and the result is the distance needed between the bends (16 inches). You place the first mark at 42 inches, the second 16 inches apart, and using the arrow of the bender, make a 30-degree bend on the same side of each mark, as shown in figure 5-46. In this example, a 30-degree bend gives us the offset we need. If you make both bends inside the marks, you will end up with much less than the desired offset. If you make both bends outside the marks, you will have too much offset. The amount of bend, in this case 30-degree at each mark, is obtained by using the degree markings on the bender, as shown in figure 5-47. Notice that the side of the conduit closest to the bender is in line with the 30-degree marking on the bender. If you have a bender without markings, a protractor (works especially well on larger conduit) can be used or you can lay a 30-degree angle out on a large piece of paper or on the floor with chalk. Then check the bend against the 30-degree angle you have laid out. Normally, offsets are made by making the first bend on the floor and the second bend in the air, as shown in figure 5-48.

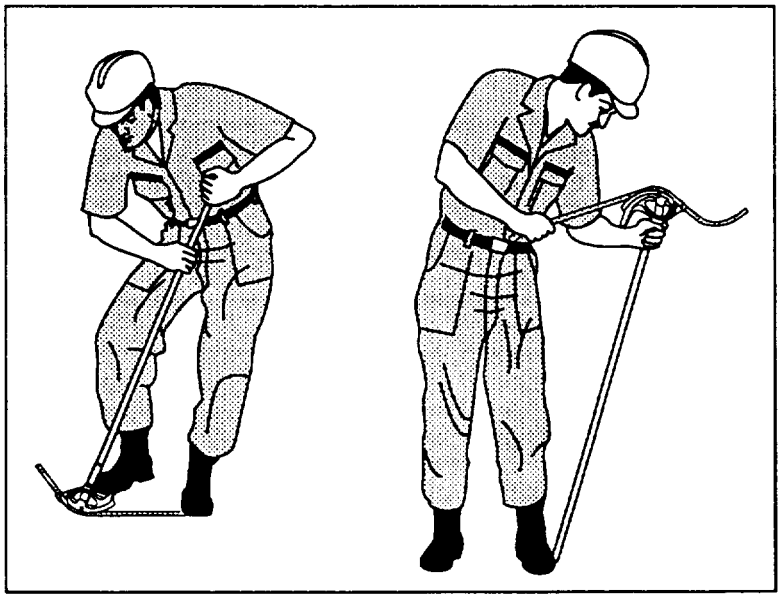


Figure 5-48.—Bending on the floor and in the air.

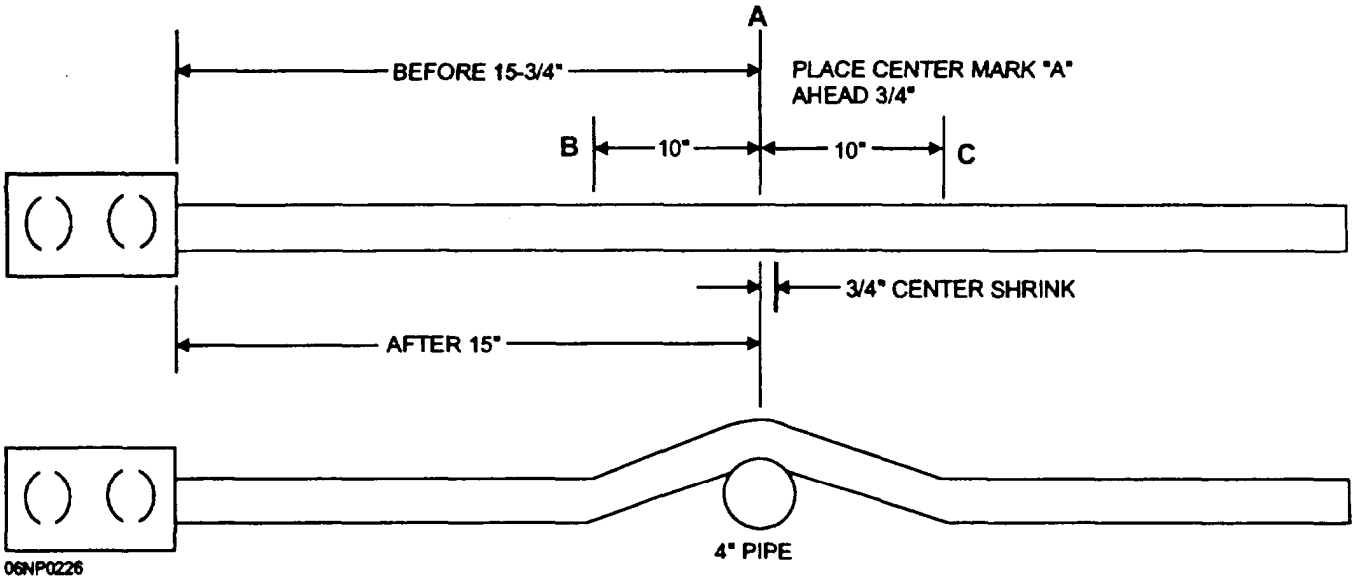


Figure 5-49.—Bending a conduit saddle bend.

SADDLE BENDS.—Saddles may be necessary when obstructions (fig. 5-49) are encountered. The most common method of straddling an obstacle is the three-bend saddle, using a 45-degree center bend and two opposing 22 1/2-degree bends. All measurements begin with locating the center of the obstruction on the conduit and marking it as Point A. Table 5-4 shows shrinkage factors and distances for marks "B" and "C." The formula is from mark “A,” add 3/16 of an inch times saddle depth and distance from mark “A” to marks "B" and "C" = 2.5 inches times saddle depth.

Figure 5-49 is an example of placing a 4-inch saddle around a conduit that is 15 inches from a junction box. Following the bending sequence shown, pay close attention to the orientation of the bender head. Remember to use the star arrow on the bender to align Point A for the 45-degree center bend and the front arrow to align the bender with marks "B" and "C" for the 22 1/2-degree bends. Be sure to line up all bends in the same plane. This procedure is true of all bends, not just a saddle.

Table 5-4.—Bending Conduit Saddle Table, Shrinkage Factors, and Distances

BENDING CONDUIT SADDLE TABLE, SHRINKAGE FACTORS, AND DISTANCES		
SADDLE DEPTH	PLACE CENTER MARK "A" AHEAD OF ACTUAL CENTER BY	PLACE MARKS "B" AND "C" EACH WAY FROM CENTER
1"	3/6"	2-1/2"
2"	3/8"	5"
3"	9/16"	7-1/2"
4"	3/4"	10"
5"	15/16"	12-1/2”
6"	1-1/8"	15"
FOR EACH ADDITIONAL INCH ADD	3/16"	2-1/2"

06NP0227

Rigid Metal Conduit

The procedures for making the different types of bends discussed thus far have all been with a one-shot bender. The same bends can be made with rigid conduit. Ahickey bender can be used on rigid metal conduit also although the procedures are slightly different. For instance, to make a 90-degree bend in 1/2-inch rigid metal conduit, you should take the steps shown in figure 5-50. Let us say you need a 20-inch stub-up at the end of the 1/2-inch stick of rigid conduit. The steps for bending with a hickey are as follows:

1. Mark off 20 inches from the end of the conduit.
2. Determine the take-up for 1/2-inch rigid conduit. (See table 5-2.)
3. Make a second mark 6 inches back toward the end of the conduit.
4. Place the hickey at the second mark and pull about 30 degrees of bend.
5. Move the bender toward the 20-inch mark about 2 inches. Pull another 30 degrees of bend.
6. Move the bender to where the heel of the bender is on the 20-inch mark and complete the 90-degree bend.

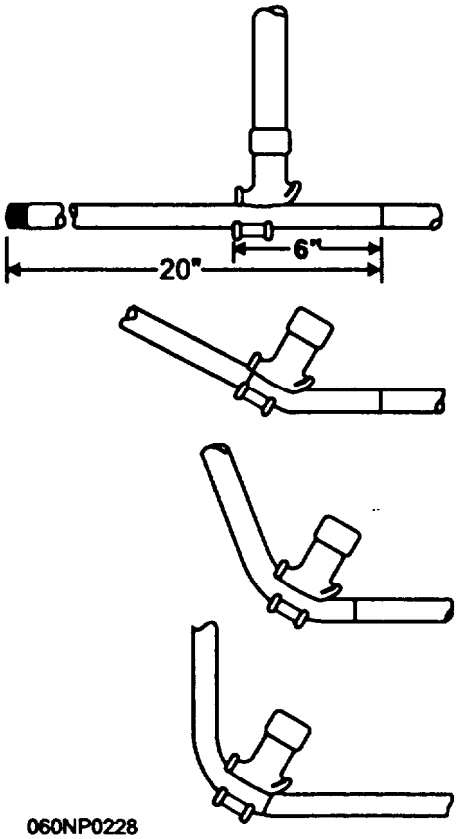


Figure 5-50.—Bending a 90 with a hickey.

Since the hickey bender does not usually have degree markings on it, you have to estimate the amount of bend you are making with each bite. Small bites, as shown in figure 5-51, reduce the possibility of crimping or kinking the conduit.

Mechanical Benders

Mechanical benders are designed to bend conduits using a built-in ratchet for fast, no kink, bends. Depending on the make and model, they are portable and easy to use. Equipped with different shoe sizes, they will bend EMT conduit from 3/4 inch through 2 inch, rigid and aluminum conduit 1/2 through 1 1/2 and IMC 1/2 through 1 1/4. Minimum stub lengths and take-up deductible inches vary from the hand benders just discussed. While the bending principles are the same, you will need to check with the manufacturers directions and bending charts.

CONDUIT INSTALLATION

In previous sections we have discussed types of conduits and the cutting, threading, and bending of conduit. Now, we will cover the requirements for installing the different types of conduit and how conductors should be pulled into them.

Several general requirements apply to all types of conduit installation: All raceways must be installed as a complete system before any conductors are pulled into them. In other words, the “run” of conduit, as described previously, including conduit, fitting, and supports, must be complete before the conductors are installed. A run of conduit should be as straight and direct as possible. When a number of conduit runs are to be installed parallel and adjacent to each other, you should install them all at the same time. The minimum-sized raceway that can be installed generally is 1/2-inch electrical trade size. Specific exceptions to this rule



Figure 5-51.—Bending with a hickey using small bites.

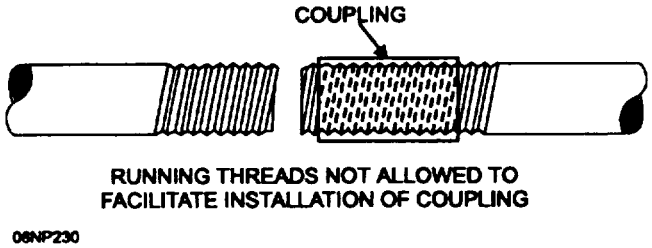


Figure 5-52.—Running threads.

include EMT, rigid, and flexible conduit installed in specific locations. The exceptions for each type are outlined in the NEC©. All types of conduit must be reamed after they have been cut. Conduit threaded in the field must be threaded with a die that has a 3/4-inch taper per foot. When threaded conduit enters a box or fitting, a bushing must be used to protect the conductor insulation from being cut or tom. Also, for those types that use threaded couplings, running threads, as shown in figure 5-52, are not to be used for connection at couplings. Running threads weaken the conduit and may come loose. Threaded couplings and connectors used with any type of conduit must be made up tight. Couplings or connectors that are to be buried in concrete or masonry have to be the concrete-tight type; those to be installed in wet locations have to be the raintight type.

Conduit must be supported by straps or hangers throughout the entire run. Figure 5-53 shows how straps are fastened on different types of surfaces. On a wooden surface, nails or wood screws can be used to secure the straps. On brick or concrete surfaces, first you just make a hole with a star or carbide drill and then install an expansion anchor. Use an expansion tool to force the anchors apart, forming a wedge to hold the anchor in the hole. Then secure the strap to the surface with machine screws attached to the anchor. On tile or other hollow material, secure the straps with toggle bolts. If the installation is made on metal surfaces, you can drill holes to secure straps or hangers with machine or sheet metal screws.

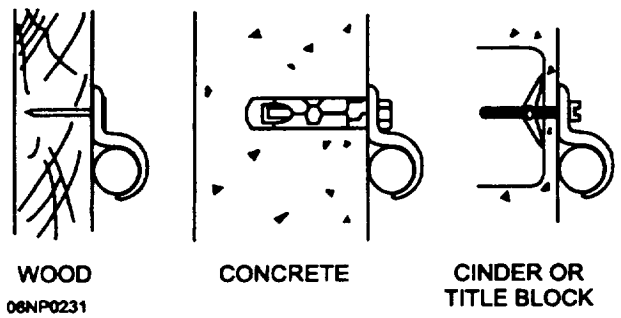


Figure 5-53.—Conduit support fastening.

Table 5-5.—Nonmetallic Conduit Support

CONDUIT (Inches)	MAXIUM SPACE BETWEEN SUPPORTS (Feet))
1/2 -1.....	3
1 1/4 - 2.....	5
2 1/2 - 3.....	6
3 1/2 - 5.....	7
6	6

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The number of supports needed depends on the type of conduit being used. Holes, or notches, in framing members may serve as supports. EMT and IMC require supports within 3 feet of each outlet box, junction box, cabinet, or fitting, and every 10 feet thereafter. Rigid metal conduit must also be supported within 3 feet of a box, but the distance between supports may be increased as the size of the conduit increases if the run is straight and is made up with threaded couplings. The distance between supports on direct vertical runs of rigid conduit from machine tools, and the like, may be increased to 20 feet if threaded couplings are used and the riser is supported at each end.

Rigid nonmetallic conduit must be supported, as shown in table 5-5. In addition, it must be supported within 3 feet of each opening.

Flexible metal conduit and liquidtight flex must be supported at intervals not to exceed 4 1/2 feet and within 12 inches on each side of every outlet box or fitting. Exceptions to this rule are runs of 3 feet or less where flexibility is needed or 6 feet where light fixtures are being connected.

When you run conduit from one point to another, you often need to make more turns than the NEC© allows in a single run (360° of bends). When this larger number of turns is the case, you can use a fitting called a conduit body. Conduit bodies are often referred to by their brand names, such as Condulet or Unilet. A conduit body is a portion of a conduit system that provides access to the system through a removable cover to the interior of that system at a junction of two or more sections or at a terminal point. An important point to remember is that all Condulets must be accessible after construction is completed. Figure 5-54 shows some of the more common conduit bodies and covers.

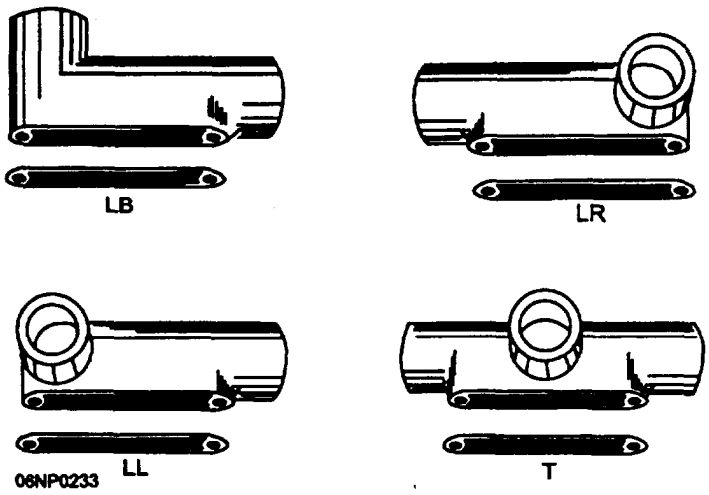


Figure 5-54.—Conduit bodies and covers.

Figure 5-55 shows how a conduit body is put in conduit between two outlets to keep the bends within NEC© limits for a single run. As you can see, the run on the left has bends that total 360 degrees, which is all the NEC© permits. Thus a conduit body, as discussed in NEC© Article 300, had to be installed so that the conduit could be continued to the box on the right. After all conduit has been installed, supported, and connected to the boxes, you are ready to install the wire.

Conductor installation into conduits is the same for all types of conduit. The most common type of wire used is TW. This letter designation simply means that the wire or conductor has thermoplastic, moisture-resistant insulation. When you are determining the length of wire needed to be pulled into the circuit, simply add the following: (1) lengths of conduit, (2) the size and number of boxes you must pull through, (3) the length of wire needed at each box, and (4) the makeup for the distribution panel.

For short conduit runs with only two wires, the conductors can be pushed through the conduit from one box to the next. When the conduit has several bends and more than two conductors will be installed, a fish tape has to be used to pull the wires through the conduit. The fish tape normally has a hook on one end, which is pushed through the conduit. The hook also makes it easier to push the tape through. If the hook is broken off, you can make a new one with a pair of pliers and a propane torch. The torch is used to heat the end of the tape to take out the temper. On a l/S-inch tape, heat

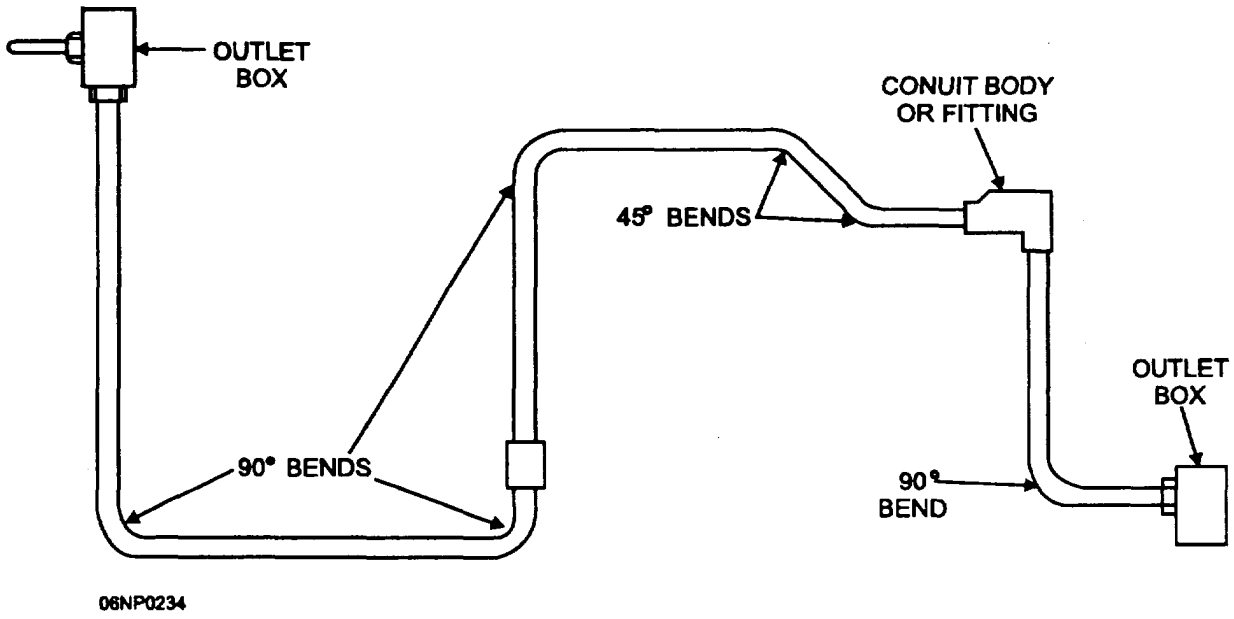
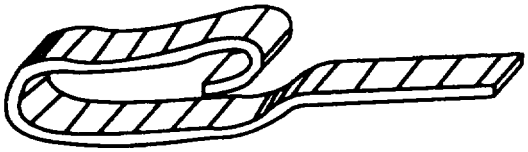


Figure 5-55.—Conduit body installed.



06NP0235

Figure 5-56.—Fish-tape hook.

about 3 inches at the end of the tape until it is red-hot, and bend a hook on it about an inch long, like that shown in figure 5-56. This shape of hook seems to work best. After the hook is formed, reheat the end of the tape until it is red. Allow the end to cool until it becomes straw-colored. Then plunge it into a can of water until it is cool. This process restores the temper to the hook area.

Once you have the fish tape in the conduit, attach the hook to the wires to be pulled, as shown in figure 5-57. Remove 4 to 6 inches of the insulation from the ends of the wires and thread the ends through the hook in opposite directions; bend them back and twist them around each other; then tape the hook and bare conductors to strengthen the attachment and make pulling easier. Use just enough tape to cover the hook and wires.

Wire pulling usually takes two people-one to pull the fish tape and the other to feed the conductors into the conduit. The fish tape should be fed into the end of the conduit run from which it will be easiest to pull. It is usually best to pull the conductors from the distribution panel to the first box in the run, especially if the panel is energized. This procedure prevents your having to pull on the steel tape near an energized bus.

WARNING

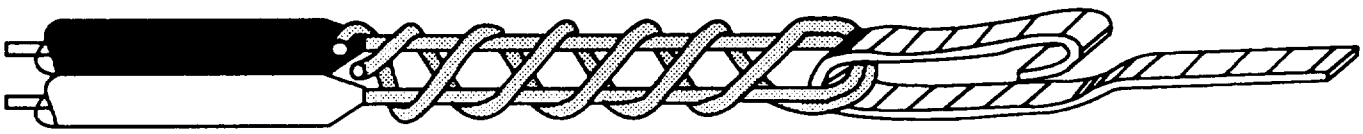
Whenever conductors are being pulled into energized panels, be careful to keep clear of the bus bars. All energized parts should be covered with a rubber blanket.

When several conductors must be fed into a conduit, you should keep them parallel, straight, and free from kinks and bends. Wires that are allowed to cross each other form a bulge and are hard to pull around bends. Whenever possible, feed conductors downward; for example, from the second floor to the first, so the weight of the wires will help in the pulling process. Another way to ease the pulling of conductors is to rub an approved lubricant, such as soap, talc, soapstone, or other noncorrosive substance, onto the insulation or blow it into the conduit. You may find that it is hard to keep the fish tape from slipping in your hands when you are pulling long runs or runs with several bends. When slipping is a problem, you can use the back side (insulation crushing point) of a pair of side-cutting pliers to grip the tape to give you a good pulling handle.

Remember to leave at least 6 inches of free conductor at each outlet and switch box to make up splices or to connect devices. Conductors that are not spliced or connected to a device can be pulled directly through the box.

The number of conductors you can have in conduit is based on the size of the conduit, the type of conductor insulation, and the size of the conductors. The NEC©, chapter 9, has several tables to help you determine how many conductors of a certain size and insulation type you can have in a given size of conduit. These tables are based on fill; that is, the cross-sectional area of the conductors inside the conduit can take up only a certain percentage of the free space inside the conduit. You must use these tables whenever there is a question on the number of conductors to be pulled. Too many conductors in a conduit cause overheating, which reduces conductor ampacity.

Once you have installed the conductors and all other finish work is complete, you are ready to do the electrical finish part. Finish work for conduit installations is the same as that for NM cable installations, which was covered previously in this chapter.



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Figure 5-57.—Wires attached to fish tape.

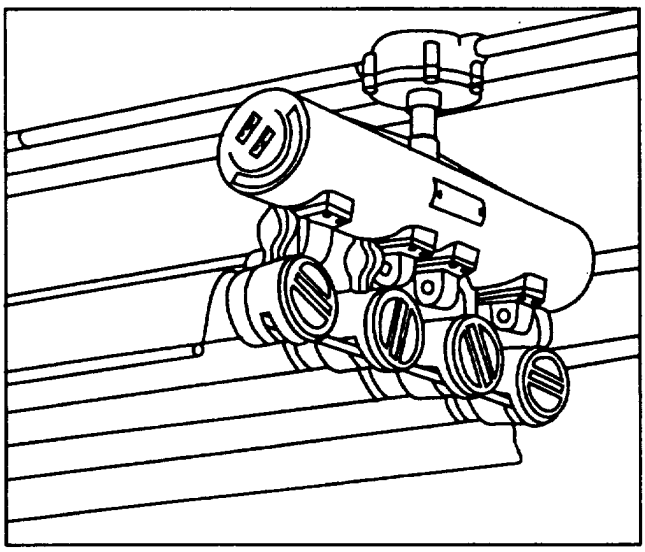
Explosion Proof Fittings

In locations specified by the NEC© (Articles 510 through 517) as explosion-hazardous, you must install explosionproof fittings. Locations are classed by number in descending order of danger: Class 1, Division 1, highly hazardous; Class 1, Division 2, slightly less hazardous; and so on.

As an example of explosionproofing, in a gasoline filling station, the pump island is classed as Class 1, Division 1. All the conduits in this area must be sealed with a special sealing fitting. On conduit for lights above the pumps, the sealing fitting must be located at a height of not less than 4 feet above the driveway surface. No junction boxes (explained in the NEC©) or Condulets may be used in the pump area. Conduits running from pumps to panels in the building must be sealed not less than 18 inches above the finished floor of the building to avoid fumes from the gasoline pumps. An approved seal must be installed on any conduit entering or leaving a dispensing pump or the enclosure on the pump island.

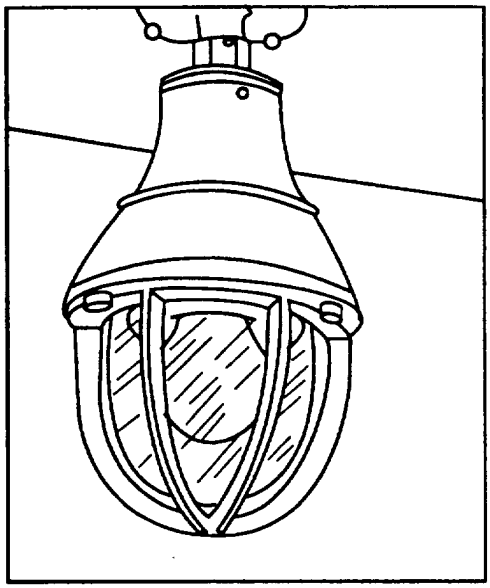
Inside the building of a gasoline station, the Class 1, Division 1, space extends 18 inches above the floor. Space above the 18-inch level is classed as Class 1, Division 2.

Paint spray booths are listed as Class 1, Division 1. Therefore all fixtures (exhaust fans, air compressors, or other electrical appliances) located in such booths must be explosionproof, as well as all switches, convenience outlets, and motor starters.



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Figure 5-58.—Explosionproof fluorescent fixture.



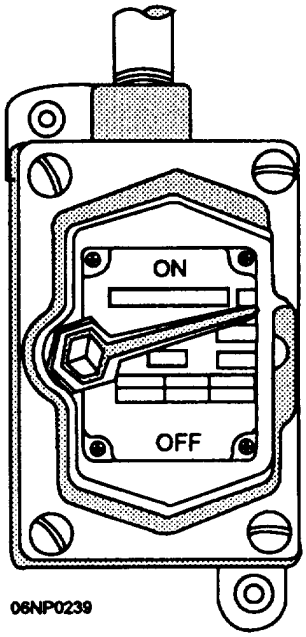
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Figure 5-59.—Explosionproof incandescent fixture.

Figure 5-58 shows an explosionproof fluorescent lighting fixture for installation in a paint spray room. In this fixture, the fluorescent tubes are sealed in a larger glass tube. The four-tube seal ends can be seen in the figure. The ballast (explained in NEC© Article 410, Part P) is enclosed in the container above the tube seals.

Figure 5-59 shows an explosionproof incandescent lighting fixture; figure 5-60 shows an explosionproof on-and-off switch for lighting.

When the interior wiring system has been completely installed, make an overall inspection to be



06NP0239

Figure 5-60.—Explosionproof ON-and-OFF lighting switch.

sure that good installation practices have been observed and all connections are correct. While you are making this check, do not forget neatness. Make sure that ground connections are tight and that ground wire is protected against injury. Be sure that all connections in the entrance switch and panelboards are tight. See that all metal noncurrent-carrying parts of portable equipment are grounded

Panelboards

The service entrance terminates in the service equipment or in a panelboard. The panelboard may be used for lighting and power branch circuits. A distribution panel, as the name implies, serves as a center or point in the electrical system where power is fed to the branch circuits. A distribution panel consists mainly of a metal cabinet that houses bus bars and individual circuit protective devices. The protective devices (fuses or circuit breakers) protect me circuits against excessive current flow. Panelboards must be rated at least as high as the feeder capacity required for the load. Panelboards are marked by the manufacturer with the voltage, current rating, and number of phases for which they are designed. This information, plus the manufacturer's name or trademark, is not to be obstructed by interior parts or wiring after the panelboard is installed. According to the NEC©, lighting and appliance panelboards cannot have more than 42 overcurrent devices besides the mains. Two-pole and three-pole circuit breakers are connected as two and three overcurrent devices, respectively.

According to the NEC©, each lighting and appliance panelboard must be protected from current flow on the supply side by not more than two main circuit breakers or two sets of main fuses that have a combined rating no greater than that of the panelboard. This protects not only the feeders but also the panelboard. The panelboard does not need individual protection if the panelboard feeder has overcurrent protection no higher than the panelboard rating. The total load on any single overcurrent device in a panelboard must not exceed 80 percent of its capacity where, in normal use, the load continues for 3 hours or longer to prevent overheating of the conductor.

Panelboard cabinets must be grounded. A terminal bar must be provided for attachment of feeder and branch circuit equipment-grounding conductors where nonmetallic raceway or cable is used. This terminal bar must be bonded to the cabinet, but not to the neutral bar except in service equipment.

Three-phase panelboards supplied by a four-wire, delta-connected system that has the midpoint of one phase grounded must have the higher voltage-to-ground conductor or bus bar marked. This high-voltage conductor should have an orange outer finish or be clearly tagged. The identification is required at any point where a connection can be made and the neutral conductor is also present. The phase arrangement on a three-phase panelboard is A, B, C, from left to right, or top to bottom when viewed from the front. The B phase will be the phase that has the higher voltage-to-ground.

There are two basic types of panelboards: fuse panels and circuit breaker panels. Fuse panels, as the name implies, contain fuses for protection of each circuit. Fuse panels are designed in a variety of ways. These designs vary in size, capacity (amperage and voltage), and type of installed fuses. The capacity of the panel is based on the ampacity of the bus bars of the panel. The number of bus bars is determined by whether the panel is single-phase or three-phase. Fuse panels are designed for plug fuses, cartridge fuses, knife-blade fuses, or a combination of these. Fuse panels use an Edison-base fuse that screws into a socket similar to the medium-based light socket. Fuse panels still exist but are not very common. Fuse panels are not to be installed either for new work or as a replacement panel unless they have been modified to accept Type S fuses. Refer to figure 5-61 for a view of the plug type of fuse and figure 5-62 for a view of the adapter and Type S fuse.

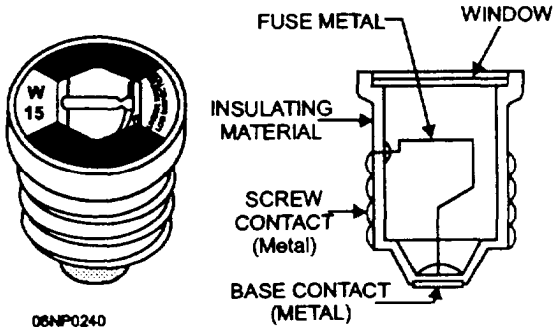


Figure 5-61.—Plug type of fuse.

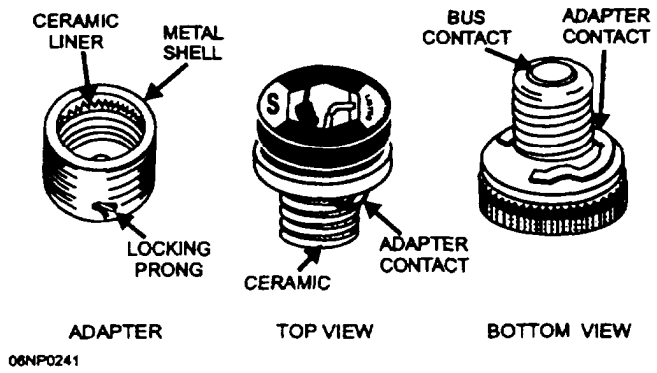


Figure 5-62.—Adapter and Type S fuses.



06NP0242

Figure 5-63.—Ferrule type of fuse.



060NP242A

Figure 5-64.—Knife-blade fuse.

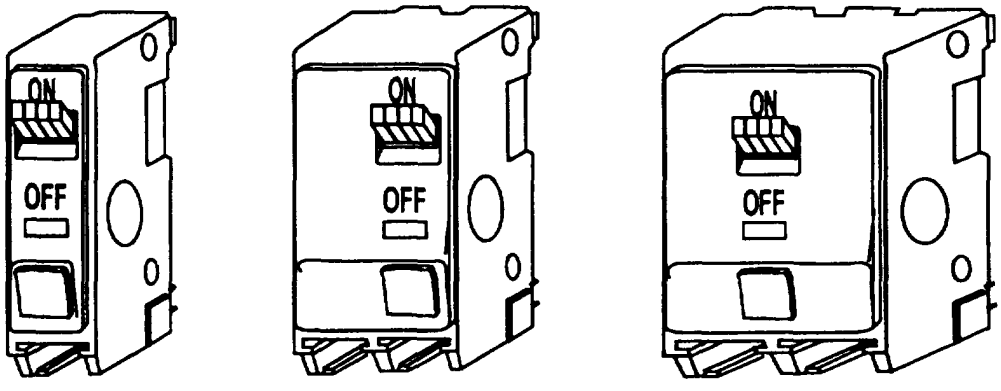
The other type of fuse you will be dealing with, as a CE, is the cartridge fuse. There are two types: the ferrule and the knife blade. Both types are available with replaceable or nonreplaceable fuse links. Ferrule fuses are available in ampere ratings from 0 through 60. Fuse panels that use the ferrule type of fuse have specially designed fuse clips in which only ferrule types will fit. Fuse diameter and length increase as amperage and voltage increase. Ferrule fuses are used in circuits up to 600 volts. Figure 5-63 shows a typical ferrule type of fuse.

Fuse panels that provide distribution for high-capacity circuits use knife-blade fuses for protection. The fuse clips are especially designed to receive knife-blade fuses only. Knife-blade fuses are available in ampere ratings of 61 through 6,000. The maximum voltage rating for knife-blade fuses is 600 volts. Figure 5-64 shows a typical knife-blade fuse.

Two factors must be considered when fuses for circuit protection are to be selected. These are the total current flow and the voltage of the circuit in which the fuse is to be installed. Since the purpose of the fuse is to protect the circuit, it must be the weakest point in the circuit. Thus the fuse used should be rated no higher than the lowest rated component to be protected. Before installing a fuse in a panel; check the condition of the fuse holder or clips. These must be clean and hold the fuse firmly.

One of the newer types of protective devices, used more often than fuses because of the way it reacts to an overload, is the circuit breaker. A circuit breaker trips on an overload but can be reset to complete the circuit again without having to be removed or replaced. Circuit breakers are classed according to their operating principle. They may be thermal, magnetic, or a combination of thermal and magnetic. Figure 5-65 shows typical circuit breakers with one, two, and three poles. Multipole breakers are designed to open all ungrounded conductors in a circuit at the same time.

A thermal type of circuit breaker has a bimetallic element within the breaker that responds to temperature change. The bimetallic element is made by fusing together two strips of dissimilar metal. Each strip has a different expansion rate when heated. Current flowing through the breaker generates heat, which increases as the flow increases. The heat causes the bimetallic element to bend and act against a latch. The breaker mechanism is adjusted so that when the current flow reaches a set level, the element bends enough to trip the latch. This action opens a set of contacts to break the circuit. The thermal type of circuit breaker is commonly called a time lag breaker because the breaker



06NP0243

Figure 5-65.—Typical circuit breakers.

does not open immediately when an overload occurs. The bimetallic element requires a short time (length depends on the size of the overload) to respond to the heat generated by the overload current.

A magnetic type of circuit breaker responds instantaneously when an excess of current flows through the breaker. A small electromagnet is used to actuate the breaker mechanism. Whenever a predetermined amount of current flows through the electromagnet, enough magnetic flux is created to attract a small armature. As the armature moves, the breaker mechanism trips and opens the circuit.

The thermal-magnetic circuit breaker, as the name implies, combines the features of both the thermal and the magnetic types. Of the three, the thermal-magnetic circuit breaker is preferred for general use. A small overload actuates the bimetallic strip to open the circuit on a time delay, while a large overload or short circuit actuates the magnetic trip to open the circuit instantaneously. Circuit breakers are rated in amperes and volts the same as fuses and you select them on the same basis. Circuit breakers are sealed units and no attempt should be made to repair them or to adjust the ampere capacity. A defective breaker must be removed and replaced.

Circuit breakers that are to be used in circuits that may pose an added hazard to the user are made with an extra safety feature. This breaker is called a ground fault circuit interrupter (GFCI). It is a thermal-magnetic breaker with an additional internal circuit that detects a current leak from the hot wire to ground and opens the breaker if that current reaches a set amount. This leakage cannot be more than 5 (±1) milliamperes (thousandths of an ampere) to ground. Most of these breakers have a test button that can be used to check the GFCI to see if it will trip when there is a fault.

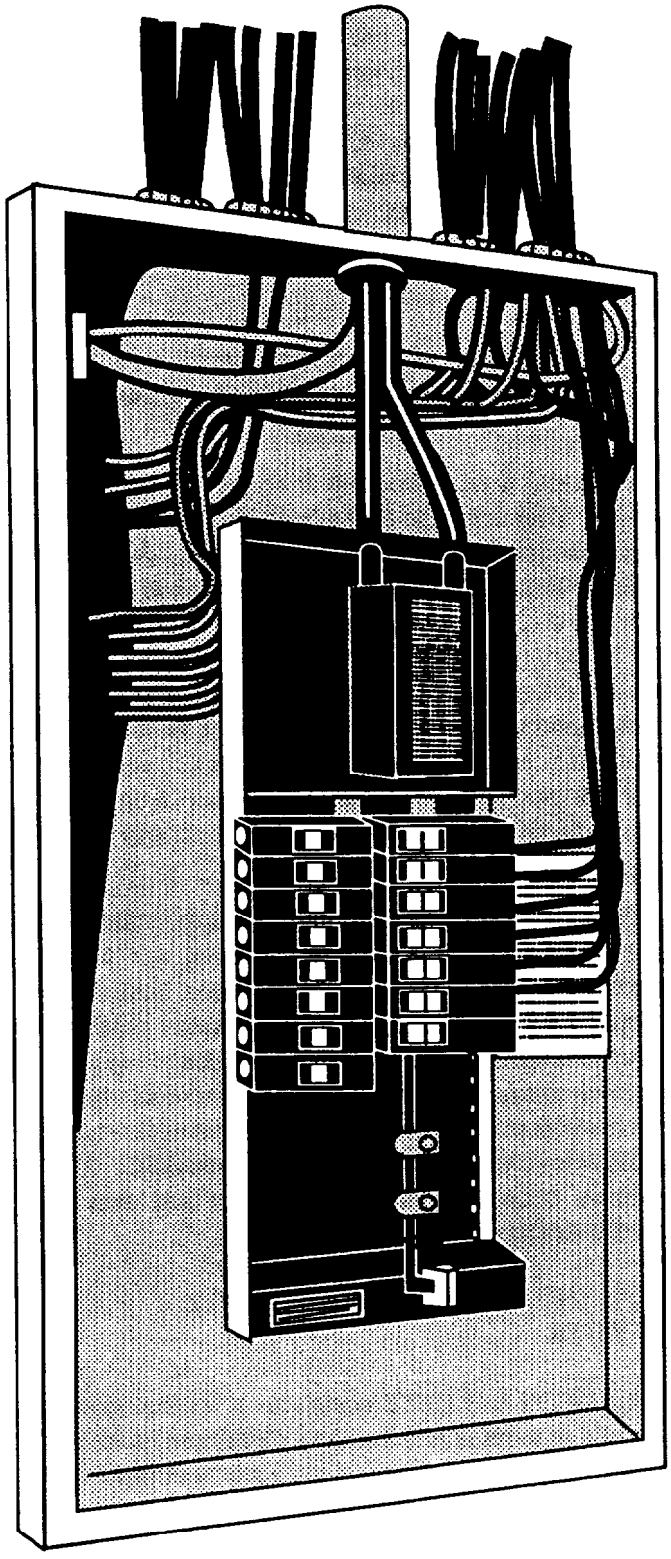
To install the GFCI, you connect the circuit hot wire to the breaker the same as you do on a standard breaker. The circuit neutral is connected to another terminal on the GFCI instead of to the neutral bar in the panel. The GFCI comes with an attached white neutral wire, which you then connect to the neutral bar. The NEC© requires that GFCIs be installed for several circuits used in the home. These circuits include ALL 120-volt, single-phase, 15- and 20-ampere receptacles in bathrooms, garages, and outdoors. GFCIs may be used elsewhere when there is a need for the added protection.

Now that we have discussed the various types of panelboards, fuses, and circuit breakers, we need to discuss panelboard connections. Once the circuits have all been brought into the cabinet, the panelboard can be mounted in the cabinet. Also, the neutral bar and the equipment ground bar are attached to the cabinet. The ground bar must be bonded to the cabinet by either a bonding jumper or the more common method of running a screw through the bar into the cabinet. The equipment ground bar and the neutral bar are not bonded together unless the panelboard also serves as the service equipment.

Quite often the panelboard is not connected until the interior wiring is done and the receptacles, switches, and fixtures have been installed. The method of attaching circuit conductors is based on conductor size and type of terminals on the panelboard. Small conductors, No. 10 and smaller, are normally looped around a screw type of terminal. Larger conductors may need to have terminal lugs, attached so the connection can be made to screw terminals. Pressure types of terminals are often provided for larger conductors, neutral conductors, and equipment-grounding conductors.

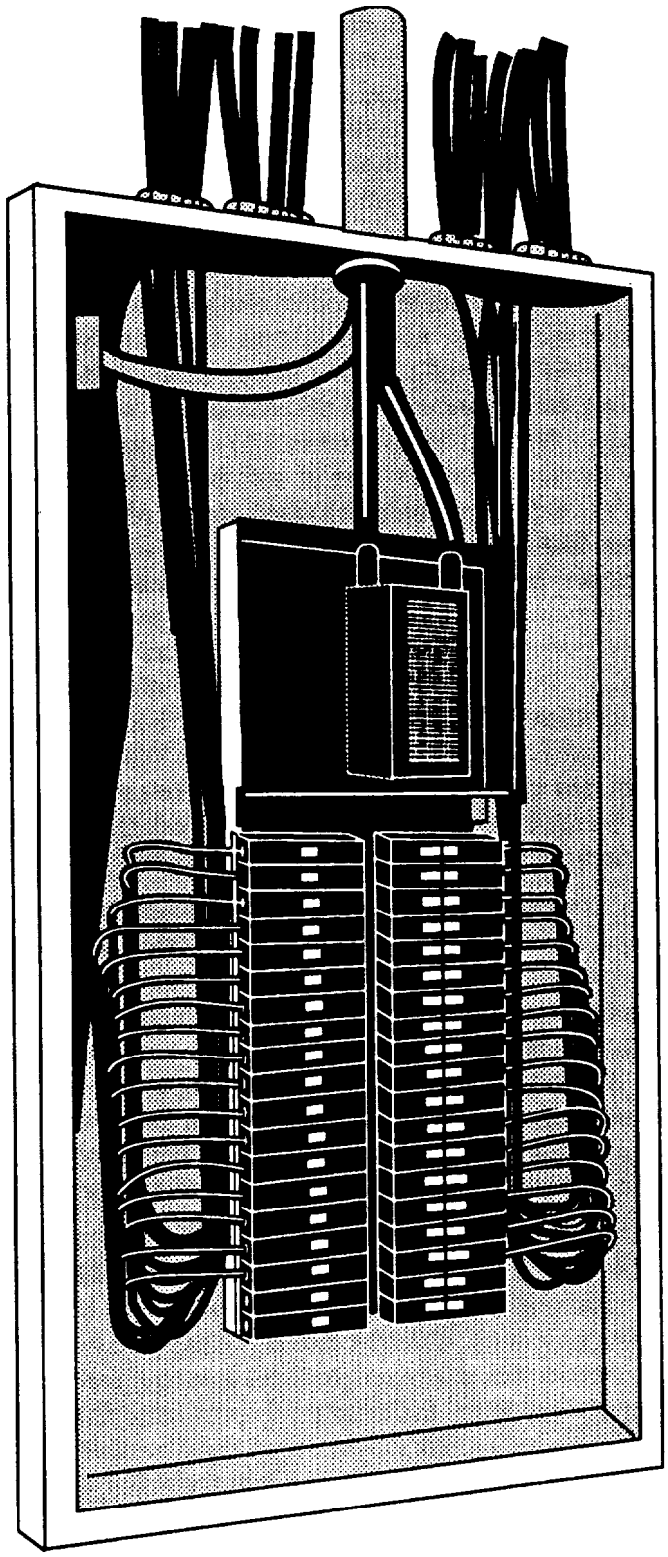
Conductors should be connected in a neat and professional manner. In many cases, conductors are connected with little excess wire. Conductors brought in through the sides of the cabinet are connected directly to the overcurrent device. Those brought in from the top or bottom of the cabinet are bent neatly opposite the fuse or circuit breaker to which they are to be attached and cut just long enough to make a good connection, as shown in figure 5-66. However, many experienced electricians feel that this system of connecting conductors is not necessarily the best, even though it presents the most uncluttered look and leaves more space around each conductor. These electricians usually try to leave an end on each conductor that is equal to the height plus the width of the cabinet. Each conductor is run along the panel and looped back 180 degrees before being connected to its fuse or circuit breaker. This method is shown in figure 5-67. Little added material is needed, and the extra length on the conductor permits it to be switched to another terminal on the panel if desired. Also, in the case of conductor breakage near the terminal, the conductor can be reconnected easily.

The ungrounded conductors in a fuse panelboard are connected directly to terminals on the bus bars. In a circuit breaker panelboard, the underground conductors are usually connected to the circuit breaker. The circuit breaker is then inserted in the panelboard. In most cases, the breaker is snapped into place and is held by spring tension. Sometimes breakers are held in the panelboard by a screw.



06NP0244

Figure 5-66.—Panelboard connections without excess wire.



06NP0245

Figure 5-67.—Panelboard connections with leaped conductors.

Load Balancing

Now that you have installed the branch circuit conductors and breakers, you must balance the load. Conductors cannot be connected to a panelboard by attaching each one as you come to it. The arrangement or sequence of attaching conductors to the panelboard is determined by the arrangement of the bus bars in the panelboard, whether the circuits are 240 volts or 120 volts, and the need to balance the load on the phase conductors. Bus bars are installed into panelboards in one of several ways. Most of the time, the bus bars are run in a vertical configuration. In one arrangement, a split-bus panelboard is used that has all the 240-volt circuits in the upper section and the 120-volt circuits in a lower section. Another type of split-bus panelboard uses one main circuit breaker to feed one set of branch circuits and a second main circuit breaker to feed a second set. In many cases, panelboards are designed so that any two adjacent terminals can be used to provide 240-volt service. This arrangement also means that two 120-volt circuits attached to adjacent terminals are connected to different phase conductors. Since there are so many panelboard layouts, you must look at the panelboard to see how it is set up for 240-volt service, and you must be sure you get the conductors for 240-volt circuits connected to the proper terminals.

Loads that are connected to a panelboard should be divided as evenly as possible between the supply conductors. This process of equalizing the load is commonly referred to as load balancing. The purpose of load balancing is to reduce voltage drop that results from overloading one side of the incoming service. It also prevents the possibility of overloading the neutral. A perfectly balanced load between the supply conductors reduces current flow in the neutral to zero.

Load balancing is no problem for 240-volt circuits on a three-wire, single-phase system since the load has to be equal on each phase conductor. However, the 120-volt circuits are a different matter. These must be connected in such a way that the loads tend to equalize. Generally speaking, the simplest way to balance the load on a panelboard is to connect an equal number of branch circuits to each phase conductor. But this method does not necessarily give you a balanced load as will be evident if you will look at the top of figure 5-68. As you can see, the indiscriminate connection of branch circuits without consideration of their loads can cause you to end up with an unbalanced condition. On the other hand, you can connect the circuits so that one with a heavy load is offset by one with a light load, which does result in the balanced condition shown in the bottom of figure 5-68. Most of the time, you should be able to connect half of the lighting circuits and half of the appliance circuits to each phase conductor to give you a reasonably well-balanced load. Spare circuits should also be equalized There is one more thing to consider: When there are appliance circuits where the loads are known to be heavy, these circuits must be divided between the phase conductors.

TROUBLESHOOTING AND REPAIR OF INTERIOR WIRING SYSTEMS

Electrical troubleshooting is an important part of your job. Your ability to find a faulty condition quickly can play an important part in shortening the downtime caused by failure. To find faulty conditions in circuits, you must do some inspecting, some calculating, and some instrument testing. A few moments spent studying the circuit diagrams before you start actual troubleshooting will simplify the task of isolating the trouble. If a circuit fails to function, use logic when you check for the fault. The trial-and-error method of finding faults in circuits is inefficient and time-consuming.

The first step to take in troubleshooting circuits is to inspect the circuit visually. Check for loose connections, loose wires, abraded wires, and loose fittings. An overloaded circuit is a serious problem. Many times the electrical demand on a circuit is so great that the circuit fuses blow or the circuit breakers trip. In some cases, the wrong fuses or circuit breakers are used, and the wires overheat and burn off the insulation. This condition causes shorts and grounds and sets up potential fire hazards.

OPEN, SHORTED, AND GROUNDED CIRCUITS

An OPEN CIRCUIT occurs in a wiring system when one or more conductors in a circuit are broken or otherwise separated. An open circuit is determined by the failure of a part or all of an electrical circuit to operate, even though the fuses may not be blown. Use the following maintenance procedures for locating the source of the trouble:

1. Initially, you should make a visual check for a broken or loose connection at the first dead (nonoperating) outlet in the circuit. If a defective connection is found, tighten or repair the connection.

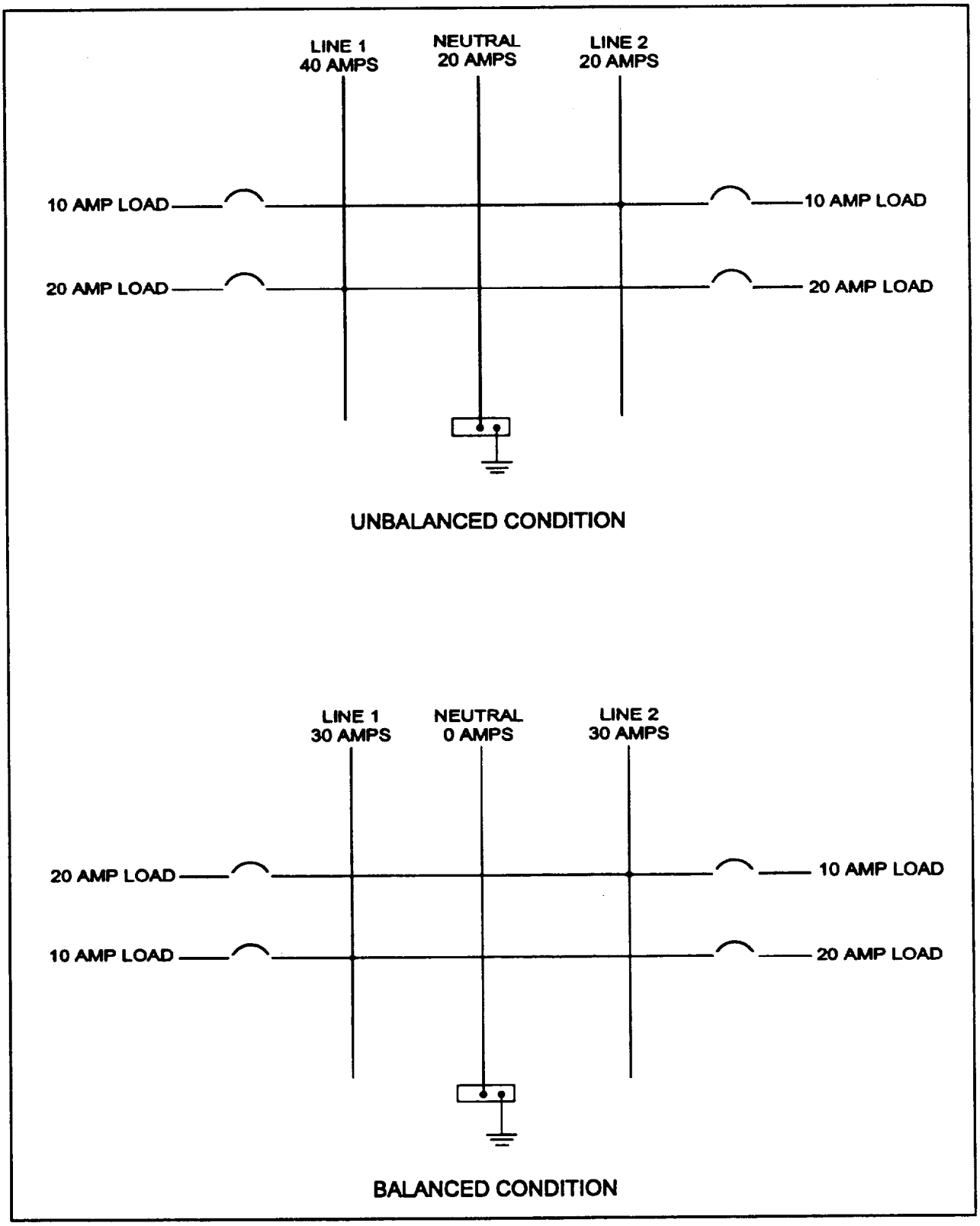


Figure 5-68.—Load balancing.

2. If you do not find the trouble, or open, by a visual check, use a voltmeter to determine whether the circuit is live (operating) up to the point of the component.

A SHORT CIRCUIT results when two bare conductors of different potential come into contact with each other. If a conductor inadvertently contacts a metallic part of a wiring system, such as a motor frame or conduit, the system is sometimes said to be GROUNDED instead of having a short circuit. Grounds or short circuits can be (1) solid, (2) partial, or (3) floating. This situation presents a serious safety hazard because the machinery may be in operation, even though it has a short circuit. This condition is especially true in motors and some appliances.

A solid ground or short circuit is one in which a full-voltage reading is obtained across the terminals of a blown fuse when the load is disconnected from the circuit. The circuit resistance, in this case, is quite low, and the current is quite high so that the fuse will blow.

A partial short or ground is one in which the resistance between the phase wires, or between the phase wire and the ground, is partially lowered. However, enough current still remains to blow the fuse. Grounds of this type are generally more difficult to locate than are solid grounds.

A floating ground is a condition in which the resistance of the defect in a system varies from time to time. Grounds of this type may be present in an electrical system for some time before their existence becomes known. A floating ground is indicated when fuses are blown on the phase side of a circuit a number of times, and a circuit test shows no defects in the system. In grounds of this type, fuse trouble may not occur for several days. Then the ground recurs, and the fuses are blown again.

The procedures used to repair the troubles mentioned thus far are usually fairly simple. In the case of an open, short, or ground in NM cable, the bad section from box to box can simply be replaced using the same procedures outlined for installation. Another method would be to cut the cable at the trouble spot, install junction boxes, and add a short piece of cable to replace the bad section. Although the latter is the cheapest, it may not be possible if the trouble is concealed. Remember, you must have at least 6 inches of free conductor in a junction box to make the splices.

Once you find out where the trouble is in a conduit system, the repair procedure is even easier. All that is required is to pull the open, shorted, or grounded conductor out and replace it with a new one. This replacement can be done by attaching the new conductor to the one that is to be removed. In any case, a little common sense and knowledge of the NEC© requirements will dictate the action you should take.

METERS

Many times a visual inspection does not uncover an apparent problem; therefore, you must advance to troubleshooting with meters. In electrical troubleshooting, you will use voltmeters, ohmmeters, ammeters, and the meter that incorporates many meters—the multimeter.

When using a voltmeter, you have to connect the power to the circuit before testing. On the other hand, you cannot use the ohmmeter on an energized circuit. You need to start voltmeter tests at the power input end of the circuit, whereas you start ohmmeter tests at the ground end

Electrical circuit troubles develop either in the wiring or in the operating unit. If you analyze the problem carefully and take systematic steps to locate it, not only will you save much time and energy, but you will also prevent damage to expensive equipment.

Either dead circuits or live circuits can be tested with instruments. Circuit defects can sometimes be located more easily by one method than the other, depending upon the type of circuit and the trouble.

To test a dead circuit, disconnect the device from the outlet or disconnect switch. Equipment for this method of testing includes such units as ohmmeters and battery-powered test lamps. Asuitable continuity tester can be made easily from a flashlight in an emergency. An ohmmeter that contains its own batteries is excellent for continuity testing. A basic factor to consider in choosing continuity test equipment is to use relatively low-voltage instruments, reducing the danger of sparking.

WARNING

When connections are made in the presence of combustible vapors, sparking is a serious fire hazard.

When you test live circuits, energize the circuit under test from the power source. Generally, you will test with a voltmeter. Make certain that the voltmeter is designed for the type of current to be tested and has a

scale of adequate range. Ensure that the circuit is disconnected from the power source before making the necessary circuit changes; then reapply the power.

WARNING

Be extremely careful not to touch the hot conductors when you use this method of testing because these live points of the circuit are exposed when the junction box covers are removed.

Let us troubleshoot a circuit with a voltmeter. The power to the circuit must be turned on. The first and most logical place to check is the fuse or circuit breaker panel. Set the voltmeter to the proper scale. If you do not know the value of the incoming voltage, set the meter to the highest scale; then work down to the proper scale. Check each incoming phase by connecting one lead of the voltmeter to the neutral and the other to each phase separately.

On a three-phase 120/208, 240-volt service, you must get 120 volts on each phase to ground. Less than 120 volts on one phase means that phase is open and you are getting a feedback from equipment connected to the lead side of the panel. Sometimes there will be a slight variation of normal voltage from the different phases; therefore, to determine if one phase is dead, check between the phases.

To perform this test, place one lead of the voltmeter on Phase A and the second lead on Phase B and read the voltage. It should read approximately 208 or 240, depending upon the system. After you have taken this reading, move the second lead to Phase C and take the reading. After this reading, move the first lead to Phase B and take the reading. You have now read between all phases and a lower than normal reading indicates an open phase.

Which phase is dead? Assume that Phase B has a blown fuse. When you take your reading between Phases A and B (fig. 5-69). you get a low-voltage reading. Your next reading, between Phases A and C, reads normal. But the next reading, between Phases B and C, again is a low reading. Each time you read to Phase B, you get low voltage. This reading is a good indication that Phase B is open.

Another way to determine which phase is open is to place one voltmeter lead on the top of the fuse and the other lead on the bottom of the same fuse. If you get a voltage reading across the fuse, that fuse is open.

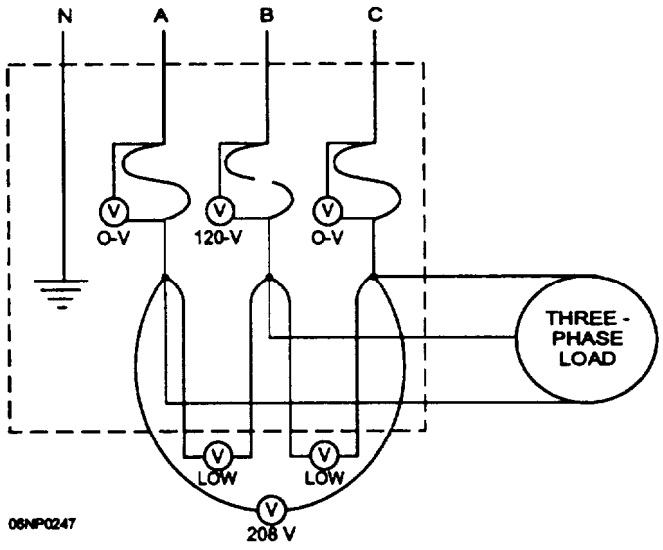


Figure 5-69.—Checking a three-phase circuit for a blown fuse.

Assuming that everything is all right at the main panel, let us examine a single 120-volt circuit. Illustrations help explain the procedure for locating an open in a circuit. Figure 5-70 shows a circuit with a lamp in series with a single-throw switch and fuse and the normal voltage readings at the various points of the circuit. If the lamp fails to light, check the circuit in progressive steps through the circuit and lamp from the last point where voltage is known to be present. In figure 5-71, we have voltage at one connection of the

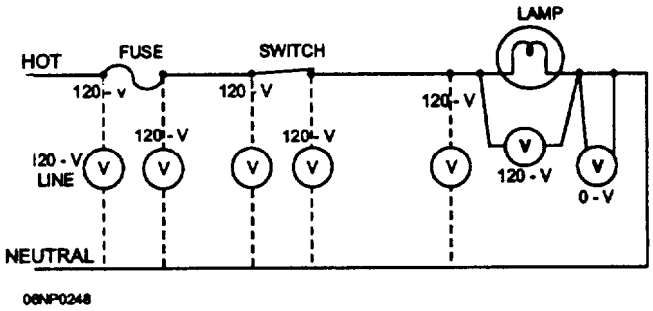


Figure 5-70.—Circuit with fuse, switch, and lamp.

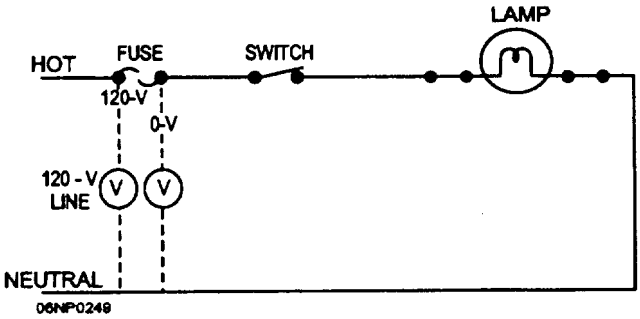


Figure 5-71.—Circuit with blown fuse.

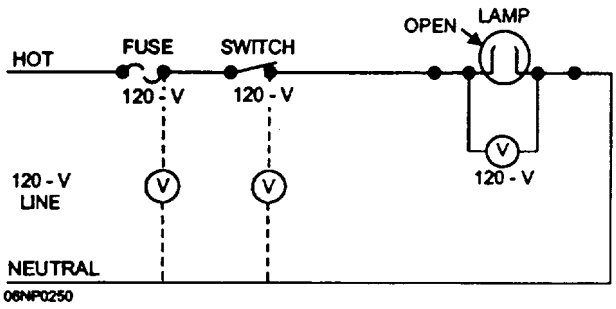


Figure 5-72.—Circuit with burned-out lamp.

fuse and no voltage at the other. Since the fuse is a conducting unit. normally the same voltage reading should occur between both sides of the fuse and the ground. The only conclusion in this case, then, is that the fuse is open.

Figure 5-72 shows that there is a voltage reading when the voltmeter is connected across the lamp. The logical assumption is that the lamp is inoperative. To be sure the lamp is inoperative, you must check it with an ohmmeter. Fuses, switches, and lamps are vulnerable; and you should check them first in a circuit.

In figure 5-73. the lamp does not light and the voltmeter shows voltage from the ground screw of the lamp to the neutral wire. These conditions indicate an open in the ground wire. When you connect the voltmeter at another point at the right of the lamp and no voltage is indicated, you can assume that there is an open in the wiring between this point and the lamp connection.

In figure 5-74, you find two lamps wired in parallel so that they can be controlled by a double-throw switch. With the switch in the OFF (center) position, there is no complete circuit, and neither lamp lights. When the switch is in the BRIGHT position, a circuit is completed

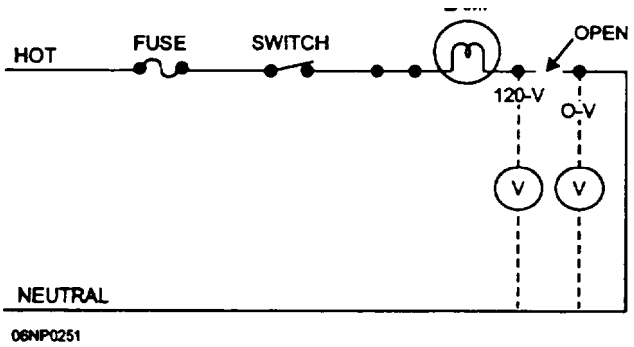


Figure 5-73.—Circuit with open in the wiring.

through the switch and through both lamps. With the switch in this position, the only resistance in the circuit is the resistance of the lamps. When the switch is in the DIM position, the circuit is completed through the lamps as before; but this circuit has an additional resistor in series with the lamps. This added resistance causes a decrease in current flow; therefore, the lamps glow with less intensity than before.

If one of the lamps lights and the other one does not, it is not necessary to check the complete circuit to find the open. The part of the circuit up to Point A is common to both lamps, and that much of the circuit must be completed for even one lamp to light. The place to begin checking the circuit is after Point A in the affected part of the circuit. In a circuit, such as the one shown in figure 5-74, it is best to use a voltmeter to locate the trouble. If you connect the negative lead of the voltmeter to the ground and the positive lead to Point A, you will get a reading on the voltmeter scale because Point A is connected through the switch to the positive line wire. If the positive lead of the voltmeter is moved in succession from A to B to C, you are able to check the continuity of wires AB and BC. If the check at Point C reveals no voltage, this condition indicates that wire BC is open.

You can make this same check with an ohmmeter, but several additional steps are required. First, remove power from the circuit by placing the circuit breaker and circuit switch in the OFF position. Next, disconnect the junction of wires at Points A and C. Then, with one ohmmeter lead placed on the loose wire at A and the other one on B, check the continuity of the wire. When this check is made and the ohmmeter indicates a low resistance, you have continuity in the wire. But if you place one ohmmeter lead on B and the other on the disconnected wire at C and you get an infinite resistance, there is an open in the wire.

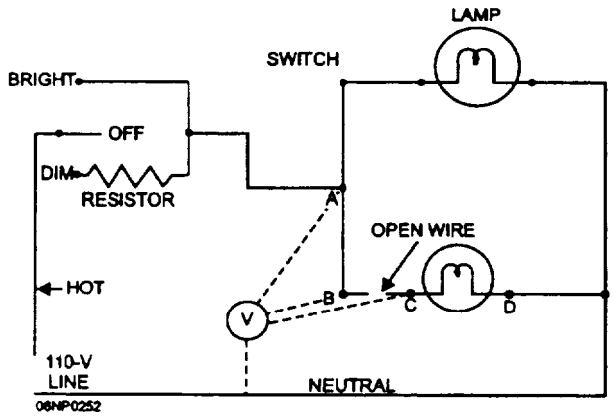


Figure 5-74.—Troubleshooting an open circuit with a voltmeter.

WARNING

For your safety, before you begin testing with an ohmmeter, BE SURE that the circuit that you are about to test is de-energized. Isolate the circuit being tested to prevent reading resistance from other circuits.

Many times you can determine the approximate location of an open by simply studying the circuit diagram before doing any actual circuit testing. For example, suppose both lamps in figure 5-74 light when the circuit switch is placed in the BRIGHT position, but neither lamp lights when the switch is placed in the DIM position. Because the lamps light when the switch is in one position, you can gather that all wires and lamps are good. The only units that could be faulty are the resistor, half of the switch, or the wires that connect the switch and the resistor. By using the ohmmeter as you did before, you can check the continuity of these parts.

A short circuit exists when there is a direct connection between two wires or conductors of different potentials. If the trouble is not found by a visual inspection, you must isolate it step by step. First, disconnect all the equipment in the circuit and install a new fuse or place the circuit breaker to the ON position. If the short is clear, then the trouble will be found in the equipment. However, if the short circuit does not clear and the fuse burns out again or the circuit breaker trips, then the trouble is in the wiring.

To find the short in the electrical wiring, you first disconnect the wires at both ends of the circuit and test each wire with an ohmmeter.

If there is a short between the wires, a low-resistance reading will appear on the ohmmeter. If no short exists between the wires, a high-resistance reading will appear on the ohmmeter. You should continue this procedure until the short is found.

Let us assume that a light circuit is faulty. Using figure 5-75 as an example, you see a circuit with three lights controlled by a switch with a short at the junction box of the middle lamp. Disconnect the wires at the fuse panel to isolate the circuit and to prevent feedback from the other circuits.

Connect one lead of the ohmmeter to neutral and the other to the wire you have just disconnected. With the switch open, the ohmmeter will read infinity. Closing the switch will cause the ohmmeter to read continuity, showing that the short is beyond the switch. You can now proceed to the nearest junction box and test at the first light. Remove all light bulbs from the circuit.

Disconnect Point A and connect the ohmmeter between the neutral and the wire leading to the first

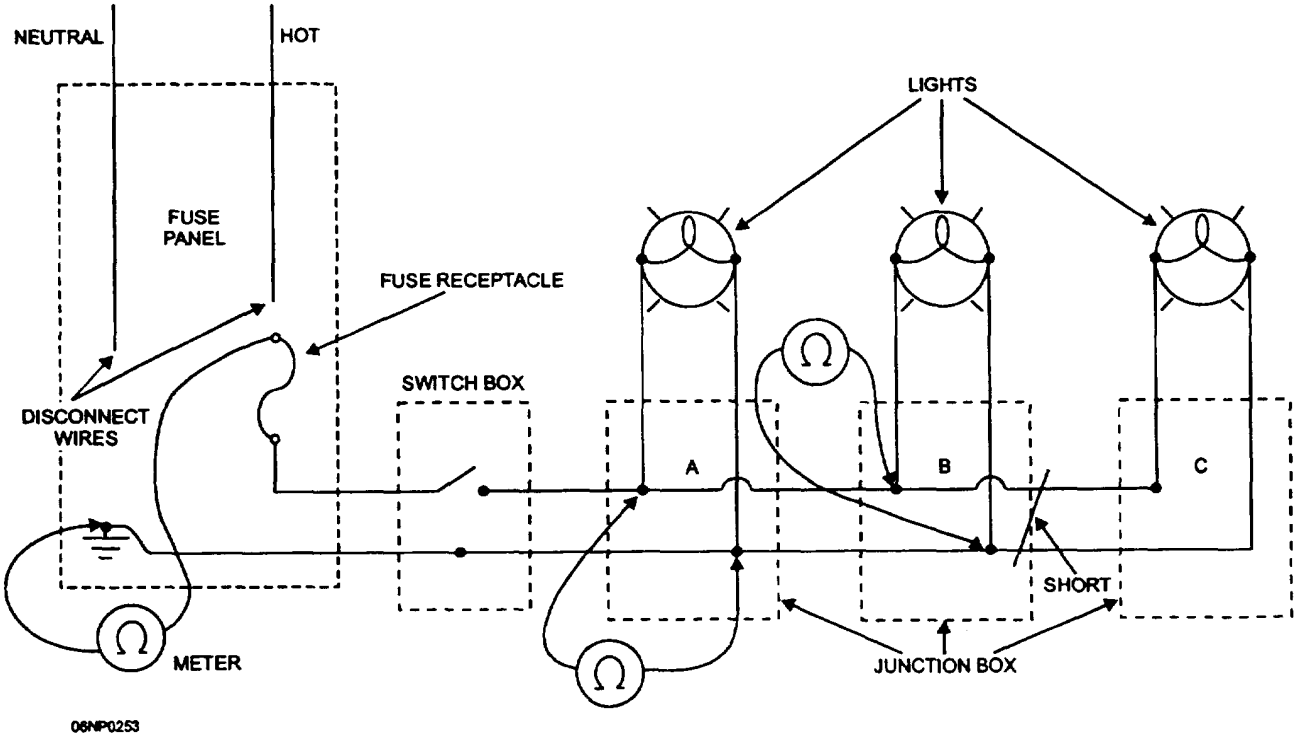


Figure 5-75.—Faulty lighting circuit.

lamp. You will read infinity. Remember, "infinity" means that the circuit is good, and "continuity" means a short. Now, connect the ohmmeter between the neutral and the lead going to the middle lamp. The reading will show continuity, indicating the short is beyond Point A. You should leave Point A open at this time and continue on to the middle lamp.

Disconnect Point B and take the same readings that you took at the first light. From these tests you can determine that the circuit between the first and middle lamp is all right (infinity reading), and the trouble must be between the second and third lamp. By checking closely at the middle junction box, you can probably see charred or frayed wires indicating the problem. You may need to continue your check to Point C. Use the same procedure as with the other lamp, and find the trouble between Points A and C.

LIGHTING

After installing the switches needed to control the lighting, you need to mount the light fixture itself. Each lighting installation is designed to produce a specific level of illumination adequate for those working in the area. The amount of illumination initially provided starts to decline almost as soon as it is put in operation. This reduction is caused by dirt on the lamps and luminaries, a decrease in lamp lumen output, and dirt on the room walls and ceilings. Illumination should be sufficient to eliminate eyestrain, support a high level of production, and promote safety and employee morale.

Lighting fixtures are designed for a particular lamp size and type. Many fixtures, however, were installed in military buildings long before the manufacturers started producing higher and higher wattage lamps in ever smaller envelopes. Consequently, it is possible to use much higher wattage lamps than the fixture or the circuit can handle adequately.

CAUTION

Excessive heat of higher wattage lamps can damage the sockets, increase failure rate, and overload the circuits. Personnel are cautioned to use only the lamp size (in watts) recommended for the fixture, rather than a higher wattage lamp that may physically fit.

INCANDESCENT LAMPS

Incandescent lamps come in a variety of voltage ratings. For most applications, the lamp voltage rating nearest the available line voltage should be selected. Under this condition, the lamp will produce its rated values of life, watts, and light output. Many incandescent lamps are available with life ratings considerably in excess of ordinary general service lamps. Some have ratings of 5,000 hours or more, and some even are guaranteed to burn for 5 years. General use of these lamps is not recommended because the initial cost is comparatively high and the extended life is gained by reducing the light output. There are, however, a few areas where it is necessary to use bulbs with a long life. Typical locations include high-ceiling auditoriums, exit lights, stairwells, and marker lights on towers or fire alarm boxes. For these areas, do not use a special rated lamp. Do use an ordinary general service lamp whose voltage rating is higher than the circuit voltage; for example, 130-volt or higher lamps for 120-volt circuits. When you are operating the lamp below its rated voltage, the life is increased at a sacrifice in light output. For general use, the lamp voltage rating nearest the available line voltage should be used.

Many kinds of incandescent lamps are especially designed for placement in a variety of situations; for example, under severe physical conditions (such as vibration or extreme temperatures), in inaccessible locations, or when special lighting effects are desired. Some of these types of incandescent lamps and their uses are as follows:

INSIDE-FROSTED LAMPS are used in most fixtures designed for incandescent lamps. The frosted finish reduces lamp brightness and glare.

CLEAR LAMPS are used in fixtures where control of the light is required (such as in reflectors having polished reflecting surfaces and in enclosed globes or reflectors of prismatic glass), particularly where concentrated light control is required, as in high, narrow bays.

Reflector equipment of the diffusing globe type, where the lamp protrudes through the bottom of the fixture, requires WHITE BOWL LAMPS. The white bowl reduces the surface brightness and glare from the working surfaces.

SILVERED-BOWL LAMPS are used principally for indirect lighting and in reflector equipment. The fixture parts should not touch the lamp as the thermal expansion may cause the bulb to crack and fail prematurely.

REFLECTOR LAMPS with the reflecting surface inside the lamp are, in effect, a fixture in themselves. A collection of dust and dirt on the exterior of the lamps can cause them to lose their effectiveness.

PROJECTOR LAMPS are installed in indoor and outdoor display lighting fixtures. They use a self-contained reflector but have an advantage over the reflector type since they are suitable for extreme temperature conditions and provide more accurate light control.

HEAT AND DRYING LAMPS, available with built-in reflectors or with separate reflectors, are an inexpensive answer to a requirement for instantaneous infrared energy. The reflector bulb keeps the initial cost to a minimum and provides a new reflecting surface with each new lamp.

HARD-GLASS LAMPS, made of special glass with high resistance to thermal shock, are effective where rain, splashing liquids, insects, snow, fixture parts, or hot metallic spray may touch the glass bulbs.

VIBRATION SERVICE LAMPS are available that withstand excessive vibration that cannot be eliminated by flexible fixture mounting.

Where the lamp will be subjected to shock, such as at the end of a drop cord or near machinery, you will want to select ROUGH SERVICE LAMPS. With filament supports, these lamps can withstand severe shocks without failure.

High-cost replacement areas, such as towers, industrial high bays, theater marquees, halls, and stairwells, are lighted with LONG-LIFE LAMPS.

QUARTZ-IODINE LAMPS offer a concentrated source of incandescent light with excellent light control characteristics, good color, and a life twice that of regular general service incandescent lamps. They depreciate at a lower rate than the general service lamp. The lamp cost is considerably higher, however, than a general service lamp, and a special fixture is required.

FLUORESCENT LAMPS

There are two principal types of fluorescent lamps: instant-start and rapid-start preheat lamps. Both have practically the same physical dimensions but different internal construction. The type of circuit in which the lamp should be used is etched on the end of the lamp. The rapid-start preheat lamp operates satisfactorily with either the preheat or rapid-start circuits. It has a short lamp life in an instant-start circuit. The instant-start lamp operates satisfactorily with an instant-start ballast, burns out the ballast in a rapid-start circuit, and does not light in a preheat circuit. Preheat lamps dominated the field for many years but are no longer considered a major type. They continue to be in use, however, particularly in fixtures using lamps smaller than 40 watts.

Examples of circuits for the major types are readily found in current manufacturers' publications. Example of some circuits are shown in figure 5-76. The 4-foot rapid-start lamp is the preferred lamp for most applications.

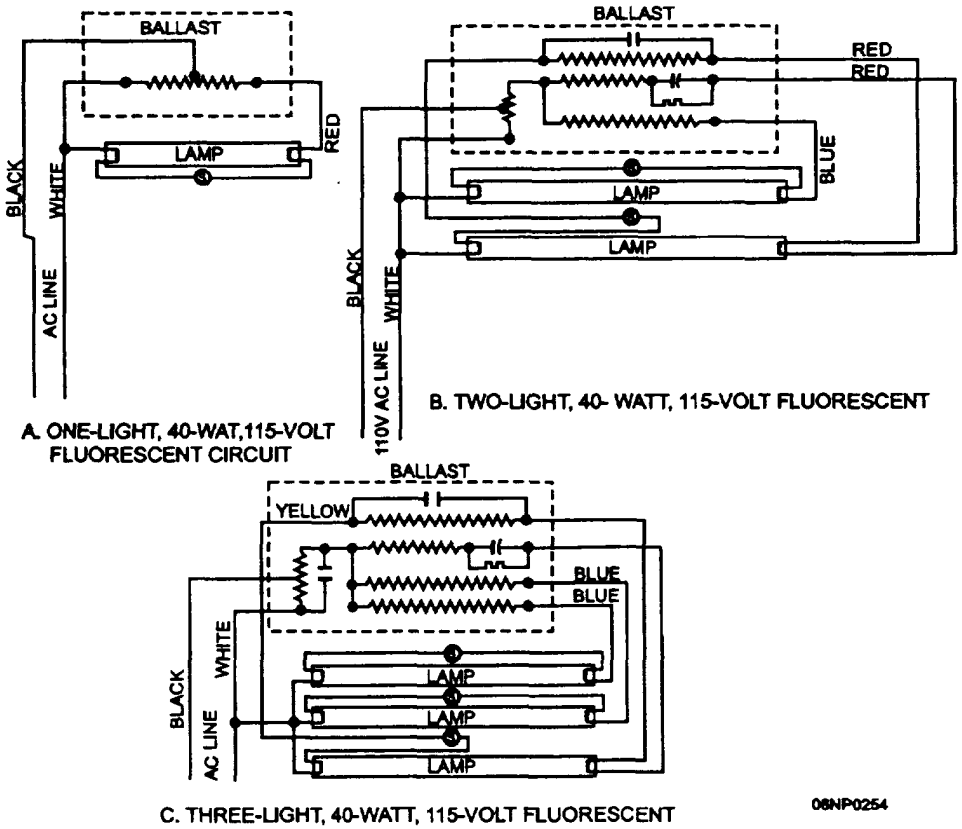


Figure 5-76.—Representative fluorescent circuits.

Fluorescent lamps are available in a variety of colors for decorative use as well as numerous shades of white for general illumination. The predominant white shade recommended for most office areas is cool white. Other shades of white used for various purposes include daylight, deluxe cool white, white, warm white, and deluxe warm white. Daylight and cool white provide a crisp, cool, businesslike atmosphere, and the warm whites find application in restaurants, homes, theaters, and similar areas. The appearance of colored materials will be better under a fluorescent light that contains a high component of the same color. Blue backgrounds improve with the cool whites and daylight. Deluxe warm whites strengthen oranges and yellows.

Fluorescent lamps require ballasts to limit the current and to supply proper voltage to start and to operate the lamps. For general lighting purposes, the ballasts also contain a capacitor to improve power factor. The NEC© requires that all indoor fluorescent fixtures (except those with simple reactance ballasts) incorporate ballasts with thermal protection. The thermal protector isolates the ballast and fixture from the circuit in the event of overheating. As a result, damage from fires and from leaking compounds should be reduced. There are small fuses available that can be installed in the fixture to provide this protection for existing ballasts.

MERCURY LAMPS

Mercury lamps (fig. 5-77) have the best maintained light output because the electrodes operate at a relatively cool temperature, resulting in less evaporation of the metals and oxides. The clear mercury lamp has a better lumen maintenance than those with phosphor coating. Long average life (16,000 hours and up) is a primary characteristic of most mercury lamps. There will be a different economic life for mercury lamps at each installation, depending on lamp mortality, power cost, equipment and wiring costs, frequency of replacement and cleaning of lamps, and other factors. Mercury lighting is one of the most economical means of lighting high- and medium-bay industrial areas, particularly in areas where color rendition is not critical. Small wattage lamps have been introduced, and it is anticipated that future designs will see a more widespread use of these in low-ceiling nonindustrial areas. An objectionable characteristic of mercury lamps is the time required to reignite (several minutes) after a momentary loss of power.

CAUTION

While the lamp bases are the same size as incandescent lamps, mercury lamps must never be’used to replace a burned-out incandescent lamp because a ballast must be used with mercury lamps.

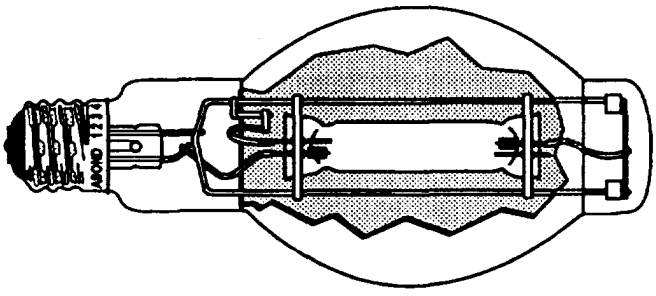
METALLIC-VAPOR LAMPS

Metallic-vapor lamps resemble mercury-vapor lamps in appearance and have similar uses. The initial efficiency and control are better with metallic-vapor lamps than with mercury-vapor lamps. In regard to disadvantages, the rate of depreciation is much greater with metallic than with mercury, the cost is higher, and the life expectancy is shorter.

High-pressure sodium-vapor lamps are used for highway interchanges, parking lots, and high-bay industrial areas. They are the most efficient of the light sources in general use in number of lumens produced per watt of electricity. The relative cost is high, the life ratings are not well established, and a special ballast is required. The color is slightly yellowish

OVERALL ILLUMINATION

Walls, ceilings, and surroundings are an important part of the overall illumination system since they redirect light to the working area. The most efficient lighting system is obtained when the fixtures are new and when the walls, ceilings, floors, and furnishings of



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Figure 5-77.—Mercury lamp.

the room are colored with a high-reflectance color. Lighting is, however, only one of many factors that make up the whole environment. While the highest lighting efficiency may be maintained in a completely white room, the psychological effect of such surroundings on the occupants may be less than harmonious. The use of color in the surroundings, even if it means sacrificing lighting efficiency, is necessary for the well-being of the occupants. Ceilings should have the lightest color, preferably an off-white. Shiny surfaces should be avoided, as they result in glare. As mentioned earlier, lighting levels start dropping immediately after the installation of the fixtures. Lamp burnouts and lamp depreciation contribute to this, but the principal cause is the accumulation of dirt. It is not uncommon to find lighting levels one half of the initial values after only a year or so of operation. The lighting maintenance program must include cleaning and painting of the walls and ceilings in addition to the fixture cleaning schedule.

When mounting any light fixture, follow the manufacturers' step-by-step instructions. The most important thing to remember when mounting any fixture or device is to ensure that all connections are both electrically and mechanically secure.

High-intensity discharge lamps (HID) will be discussed further in chapter 6.

TROUBLESHOOTING LAMPS

As light sources are designed to operate most efficiently and economically at their rated voltages, special emphasis should be given to using lamps to suit the voltage of the circuit. Operation within the normal operating range is desirable; because both overvoltage and undervoltage operations have a determined effect on the life, efficiency, and economy of the light source. The effect on lamps operated over or under their rated voltage range is described below.

FLUORESCENT LAMPS

Line voltage higher than the maximum of the ballast range will shorten lamp and ballast life. Line voltage below the minimum range will reduce illumination and may cause uncertain starting of some types of fluorescent lamps.

INCANDESCENT LAMPS

Line voltage higher than the maximum lamp range will increase the light output but will shorten lamp life. Line voltage below the minimum range will extend lamp life but will reduce light output approximately 3 percent for each 1 percent in voltage drop.

MERCURY LAMPS

Line voltage higher than the maximum lamp range will shorten lamp and ballast life. Line voltage below the minimum range will reduce illumination and may cause uncertain starting.

LAMP GUIDES

The most common troubles encountered with lamp equipment, the probable causes, and the suggested solutions are contained in table 5-6.

MAINTENANCE OF LIGHTING SYSTEMS

Lighting has a great influence on the quality and quantity of work as well as a direct bearing on employee morale. The necessity for periodic attention to the lighting system cannot be overemphasized. To prevent progressive deterioration of the system, personnel must provide regular maintenance and prompt repair of any deficiency.

Maintain the required illumination intensity by keeping lamps, fixtures, and reflective areas clean and in good repair; by replacing defective lamps; and by keeping the voltage steady.

It is well known that dirt absorbs and masks light. The progressive decrease of light caused by accumulating dirt renders periodic cleaning of lighting equipment a necessity. The frequency of cleaning depends largely upon local conditions. Fixtures in air-conditioned and air-filtered rooms may require cleaning only once a year. In an atmosphere that is heavy with dust and fumes, cleaning every few weeks may be necessary.

The cleaning schedule for a particular installation should be determined by light meter readings after the initial cleaning. When subsequent foot-candle readings have dropped 20 to 25 percent, the fixtures should be cleaned again. Readings should be made with the light meter at the working surface with the meter reader in the position of the operator or person using the working surface.

Lighting equipment should be washed, not just wiped off with a dry cloth. Washing reclaims 5 to 10 percent more light than dry wiping and reduces the possibility of marring or scratching the reflecting surface of the fixtures.

To clean removable glassware, reflectors, and diffusing louvers, immerse them in a solution of

Table 5-6.—Lighting Maintenance Chart

INCANDESCENT

SYMPTON	POSSIBLE CAUSE	REMEDY
Lamp out, but defective	Loose lamp, or loose or broken connections.	Tighten in socket, or secure terminals, or repair wiring.
Lamp burns dim	Low voltage	Match lamp rating to line voltage. Increase line voltage.
Short lamp life	High voltage, or bulb cracked, or incorrect lamp, or excessive vibration.	Match lamp rating to line voltage and reduce voltage. Replace lamp. Replace with lamp of proper rating. Use shock-absorbing device.
Lamp breakage	Water contracts lamp bulb, or bulb touches luminaire.	Use in closed, vaportight luminaire if water vapor is present. Seal joint where conduct stem enters luminaire. Use correct-size lamp. Straighten socket.

FLUORESCENT

SYMPTON	POSSIBLE CAUSE	REMEDY
Lamp does not start or flashed on and off NOTE: A flashing lamp usually indicates end of lamp life.	Lamp pins not contracting, or lamp worn out, or starter defective, or low line voltage, or fault in circuit or luminaire.	Seat lamp firmly and correctly. Replace with tested lamp. Replace with tested starter. Check with voltmeter. Check wiring and lamp holders. Check ballast
Lamp flickers: ARC wiggles, swirls or flutters.	Defect which occurs in both new and old lamps.	Turn luminaire on and off several times. Allow a new lamp to operate a few hours for seasoning. Remove lamp and shake one end down. Replace lamp if flicker persists. If flicker is repeated in new lamp replace starter.
Lamp starts slowly (should start in a few seconds)	Low line voltage or slow starter.	Check with voltmeter. Replace starter.
Short lamp life (A few early failures do not indicate average for group. Some fail after a few hundred hours; others last 4000 - 6000 hours.)	Low line voltage, or lamps turned on and off too often	Check with voltmeter.
Radio interference	May originate from other source. Radio too close to lamp. Aerial lead-in not shielded.	Operate radio with fluorescent lamps turned off. Move radio 9 to 10 feet from lamp. Shield lead-in and ground shield. Install filter radio or luminaire.
Noise from ballast. (Don't expect perfect silence)		If quiet necessary, take special precautions in locating ballast. If unit very noisy, replace ballast..

MERCURY LAMP

SYMPTON	POSSIBLE CAUSE	REMEDY
Lamp fails to start	Lamp loose.	Tighten in socket.
	Lamp burned out.	Replace.
	Low voltage.	Increase lamp voltage by changing transformer tap.
	Wiring fault.	Check wiring. Tighten connections.
	Low temperature.	Lamps may not start when temperature is below 32 F. ●
	Fluctuating voltage.	Check line voltage. (Momentary dips of 10 percent, or more, often cause light to go out.)
Lamp frequency goes out	Wiring fault.	Tighten connections. Check wiring. Separate lighting circuits from heavy power circuits.
Annoying stroboscopic effect	Cyclic flicker.	Where there is a 3-phase supply. Connect luminaires on alternate phases. On single-phase, add incandescent luminaires to the system.

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synthetic detergent cleaner and scrub them with a soft brush or sponge. When incrustation is not removed by scrubbing, use No. 0 steel wool to remove dirt film. Rinse in warm, clear water and dry with a clean cloth.

CAUTION

Do not immerse lamp base or electrical connections in the cleaning solution.

Glassware, reflectors, and diffusing louvers that cannot be removed should be cleaned as follows:

Wipe with a moist cloth or sponge, using a solution of synthetic detergent cleaner. When incrustation is not removed by sponging, use No. 0 steel wool to remove dirt film. Take care to ensure that shreds of steel wool do not touch the pin contacts or get into the lamp socket. Wipe off excess moisture with a clean cloth. Clean fixture holders and stem hangers with a moist sponge or cloth dampened with synthetic detergent cleaner and wipe dry. Enameled, chrome, aluminum, or silver-plated reflecting surfaces that cannot be adequately cleaned and polished should be replaced.

Neglected lamp outages reduce illumination. If burned-out lamps are not promptly replaced, illumination may drop to unsafe foot-candle levels in a short time because of outages alone. In some cases, it may be satisfactory and more economical to clean lamp surfaces and fixture interiors only at the time of relamping. Each activity must determine whether cleaning is to be accomplished by electrical, self-help, or custodial service personnel.

Burned-out lamps are replaced on request. To prevent reduced illumination from lamp outages, do the following:

- Instruct employees to report burnouts as they occur.

- Replace blackened or discolored lamps, even though they are still burning. Discoloration indicates the lamp is nearing the end of its useful life.

- Replace fluorescent lamps as soon as they begin to flicker. A burned-out lamp in a live circuit may cause damage to starter and ballast. Blackening at the ends of the tube adjacent to the base indicates that the lamp is near the end of its useful life.

- In general, replace with the same type, wattage, and voltage as that of the lamp removed. If frequent burnouts occur, the voltage rating of the lamps may be too low. Lamps of higher wattage than called for on lighting design plans should not be used.

SCAFFOLDING

As the working level of a structure rises above the reach of crew members on the ground, temporary elevated platforms, called SCAFFOLDING, are erected to support the crew members, their tools, and materials.

There are two types of scaffolding in use today: wood and prefabricated. The wood types include the swinging scaffold, which is supported on the ground. For information concerning the wood type of scaffolding, refer to *Builder 3 & 2*, volume 1, NAVEDTRA 12520, chapter 4. The prefabricated type is made of metal and is put together in sections as needed. As a CE, you will be working more with the prefabricated type of scaffolding.

This section provides only general information on prefabricated scaffolding. For further details of scaffolding, consult the latest copy of the Code of Federal Regulations (29 CFR 1926).

PREFABRICATED SCAFFOLDING

Several types of patent-independent scaffolding are available for simple and rapid erection, as shown in figure 5-78. The scaffold uprights are braced with

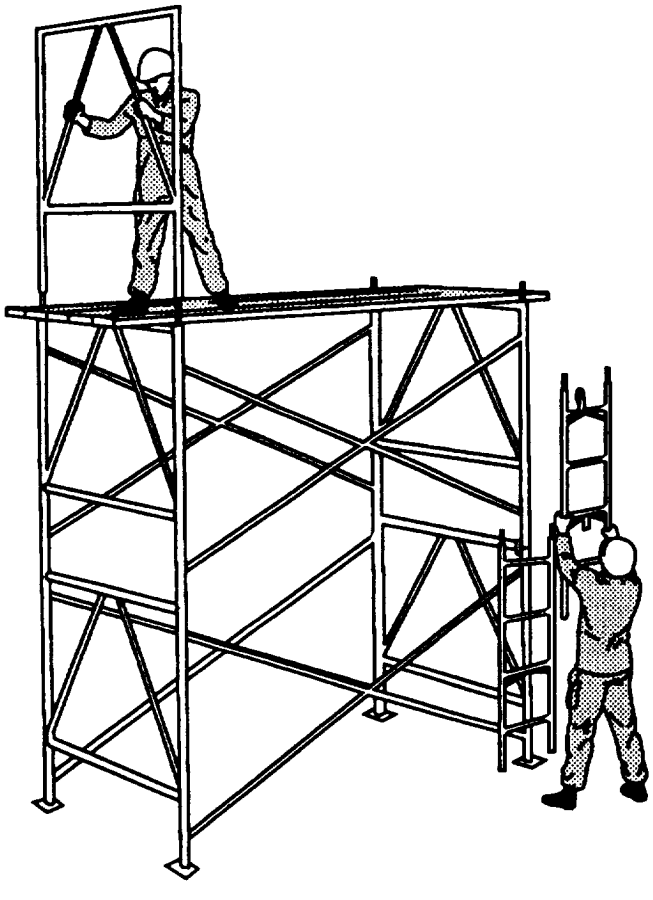


Figure 5-78.—Assembling prefabricated independent-pole scaffolding.

diagonal members, as shown in figure 5-79, and the working level is covered with a platform of planks. All bracing must form triangles, and the base of each column requires adequate footing plates for bearing area on the ground. The patented steel scaffolding is usually erected by placing the two uprights on the ground and inserting the diagonal members. The diagonal members have end fittings that permit rapid locking in position. The first tier is set on steel bases on the ground. The second tier has the bottom of each upright locked to the top of the lower tier. A third and fourth upright can be placed on the ground level and locked to the first set with diagonal bracing. The scaffolding can be built as high as desired, but high scaffolding should be tied to the main structure.

Steel and aluminum scaffolding is used to speed up construction and maintenance operations. Many types are available for interior work and erection. This kind of scaffolding is used around many construction sites because it can be disassembled and transported whenever necessary. The scaffolds are mounted on steel casters with brakes and adjustable supports, which permit quick movement and positioning of each tower This scaffolding is equipped with special trussed planks, 12 feet long, that are placed to enable crew members to be within comfortable and safe working distance of all working space.

Prefabricated scaffolding of this type comes in three categories: light, medium, and heavy duty. Light-duty scaffolding has nominal 2-inch-outside-diameter steel-tubing bearers. Posts are spaced no more than 6 to 10 feet apart. The load it can handle is 25 pounds per square foot. Medium-duty scaffolding normally uses 2-inch-outside-diameter steel-tubing bearers. Posts should be spaced no more than 5 to 8 feet apart. If 2 1/2-inch-outside-diameter steel-tubing bearers are used, posts are spaced 6 to 8 feet apart. The load it can handle is 50 pounds per square foot. Heavy-duty scaffolding should have bearers of 2 1/2-inch-outside-diameter steel tubing with the posts spaced not more than 6 feet 6 inches apart. The load it can handle is 75 pounds per square foot.

To find the load per square foot of a pile of materials on a platform, divide the total weight of the pile by the number of square feet of platform it covers.

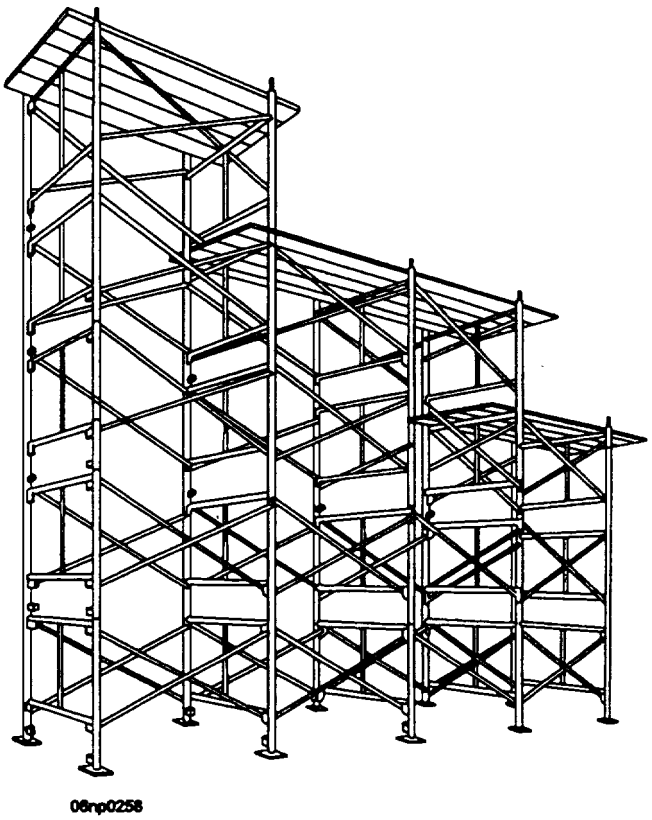


Figure 5-79.—Prefabricated independent-pole scaffolding.

SAFETY

The following safety precautions must be observed by all persons working on scaffolds or tending other persons who are working on scaffolds. Construction Electrician petty officers must not only observe the safety precautions themselves, but they must also issue them to their crew and ensure that the crew observes them.

- Scaffolds must be kept clear of accumulations of tools, equipment, materials, and rubbish.

- No scaffold may be used for the storage of materials in excess of those currently required for the job.

- Tools not in immediate use on scaffolds must be stored in containers to prevent tools left adrift from being knocked off. Tool containers must be lashed or otherwise secured to the scaffolds.

- Throwing objects to or dropping them from scaffolds is absolutely prohibited. Hand lines must be used for raising or lowering objects that cannot be passed hand to hand

- A standard guardrail and toeboard should be provided on the open side of all platforms 5 feet or more above ground; otherwise, safety belts tied off to safety lines must be used.

- No person should remain on a rolling scaffold while it is being moved.

- All scaffolds must be maintained in safe condition, and they must not be altered or disturbed while in use. Personnel must not be allowed to use damaged or weakened scaffolds.

- Access to scaffolds must be by standard stairs or by fixed ladders only.

- When scaffolding is being dismantled, it should be cleaned and made ready for storage or use. Scaffolding that is not ready for use should never be stored.

CHAPTER 6

COMMUNICATIONS AND LIGHTING

Many advances in lighting and communications have occurred in the past few years. With the cost of energy rising daily and the demand for accurate and reliable communications, any system that provides a higher level of efficiency must be considered.

In this chapter we will discuss public address systems, interoffice communications, and the fundamentals of fiber-optic communication cables and components. This chapter also will cover area streetlighting, floodlighting, and security lighting.

PUBLIC ADDRESS SYSTEM

The type of public address system that you will install, maintain, and troubleshoot is intended for installation in administrative and living quarter areas. This system will be used for general announcements, for indoor talk-back paging, and to entertain or address personnel.

A common system authorized by the General Services Administration consists of one 100-watt solid-state amplifier, four trumpet speakers with drivers, two paging speakers, one dynamic microphone with floor stand, and all accessory terminal fittings and hardware required to operate this system. The set will conform to the design and functional test requirements of Underwriters Laboratory (UL) 813 Standard and the wiring and design requirements of the National Fiie Protection Association (NFPA) 70.

INSTALLATION

Before you install a public address system, refer to the National Electrical Code© (NEC©) and the manufacturers' recommendations. Several factors must be met for the permanent or temporary installation of a public address (PA.) system.

We will discuss these factors for the installation of a public address system, consisting of an amplifier (console), speakers, and cable that are approved for this system.

Amplifier

The solid-state amplifier comes with an ac power cord that is terminated in a three-prong plug. The power cord must be plugged into a three-wire, 120-volt, 60-hertz grounded outlet. The cord will ground the amplifier and the auxiliary power receptacle. The auxiliary power receptacle is a three-wire grounded outlet that supplies power to accessory sound equipment. The receptacle will supply power only as long as the amplifier is connected to a 120-volt power source and turned on.

The amplifier will be internally wired with a circuit breaker for protection. If the breaker trips, turn off the amplifier and reset the circuit breaker. Turn on the amplifier, and, if the breaker trips again, do not attempt to reset it. A problem exists that you will need to investigate and correct.

Speakers

The speakers will be weatherproof and have adjustable mounting brackets. The input impedance of the speakers will match the amplifier output with a low-frequency cutoff, as shown in figure 6-1.

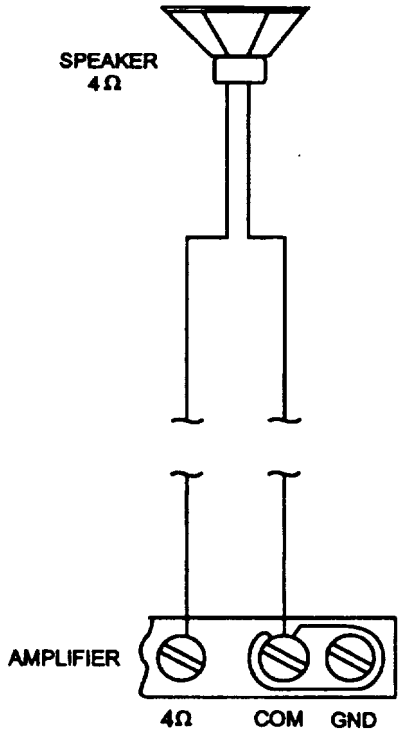


Figure 6-1.—Total speaker impedance matches the output impedance of the amplifier.

The output speaker voltage will be either 25 or 70.7 volts. The speaker will have a microphone precedence over other input singles and four output terminals with circuit protection.

Speaker installation is an important element whenever you install a P.A. system. No matter how good the amplifier is, if the speaker installation is not done properly, the sound produced will be inadequate. There are a number of factors you must consider when you install speakers. The placement and connection of speakers is the most important step. For indoor systems, two types of placement can be used. The speakers may be placed flat against a wall and the speaker turned so that it will radiate sound at an angle from the wall. The other type of placement is to mount the speakers in the corners of a room; for example, alcoves, balconies, booths, and dividing walls. A variation of these two methods mentioned may be considered for installation.

For outdoor systems, the main considerations are the area to be covered and the direction of sound. Highly directive trumpet speakers are normally used for an outdoor area.

When connecting speakers together, you must consider impedance matching and phase relations. Mismatching the impedance of a speaker to an amplifier output in either an upward or a downward manner will produce different effects. Mismatching upward (connecting an 8-ohm speaker to the 4-ohm output) will affect the power delivered to the speaker. Power loss will be about proportional to the upward impedance mismatch; in this case, about 50 percent. As a general rule, no serious frequency response deficiency will be noted and cannot damage a well-designed amplifier. Mismatching downward (connecting a 4-ohm speaker to an 8-ohm output) should always be avoided. It will reduce the amplifier power output and cause an overload on the output side with possible damage to the amplifier.

Figure 6-2 shows an example of two speakers connected in series. Add the individual speaker impedances together to obtain the total matching impedance. The formula for this where Z = impedance is Zt = Z1 + Z2.

For parallel connection (fig. 6-3) add the reciprocal of the individual speaker impedances together to obtain the reciprocal of the total matching impedance. The formula for parallel connections is as follows:

For series/parallel connections, combine the two formulas as the speaker connections indicate; for example, see figure 6-4, and apply the series formula for A and B, then for C and D. Take the results of this and apply the parallel formula to obtain the final matching impedance.

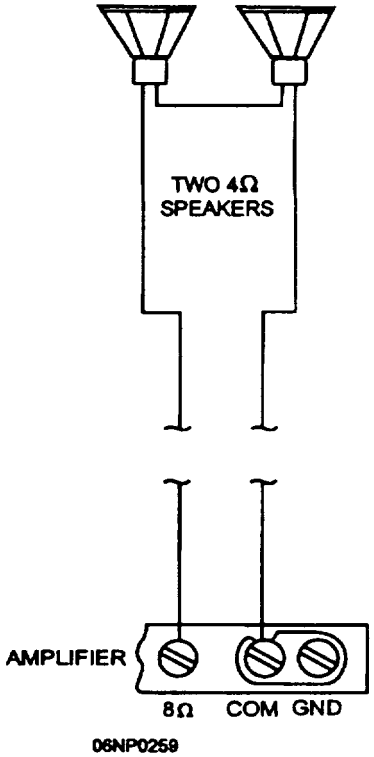


Figure 6-2.—Two speakers connected in series.

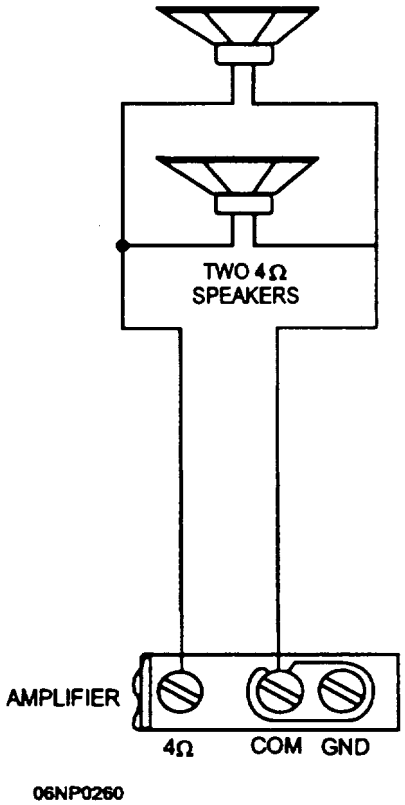


Figure 6-3.—Matching two speakers connected in parallel.

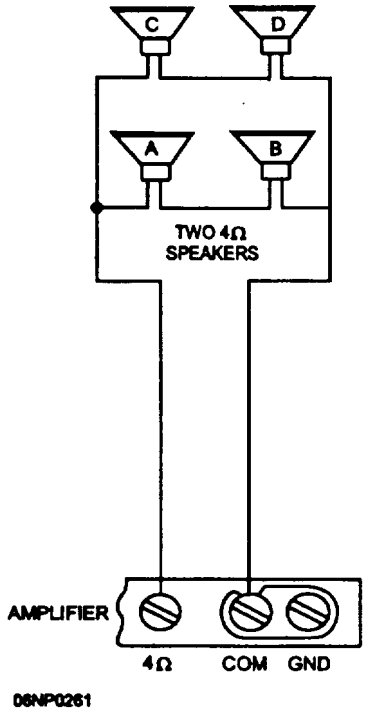


Figure 6-4.—Matching four speakers connected in series parallel.

When you use more than one speaker in a sound system installation, phase the speakers to reduce the cancellation effect, as shown in figure 6-5. Speakers out of phase will lose up to one half of their normal volume and operate with degraded tone quality.

For speakers facing in the same general direction, they are in phase when their respective diaphragms move in the same direction. This is achieved by connecting the speakers + to + and - to -. For speakers facing each other, they are in phase when their respective diaphragms move in opposite Directions. This is achieved by connecting the speakers + to - and - to +.

Efficient transfer of power from the amplifier to the speakers is the prime consideration in sound system connections. Basically, there are two methods of connection. One connection runs from the amplifier directly to the speaker voice coils and the other connection runs from the amplifier to the speaker voice coils through a transformer. You should use the first method with short runs (not over 200 feet) of wire and a simple speaker arrangement with low impedances. Use the second method whenever a 15-percent power loss in the transmission lines is noted or when wire runs are more than 200 feet, or there is a complex speaker arrangement. Constant voltage transformers are most commonly used for this purpose although impedance-matching transformers may be used. For an in-depth look, refer to NEETS, Module 8, *Introduction to Amplifiers.*

Cable

Cable installations are just as important as the other component installations. The cable used should be recommended by the manufacturer and in compliance with the NEC©. For the best results in sound, a two-conductor shielded cable should be used.

In complex systems where the input lines are run in close proximity to the speaker lines for long distances, currents in the speaker lines may be picked up by the input lines. When these stray currents are fed back to the amplifier, cross talk and hum can be heard, or the amplifier may oscillate. Because of this, balanced line connections are recommended when long input and speaker lines are run close together. A balanced line is achieved by ungrounding the common terminal, leaving the outputs floating. Any current that develops on one side of the line and is offset by an equal and opposite current on the other side is called a BALANCED LINE. This reduces the possibility of creating stray currents in nearby input tines.

If hum is encountered with a balanced line, it may be necessary to run a shielded two-conductor cable to the speakers and ground the cable at the amplifier.

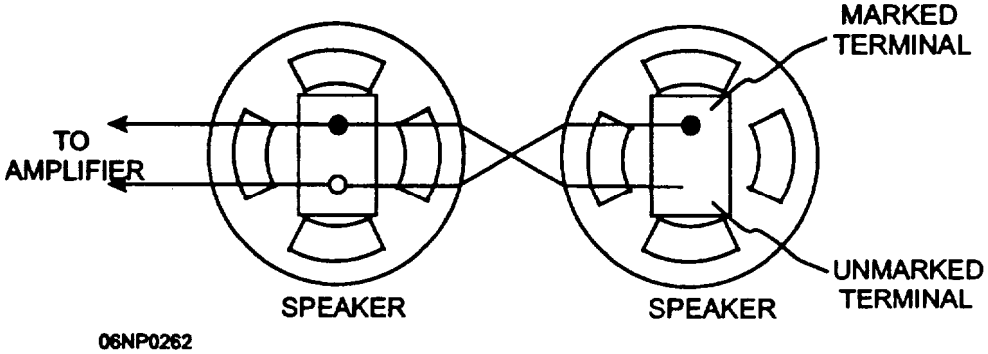


Figure 6-5.—Phasing speakers facing in the same and opposite direction.

MAINTENANCE AND REPAIR

The best designed and built equipment occasionally develops faults. There are many factors that cause faults: moving equipment, atmospheric conditions, and the age of the equipment, just to name a few. A preventive maintenance schedule should be developed that requires a set routine of periodic tests, checks, and inspections to head off trouble before it develops.

When repairing a PA. system, you should always follow the manufacturers' recommendations and guidelines. Replacing faulty parts with the exact replacement parts is always the correct procedure.

Trouble in a public address system is often caused by nothing more than a loose connection or a break in the cable shield. Check for simple faults of this type before you begin a lengthy test of the system.

The identification and location of serious troubles in a system may require the use of signal-tracing equipment, such as an audio-signal generator, a meter, or an oscilloscope. When you test the electrical circuit, the most important point to remember is that you need to pinpoint the location of the trouble. A careful study of the circuit diagram is essential.

Some of the problems that cause defects in a P.A. system are poor solder connections and loose mechanical connections. When checking solder connections, make certain that both metals are absolutely clean and that the completed soldering job is firm and durable. Faulty soldering in a P.A. system can cause defects that are difficult to identify and locate. Too much solder can cause shorts in microphone connections that may not be visible.

Mechanical connections are easy to check; just ensure that all connections with a mechanical connector are tight. This type of connector will be found in the rear of the amplifier or in the console and speakers.

INTEROFFICE COMMUNICATION SYSTEMS

An interoffice communication system is used to transmit orders and information among offices that are only a short distance apart. Frequently, such offices are in the same building. When an interoffice communication system is used, you are responsible for the installation and maintenance of the system.

CONFIGURATIONS

An intercom system consists of two basic configurations: the all-master system and the single-master multiple remote system.

With the all-master system, any station can call any other station or several stations can be connected together for a conference.

With the single-master multiple remote system, the single-master station can selectively call any remote station, and any remote can call the master station.

COMPONENTS

Basically, an intercom system consists of one or more stations, a junction box, one or more remote speaker units, and the wire necessary to make the connections.

The basic parts of a master station consist of a speaker-microphone, a selector switch panel, a combination volume control, ON/OFF switch, a pilot light, and a listen-talk switch, all of which are mounted in a cabinet.

The basic parts of a remote speaker unit consist of a speaker-microphone, a push switch for signaling the master, and a terminal board for interconnection to the master station.

MASTER AND REMOTE STATION INSTALLATION

You can accomplish the installation of an intercom system easily if you follow the manufacturers' instructions and the NEC© guidelines.

Any combination of master stations and remote stations up to the capacity of the master station can be used. Where it is not necessary for remote stations to communicate among themselves, you should usually install only one master station.

Install the master station within reach of a 120-volt, 60-hertz ac power outlet. The master station and the remote stations should be installed on the desk or in the working spaces of the personnel who will use them. If some of the units are to be installed outdoors, take the necessary precautions to protect them from adverse weather conditions.

The size of cable to be used in making connections between units is governed by the length of wire and the type of system you install. The maximum wire resistance permissible will be stated in the operating

instructions of the manufacturer's literature. Component and cable installation will depend on the type of system to be installed.

After the cable is installed, check the resistance with an ohmmeter. Make certain that the maximum permissible resistance is not exceeded and that there are no opens, grounds, or shorts.

NOTE: Always follow the installation instructions that come with each system.

MAINTENANCE OF INTEROFFICE COMMUNICATIONS SYSTEMS

In general there are four basic steps in intercom maintenance: inspect, tighten, clean, and adjust. Inspection is always of primary importance.

The components in an intercom system are readily accessible, and, for the most part, can be replaced when faulty.

With the solid-state devices of today, all maintenance programs are basically the same. One of the first and the most important factors you must take is to consult the manufacturers' recommendations and guidelines when performing maintenance on any intercom system.

Common troubles within an intercom system are normally nothing more than loose connections or breaks in the cable. If a component should need replacement, be sure to replace it with the manufacturer's suggested component.

FIBER OPTICS

People have used light to transmit information for hundreds of years. However, it was not until the 1960s with the invention of the laser that widespread interest in optical (light) systems for data communications began. The invention of the laser prompted researchers to study the potential of fiber optics for data communications, sensing, and other applications. Laser systems could send a much larger amount of data than the telephone, microwave, and other electrical systems. The first experiment with the laser involved letting the laser beam transmit freely through the air. Also, researchers conducted experiments that transmitted the laser beam through different types of waveguides. Glass fibers, gas-filled pipes, and tubes with focusing lenses are examples of optical waveguides.

Glass fibers soon became the preferred medium for fiber-optic research. Initially, the large losses in the optical fibers prevented coaxial cables from being replaced. **Loss** is the decrease in the amount of light reaching the end of the fiber. Early fibers had losses around 1,000 dB/km, making them impractical for communications use. In 1969, several scientists concluded that impurities in the fiber material caused the signal loss in optical fibers. The basic fiber material did not prevent the light signal from reaching the end of the fiber. These researchers believed it was possible to reduce the losses in optical fibers by removing the impurities. By removing the impurities, researchers made possible the construction of low-loss optical fibers.

Developments in semiconductor technology that provided the necessary light sources and detectors furthered the development of fiber optics. Conventional light sources, such as lamps or lasers, were not easily used in fiber-optic systems. These light sources tended to be too large and required lens systems to launch light into the fiber. In 1971, Bell Laboratories developed a small area light-emitting diode (LED). This light source was suitable for a low-loss coupling to optical fibers. Researchers could then perform source-to-fiber jointing easily and repeatedly. Early semiconductor sources had operating lifetimes of only a few hours; however, by 1973, projected lifetimes of lasers advanced from a few hours to greater than 1,000 hours. By 1977, projected lifetimes of lasers advanced to greater than 7,000 hours. By 1979, these devices were available with projected lifetimes of more than 100,000 hours.

In addition, researchers also continued to develop new fiber-optic parts. The types of new parts developed included low-loss fibers and fiber cables, splices, and connectors. These parts permitted demonstration and research on complete fiber-optic systems.

Advances in fiber optics have permitted the introduction of fiber optics into present applications. These applications are mostly in the telephone long-haul systems but are growing to include cable television, computer networks, video systems, and data links. Research should increase system performance and provide solutions to existing problems in conventional applications. The impressive results from early research show there are many advantages offered by fiber-optic systems.

FIBER-OPTIC SYSTEMS

System design has centered on long-haul communications and the subscriber-loop plants. The subscriber-loop plant is the part of a system that connects a subscriber to the nearest switching center. Cable television is an example. Also, limited work has been done on short-distance applications and some military systems. Initially, central office trunking required multimode optical fibers with moderate to good performance. Fiber performance depends on the amount of loss and signal distortion introduced by the fiber when it is operating at a specific wavelength. Two basic types of optical fibers are used in industry: multimode fibers and single mode fibers.

Future system design improvements depend on continued research. Researchers expect fiber-optic product improvements to upgrade performance and lower costs for short-distance applications. Future systems center on broadband services that will allow transmission of voice, video, and data. Services will include television, data retrieval, video word processing, electronic mail, banking, and shopping.

ADVANTAGES AND DISADVANTAGES OF FIBER OPTICS

Fiber-optic systems have many attractive features that are superior to electrical systems. These include improved system performance, immunity to electrical noise, signal security, and improved safety and electrical isolation. Other advantages include reduced size and weight, environmental protection, and overall system economy. Table 6-1 details the main advantages of fiber-optic systems.

Despite the many advantages of fiber-optic systems, there are some disadvantages. Because of the relative newness of the technology, fiber-optic components are expensive. Fiber-optic transmitters and receivers are still relatively expensive compared to electrical interfaces. The lack of standardization in the industry has also limited the acceptance of fiber optics. Many industries are more comfortable with the use of electrical systems and are reluctant to switch to fiber optics; however, industry researchers are eliminating these disadvantages.

Standards committees are addressing fiber-optic part and test standardization. The cost to install fiber-optic systems is falling because of an increase in the use of fiber-optic technology. Published articles, conferences, and lectures on fiber optics have begun to educate managers and technicians. As the technology matures, the use of fiber optics will increase because of its many advantages over electrical systems.

Table 6-1.—Advantages of Fiber Optics

System Performance	• Greatly increased band. width and capacity • Lower signal attenuatior (loss)
Immunity to Electrical Noise	• Immune to noise (electromagnetic interference [EMI] and radio-frequency interference [RFI]) • No cross talk • Low bit error rates
Signal Security	• Difficult to tap • Nonconductive (does no radiate signals)
Electrical Isolation	• No common ground required • Freedom from short circuit and sparks
Size and Weight	• Reduced size and weigh cables
Environmental Protection	• Resistant to radiation and corrosion • Resistant to temperature variations • Improved ruggedness and flexibility • Less restrictive in harsh environments
Overall System Economy	• Low per-channel cost • Lower installation cost • Silica is the principal abundant, and inexpensive material (source is sand)

BASIC STRUCTURE OF AN OPTICAL FIBER

The basic structure of an optical fiber consists of three parts: the **core,** the **cladding,** and the **coating** or **buffer.** The basic structure of an optical fiber is shown in figure 6-6. The **core** is a cylindrical rod of dielectric material. Dielectric material conducts no electricity. Light propagates mainly along the core of the fiber. The core is generally made of glass. The core is surrounded by a layer of material called the **cladding.** Even though light will propagate along the fiber core without the layer of cladding material, the cladding does perform some necessary functions.

The **cladding** layer is made of a dielectric material. Cladding is generally made of glass or plastic and performs the following functions:

- Reduces loss of light from the core into the surrounding air
- Reduces scattering loss at the surface of the core
- Protects the fiber from absorbing surface contaminants
- Adds mechanical strength

For extra protection, the cladding is enclosed in an additional layer called the **coating** or **buffer.**

The **coating** or **buffer** is a layer of material used to protect an optical fiber from physical damage. The material used for a buffer is a type of plastic. The buffer is elastic in nature and prevents abrasions. Also, the buffer prevents the optical fiber from scattering losses caused by microbends. Microbends occur when an optical fiber is placed on a rough and distorted surface. Microbends are discussed later in this chapter.

OPTICAL CABLES

Optical fibers have small cross-sectional areas. Without protection, optical fibers are fragile and can be broken. The optical cable structure protects optical fibers from environmental damage. Cable structure includes buffers, strength members, and jackets. Many factors influence the design of fiber-optic cables. The cable design relates to the intended application of the cable. Properly designed optical cables perform the following functions:

- Protect optical fibers from damage and breakage during installation and over the lifetime of the fiber.
- Provide stable fiber transmission characteristics compared with uncabled fibers. Stable transmission includes stable operationin extreme climate conditions.
- Maintain the physical integrity of the optical fiber by reducing the mechanical stresses placed on the fiber during installation and use. Static fatigue caused by tension, torsion, compression, and bending can reduce the lifetime of an optical fiber.

FIBER BUFFERS

Coatings and buffers protect the optical fiber from breakage and loss caused by microbends. During the fiber drawing process, the addition of a primary coating protects the bare glass from abrasions and other surface contaminants. For additional protection, manufacturers add a layer of buffer material. The buffer material provides additional mechanical protection for the fiber and helps preserve the inherent strength of the fiber.

Manufacturers use a variety of techniques to buffer optical fibers. The types of fiber buffers include tight-buffered, loose-tube, and gel-filled loose-

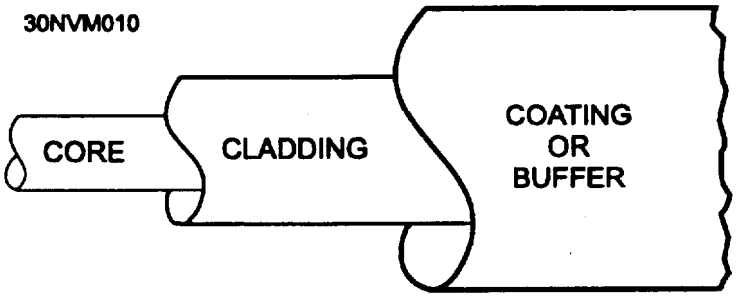


Figure 6-6.—Basic structure of an optical fiber.

tube. Figure 6-7 shows each type of fiber buffer. The choice of buffering techniques depends on the intended application. In large fiber count commercial applications, manufacturers use the loose-tube buffers. In commercial building and Navy applications, manufacturers use tight buffers.

CABLE STRENGTH AND SUPPORT MEMBERS

Fiber-optic cables use strength members to increase the strength of the cable and protect the fiber from strain. Fiber-optic cables may use central support members in cable construction The central support members generally have buffered fibers or single fiber subcables stranded over their surface in a structured, helical manner. The central members may support the optical fibers as cable strength members or may only serve as fillers. Strength and support members must be light and flexible. The materials used for strength and support include steel wire and textile fibers (such as nylon and arimid yarn). They also include carbon fibers, glass fibers, and glass reinforced plastics.

CABLE JACKET MATERIAL

The jacket, or sheath, material provides extra environmental and mechanical protection. Jacket materials may possess any number of the following properties:

- Low smoke generation
- Low toxicity
- Low halogen content
- Flame retardance
- Fluid resistance
- High abrasion resistance
- Stable performance over temperature

It is difficult to produce a material compound that satisfies every requirement without being too costly. Jacket materials currently used include polyethylene, polyvinyl chloride, polyurethane, and polyester elastomers. Most commercial jacket materials are unsuitable for use in naval applications.

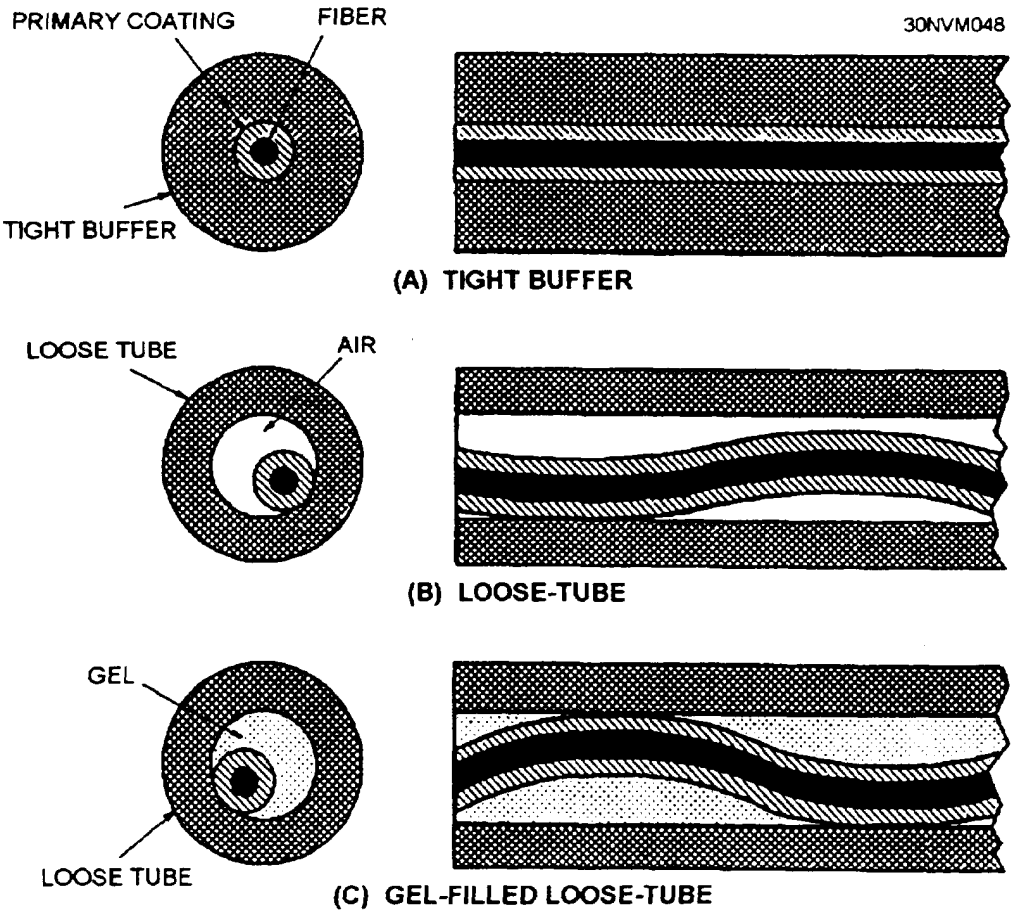


Figure 6-7.—Tight-buffered, loose-tube, and gel-filled loose-tube buffer techniques.

CABLE DESIGNS

Manufacturers design fiber-optic cables for specific applications. For example, is the cable buried underground or hung from telephone poles? Is the cable snaked through cableways, submerged in water, or just laid on the ground? Is the cable used in industrial, telecommunication, utility, or military applications? Each type of application may require a slightly different cable design.

Agreement on standard cable designs is difficult. Cable design choices include jacket materials, water-optic cables. Some fiber-optic cables are used in commercial applications, and others are used in military applications. Standard commercial cable designs will develop over time as fiber-optic technology becomes more established.

FIBER-OPTIC DATA LINKS

A fiber-optic data link sends input data through fiber-optic components and provides this data as output information. It has the following three basic functions:

- To convert an electrical input signal to an optical signal
- To send the optical signal over an optical fiber
- To convert the optical signal back to an electrical signal

A fiber-optic data link consists of three parts: **transmitter, optical fiber,** and **receiver.** Figure 6-8 is an illustration of a fiber-optic data-link connection. The transmitter, optical fiber, and receiver perform the basic functions of the fiber-optic data link. Each part of the data link is responsible for the successful transfer of the data signal. A fiber-optic data link needs a transmitter that can effectively convert an electrical input signal to an optical signal and launch the data-containing light down the optical fiber. Also, fiber-optic data link needs a receiver that can effectively transform this optical signal back into its original form. This means that the electrical signal provided as data output should exactly match the electrical signal provided as data input.

FIBER-OPTIC SPLICES

A fiber-optic splice is a permanent fiber joint whose purpose is to establish an optical connection between two individual optical fibers. System design may require that fiber connections have specific optical properties (low loss) that are met only by fiber splicing. Also, fiber-optic splices permit the repair of optical fibers damaged during installation, accident, or stress. System designers generally require fiber splicing whenever repeated connection or disconnection is unnecessary or unwanted.

Mechanical and fusion splicing are two broad categories that describe the techniques used for fiber splicing. A **mechanical** splice is a fiber splice where mechanical fixtures and materials perform fiber alignment and connection. A **fusion splice** is a fiber splice where localized heat fuses or melts the ends of two optical fibers together. Each splicing technique seeks to optimize splice performance and reduce splice loss. Low-loss fiber splicing results from proper fiber end preparation and alignment.

FIBER-OPTIC CONNECTORS

A fiber-optic connector is a device that permits the coupling of optical power between two optical fibers or two groups of fibers. Designing a device that allows for repeated fiber coupling without significant loss of light is difficult. Fiber-optic connectors must maintain fiber alignment and provide repeatable loss measurements during numerous connections. Fiber-optic connectors should be easy to assemble (in a laboratory or field environment) and should be cost effective. Also, they should be reliable. Fiber-optic connections using connectors should be insensitive to environmental conditions, such as temperature, dust, and moisture. Fiber-optic connector designs attempt to optimize connector performance by meeting each of these conditions.

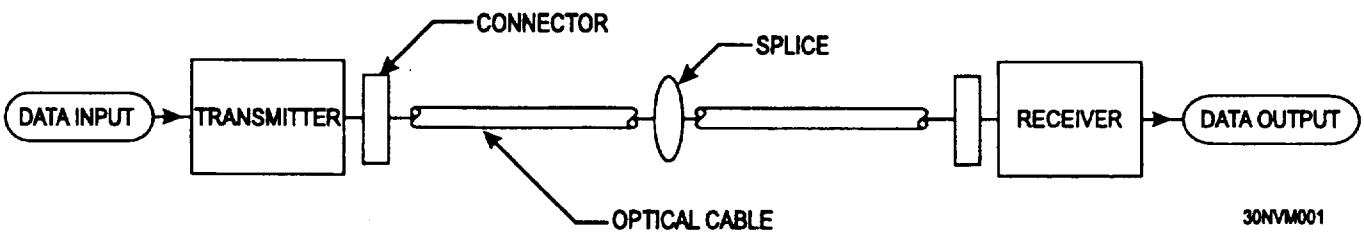


Figure 6-8.—Parts of a fiber-optic data link.

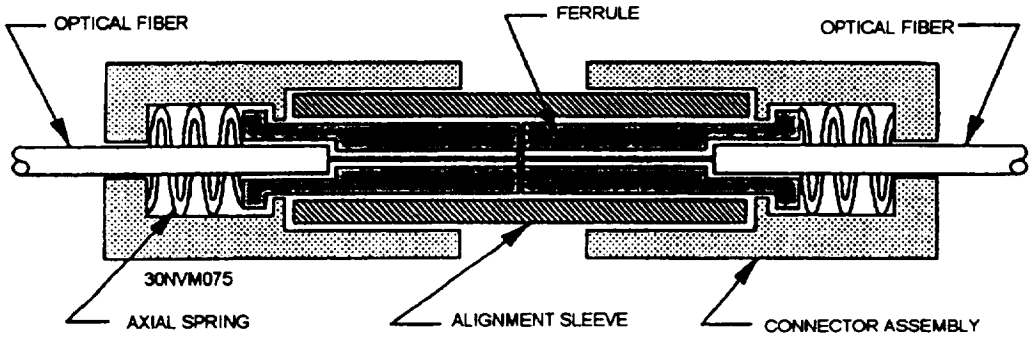


Figure 6-9.—Basic ferrule connector design.

Butt-jointed connectors and **expanded-beam connectors** are the two basic types of fiber-optic connectors. Fiber-optic **butt-jointed connectors** align and bring the prepared ends of two fibers into close contact. The end faces of some butt-jointed connectors touch, but others do not. depending upon the connector design. Types of butt-jointed connectors include cylindrical ferrule and biconical connectors. Figure 6-9 shows a basic ferrule design. Fiber-optic **expanded-beam connectors** use two lenses to first expand and then refocus the light from the transmitting fiber into the receiving fiber. Single fiber butt-jointed and expanded-beam connectors normally consist of two plugs and an adapter (coupling device) (fig. 6-10).

Expanded-beam connector shown in figure 6-11 uses two lenses to expand and then refocus the light from the transmitting fiber into the receiving fiber. Expanded-beam connectors are normally plug-adapter-plug type connections Fiber separation and lateral misalignment are less critical in expanded-beam coupling than in butt-jointing. The same amount of fiber separation and lateral misalignment in expanded-beam coupling produces a lower coupling loss than in butt-jointing; however, angular misalignment is more critical. The same amount of angular misalignment in expanded-beam coupling produces a higher loss than in butt-jointing. Also, expanded-beam connectors are much harder to produce. Resent applications for expanded-beam connectors include multifiber connections, edge connections for printed circuit boards, and other applications.

FIBER-OPTIC COUPLERS

Some fiber-optic data links require more than simple point-to-point connections. These data links may be of a much more complex design that requires multiport or other types of connections. In many cases, these types of systems require fiber-optic components that can redistribute (combine or split) optical signals throughout the system.

One type of fiber-optic component that allows for the redistribution of optical signals is a fiber-optic coupler. A fiber-optic coupler is a device that can distribute the optical signal (power) from one fiber among two or more fibers. Also, a fiber-optic coupler

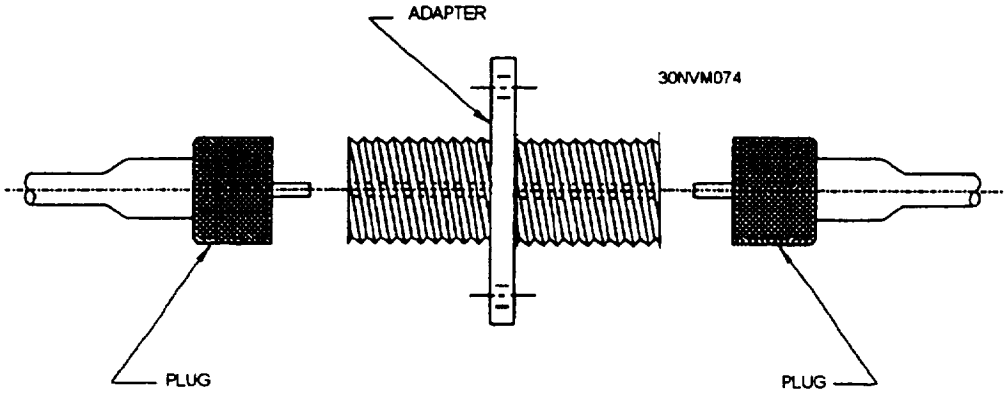


Figure 6-10.—Plug-adapter-plug configuration.

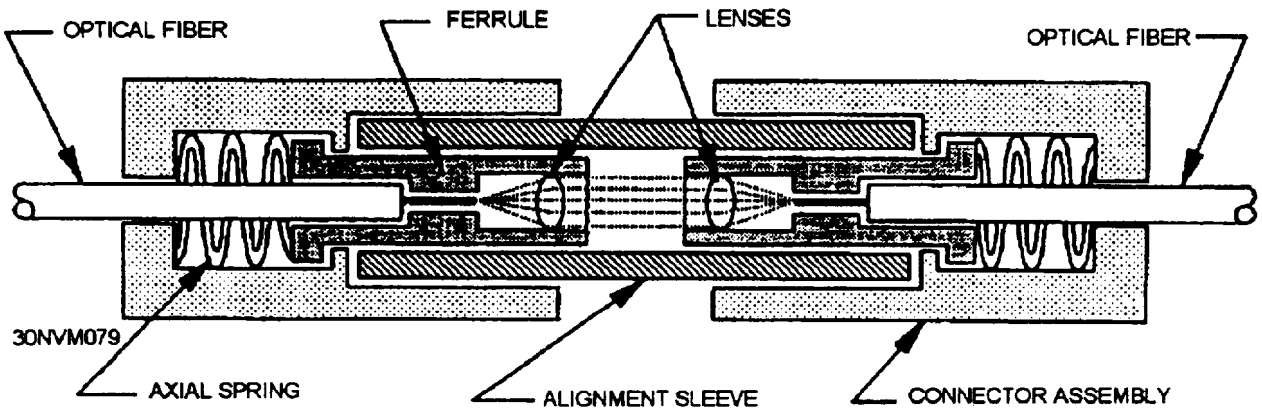


Figure 6-11.—Expanded-beam connector operation.

can combine the optical signal from two or more fibers into a single fiber.

Fiber-optic couplers can be either active or passive devices. The difference between active and passive couplers is that a **passive coupler** redistributes the optical signal without optical-to-electrical conversion. **Active couplers** are electronic devices that split or combine the signal electrically and use fiber-optic detectors and sources for input and output.

Figure 6-12 shows the design of a basic fiber-optic coupler. A basic fiber-optic coupler has N input ports and M output ports. N and M ports typically range from 1 to 64. The number of input ports and output ports varies, depending on the intended application for the coupler. Types of fiber-optic couplers include optical splitters, optical combiners, X couplers, star couplers, and tree couplers.

AREA LIGHTING SYSTEMS

This section covers streetlighting, floodlighting, and security lighting systems. When properly constructed and installed, these original basewide lighting systems will provide years of trouble-free operation with a minimum of minor maintenance and bulb changing required to keep the system fully operational.

Several factors can change the base requirements for area lighting. These factors include such changes as facility usage, updating of systems, changes in the base mission, or expanding existing systems.

With the cost of energy rising daily, any system that can provide a higher level of efficiency for the energy used must be considered. The use of the newer high-pressure discharge systems for lighting seems to offer savings both in the lifespan of the bulbs and in the lumens per watt of energy used These systems are replacing the older incandescent systems in an ever-increasing pace. The higher initial cost of these systems is being offset by the efficiency of the energy used and savings of energy dollars.

TERMINOLOGY AND DEFINITIONS

You will need an understanding of lighting techniques and effects to understand the physical concepts and terminology involved in lighting systems. We will use both the American Standard (AS) and the metric system (SI) when discussing lighting concepts. The AS standards will be without brackets, whereas the SI terms will be noted in square brackets [ ].

The candlepower [candela], abbreviated cp [cd], is the unit of luminous intensity. It is comparable to the voltage in an electrical circuit and represents the force that generates the light you can see. An ordinary wax candle has a luminous intensity of approximately one

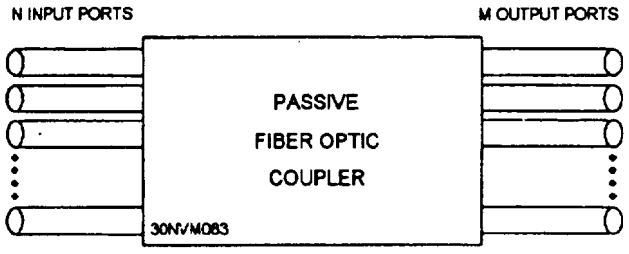


Figure 6-12.—Basic passive fiber-optic coupler design.

candlepower [candela], hence the name (fig. 6-13). A candle radiates light equally in all directions. If you imagine such a source surrounded by a transparent sphere of one foot [meter] radius (figure) than by definition, the amount of luminous energy (flux) emanating from one square foot [meter] of surface on the sphere is one lumen [lumen], abbreviated lm.

Since there are 40 square feet [meters] of surface area in such a sphere, it follows that a source of one candlepower [candela] intensity produces 40 or 12.57 lm (a lumen is a unit of light quantity), and in terms of power is equal to 0.0015 watt. It therefore also follows that 1-cp [cd] source produces 12.57 times 0.0015 watt; that is, 0.0189 watt or approximately 1/50 watt of luminous energy. The lumen, as luminous flux, or quantity of light, is comparable to the flow of current in an electrical circuit

One lumen of luminous energy occurrence on one square foot of area produces an illumination of one footcandle (fc). When the area is expressed in square meters, the illumination is expressed in lux (lx). If you were to consider a light bulb to be comparable to a sprinkler head, then the amount of water released would be the lumens and the amount of water per square foot (meter) of floor area would be the footcandles [lux]. The metric unit, lux, is smaller than the corresponding unit, footcandles, by a ratio of approximately 10 to 1. In order to change footcandle to lux, you would multiply by 10.764.

Restating what you have just learned mathematically, it would look like this:

$$footcandles = \frac{lumens}{square\ feet\ of\ area}$$

Or

$$lux = \frac{lumens}{square\ meter\ of\ area}$$

High Intensity Discharge Lighting

Efforts to improve the power efficiency and reduce the maintenance costs led to the development of a new family of lighting that has been generally categorized as high--intensity-discharge lamps (HID). These lamps all have a negative-resistance characteristic. This means that the resistance decreases as the lamps heat up. As the resistance decreases, the current increases. In fact, the current will increase indefinitely unless a current--limiting device is provided. All gaseous conduction HID lamps, therefore, have current limiters, called **"ballasts."** Lamp life and more light per watt are two main advantages that HID lamps have over incandescent bulbs. The basic types of HID lamps used in area lighting consist of three groups of lamps:

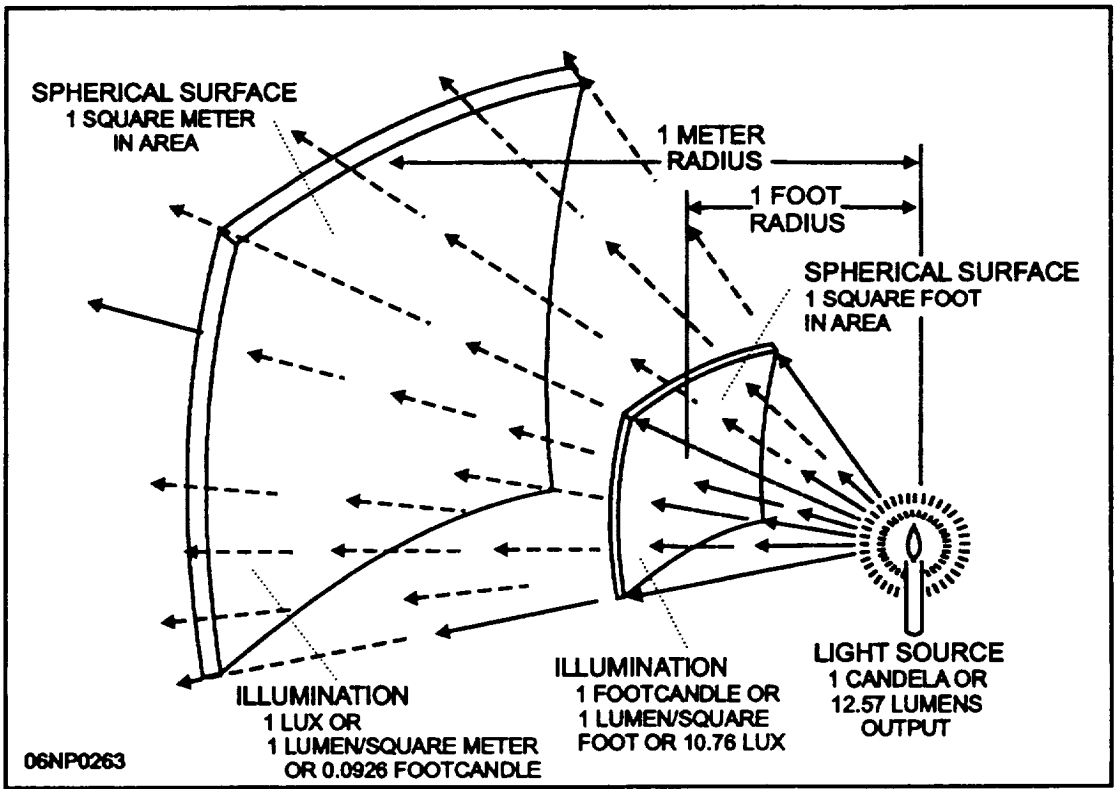


Figure 6-13.—Relationship between a light source of one candlepower and the illumination produced.

mercury lamps, metal halide lamps, and high-pressure sodium lamps. All high-intensity-discharge lamps produce light from an arc tube that is usually contained in an outer glass bulb.

Figure 6-14 shows the basic configuration of a HID lamp. In these lamps, a material, such as sodium, mercury, or metal halide, is added to the arc tube. In design, the lamp has three electrodes—one acting as a cathode and the other as an anode with the other electrode being used for starting. The arc tube contains small amounts of pure argon gas, halide salts, sodium, and vapor to aid in starting. Free electrons are accelerated by the starting voltage. In this state of acceleration, these electrons strike atoms and displace other electrons from their normal atomic positions. Once the discharge begins, the enclosed arc becomes the light source.

Commercial companies that produce these light bulbs claim a 100-percent increase in lamp life over tungsten filament bulbs that produce the same amount of light. The power in watts required to operate these lamps is less than one half of that required for filament lamps. The initial cost of the components for lights is substantially greater as these lights will require ballasts; however, this cost can be made up later by the savings of energy costs. The selection of lighting fixtures will depend on budgeted dollars for new installation projects versus maintenance dollars.

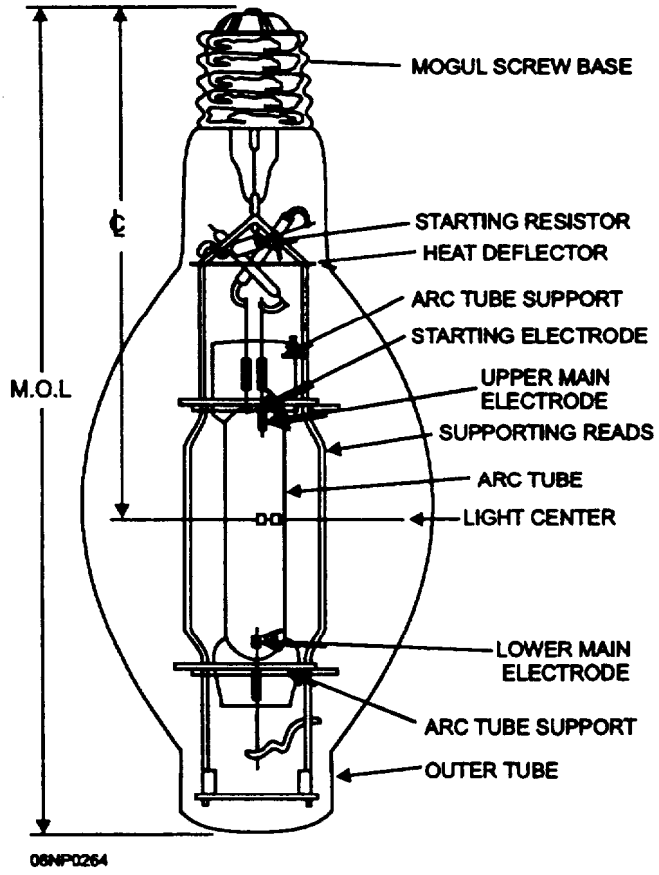


Figure 6-14.—HID lamp configuration.

Most discharge lighting fixtures are supplied with the required ballast installed in the fixture. In some cases ballasts, usually called transformers, are externally installed.

High Pressure Mercury Lamps

This lamp consists of a quartz arc tube sealed within an outer glass jacket or bulb. The inner arc tube is made of quartz to withstand the high temperatures, resulting when the lamp builds up to normal wattage. Two main electronemissive electrodes are located at opposite ends of the tube; these are made of coiled tungsten wire. Near the upper main electrode is a third, or starting, electrode in series with a ballasting resistor and connected to the lower main-electrode lead wire.

The arc tube in the mercury lamp contains a small amount of pure argon gas that is vaporized. When voltage is applied, an electric field is set up between the starting electrode and the adjacent main electrode. This ionizing potential causes current to flow, and, as the main arc strikes, the heat generated gradually vaporizes the mercury. When the arc tube is filled with mercury vapor, it creates a low-resistance path for current to flow between the main electrodes. When this takes place, the starting electrode and its high-resistance path become automatically inactive.

Once the discharge begins, the enclosed arc becomes a light source with one electrode acting as a cathode and the other as an anode. The electrodes will exchange functions as the ac supply changes polarity.

The quantity of mercury in the arc tube is carefully measured to maintain quite an exact vapor pressure under design conditions of operation. This pressure differs with wattage sizes, depending on arc-tube dimensions, voltage-current relationships, and various other design factors.

Efficient operation requires the maintenance of a high temperature of the arc tube. For this reason, the arc tube is enclosed in an outer bulb made of heat-resistant glass that makes the arc tube less subject to surrounding temperature or cooling by air circulation. About half an atmosphere of nitrogen is introduced into the space between the arc tube and the outer bulb. The operating pressure for most mercury lamps is in the range of two

to four times the atmospheric pressure. Lamps can operate in any position; however, light output is reduced when burned in positions other than vertical. Mercury lamps for lighting applications range in wattage from 40 to 1,000 watts. The 175- and 400-watt types are the most popular. Mercury lamps are used in streetlighting, security lighting, and outdoor area lighting. In new installations today, mercury lamps are being replaced with more efficient metal halide or high-pressure sodium systems.

Metal Halide Lamps

The halide lamps are similar to mercury lamps in construction because the lamp consists of a quartz arc tube mounted within an outer glass bulb; however, in addition to mercury, the arc tubes contain halide salts, usually sodium and scandium iodide. During lamp operation, the heat from the arc discharge evaporates the iodide along with the mercury. The result is an increase in efficiency approximately 50 percent higher than that of a mercury lamp of the same wattage together with excellent color quality from the arc.

The amount of iodide vaporized determines lamp efficiency and color and is temperature-dependent. Metal halide arc tubes have carefully controlled seal shapes to maintain temperature consistency between lamps. In addition, one or both ends of the arc tube are coated to maintain the desired arc-tube temperature. There is some color variation between individual metal halide lamps owing to differences in the characteristics of each lamp.

Metal halide lamps use a starting electrode at one end of the arc tube that operates in the same manner as the starling electrode in a mercury lamp. A bimetal shorting switch is placed between the starting electrode and the adjacent main electrode. This switch closes during lamp operation and prevents a small voltage from developing between the two electrodes, that in the presence of the halides could cause arc-tube seal failure.

High Pressure Sodium Lamps

The high-pressure sodium lamp, commonly referred to as HPS, has the highest light-producing efficiency of any commercial source of white light. Like most other high-intensity-discharge lamps, high-pressure sodium lamps consist of an arc tube enclosed within an outer glass bulb. The arc operates in a sodium vapor at a temperature and pressure that provide a warm color with light in all portions of the visible spectrum at a high efficiency. Owing to the chemical activity of hot sodium, quartz cannot be used as the arc-tube material; instead, high-pressure sodium arc tubes are made of an alumina ceramic (polycrystalline alumina oxide) that can withstand the corrosive effects of hot sodium vapor.

There are coated-tungsten electrodes sealed at each end of the arc tube. The sodium is placed in the arc tube in the form of a sodium-mercury amalgam that is chemically inactive. The arc tube is filled with xenon gas to aid in starting.

High-pressure sodium lamps are available in sizes from 35 to 1,000 watts. They can be operated in any burning position and have the best lumen-maintenance characteristic of the three types of HID lamps. Except for the 35-watt lamp, most high-pressure sodium lamps have rated lives of more than 24,000 hours. The 35-watt lamp has a rated life of 16,000 hours. The 50-, 70-, and 150-watt sizes are available in both a mogul-base and a medium-base design.

Fluorescent Lighting

Fluorescent lamps of high-pressure, hard glass are used to some extent for floodlighting where a low-level, highly diffused light is desired. This would include club parking lots, outside shopping areas, parks, or grass areas. This bulb is much the same in operation as the mercury-vapor lamp with the exception that the fluorescent tube has an inside coating of material, called phosphor, that gives off light when bombarded by electrons. In this case, the visible light is a secondary effect of current flow through the lamp. Just like the HID lamps, the fluorescent lamp requires a ballast for operation. The color produced by the light depends on the type of phosphor material used.

High-Intensity-Discharge Lamp Ballasts

All HID lamps have a negative-resistance characteristic. As a result, unless a current-limiting device is used, the lamp current will increase until the lamp is destroyed. Ballasts for HID lamps provide three basic functions: to control lamp current to the proper value, to provide sufficient voltage to start the lamp, and to match the lamp voltage to the line voltage. Ballasts are designed to provide proper electrical characteristics to the lamp over the range of primary voltage stated for each ballast design. Typical ballasts are shown in figure 6-15.

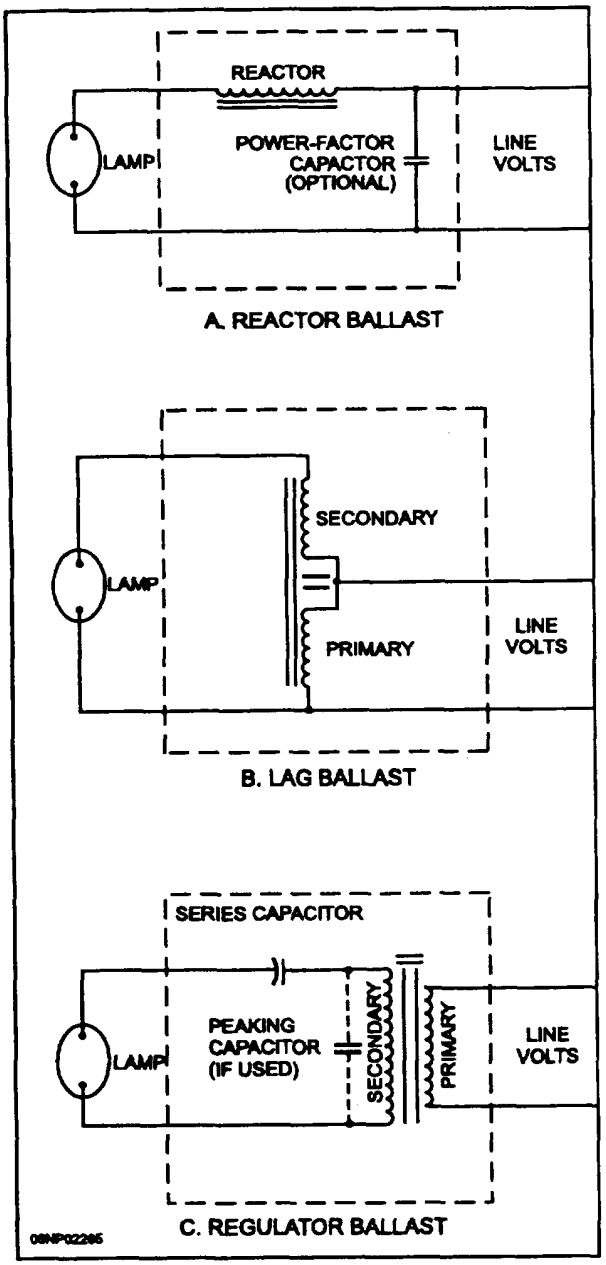


Figure 6-15.—Mercury-lamp ballast circuits.

Ballasts are classified into three major categories depending on the basic circuit involved: nonregulating, lead-type regulating, and lag-type regulating. Each type has different operating characteristics.

High-Intensity-Discharge System Troubleshooting

HID lighting systems include the power supply system (wiring, circuit breakers, and switches), lighting fixture (socket, reflector, refractor or lens, and housing), ballast, lamp, and frequently a photoelectric cell to turn on the fixture at dusk. When an HID system does not operate as expected, the source of the problem can be in any part of the total system.

It is important to understand normal lamp-failure characteristics to determine whether or not operation is abnormal. All HID lamps have expected lamp-failure patterns over life; these are published by lamp manufacturers. Rated life represents the expected failure point for one third to one half of the lamps, depending on the lamp type and the lamp manufacturer's rating.

The end-of-life characteristics vary for the different HID lamps of the following types:

1. *Mercury.* Normal end of life is a nonstart condition or low-light output, resulting from blackening of the arc tube that is due to electrode deterioration during the life of the lamp.

2. *Metal halide.* Normal end of life is a nonstart condition, resulting from a change in the electrical characteristic when the ballast can no longer sustain the lamp. Lamp color at the end of life will usually be warmer (pinker) than that of a new lamp due to arc-tube blackening because of changes in thermal balance within the tube. The lamp manufacturers' recommendations regarding metal-halide lamp enclosures should be reviewed.

3. *High-pressure sodium.* Normal end of life is on-off cycling. This results when an aging lamp requires more voltage to stabilize and operate than the ballast is able to provide. When the normally rising voltage of the lamp exceeds the ballast output voltage, the lamp is extinguished. Thea, after a cool-down period of about 1 minute, the arc will restrike and the cycle is repeated. This cycle starts slowly at first and then increases in frequency if the lamp is not replaced. Ultimately, the lamp fails because of overheating of the arc-tube seal.

There are four basic visual variations in the lamp of a HID lighting system that indicates when a problem may exist: (1) the lamp does not start, (2) the lamp cycle is on and off or is unstable, (3) the lamp is extra bright, or (4) the lamp is dim. The following table indicates the most likely possible causes for each of these system conditions.

HID-system conditions	Other than lamp	Lamp
Lamp does not start.	Ballast failure Incorrect or loose wiring Low supply voltage Low ambient temperature Circuit breakers tripped Inoperative photocell Starting-aid failure (HPS)	Lamp loose in socket Improper lamp wattage Normal end of life Lamp internal structure broken
Lamp cycle is on and off or is unstable.	Low supply voltage Incorrect ballast High supply voltage (HPS) Ballast voltage low System voltage dipping Fixture concentrating energy on lamp (HPS)	Normal end of life (HPS) Lamp operating voltage too high (HPS) Lamp arc tube unstable
Lamp is extra bright.	Shorted or partially shortedballast or capacitor Overwattage operation	Improper lamp wattage High lamp voltage
Lamp is dim.	Low supply voltage Incorrect ballast Low ballast voltage to lamp Dirt accumulation Ballast capacitor shorted Corroded connection in fixture	Improper lamp wattage Low lamp voltage Lamp difficult to start

FIXTURES

There are fixture configurations to meet almost any lighting requirement or design. While the basic purpose of the fixture is to hold and prevent damage to the lamps and lamp sockets, the fixture also helps direct the light beams into the lighting patterns desired. The fixture, with its reflector and lens, determines the quality of the light being produced. Reflectors can either concentrate or diffuse light rays, and the lens can pass or refract light rays. Quite often, the lens may be used to do both from one light source; that is, part of the light rays are refracted to produce a soft, even spread of light in the outer part, while the light rays are concentrated in other areas of the lens to produce a bright, hard light at a specific area. Some streetlight fixtures are examples of this. The sides of the lenses produce a general diffused lighting to prevent blinding automobile operators and, at the same time, they produce a bright light pattern below the lamp along the curb.

Flood or security lighting fixtures may be either open or enclosed. The open fixtures provide higher maintained efficiency and more accurate beam control. The open fixture will, under some conditions, require a “hard glass” bulb to prevent bulb breakage.

Most fixtures will have provisions for mounting ballasts (transformers) within the fixture and will provide protection for the ballast. In some cases, particularly in light pole lighting, the ballasts may be mounted in the pole base and not mounted in the fixture. Several methods of fixture attachment are possible and should be considered when fixtures for a particular job are ordered The location and job determine whether the fixture is suspended, bracket-mounted, or arm-mounted. Most brackets can be attached either to wood

or metal support structures. In either case, the fixture should be firmly attached to the structure so that precise aiming for light distribution can be made.

LIGHT CIRCUITS

As we stated earlier, a number of light systems are in use today, such as streetlights, floodlights, and security lights. These systems are either series or multiple (parallel), depending on how they are used and the equipment available.

SERIES AND MULTIPLE CIRCUITS

The series circuit is supplied by a regulating transformer that gives a constant current, usually of 6.6 amperes, to the lighting circuit. If a higher amperage is required, autotransformers are available for stepping up the current to 15 or 20 amperes. This higher amperage permits the use of more rugged lamp filaments that give longer life for lamps of equal candlepower and higher lamp efficiency.

The multiple (parallel) circuit consists of a number of streetlights supplied by a distribution transformer, delivering a constant low voltage to a circuit or secondary main that also supplies other loads; however, running secondary conductors any great distance to supply a parallel connected lamp or a group of lamps is impractical because of the excessive voltage drop.

The cost of the multiple luminaire is low compared to the series type because the low voltage allows for the elimination of other luminaire accessories. This saving is largely offset, however, by the increased requirement for control devices and the copper wire cost. Lamp life and efficiency are comparatively low, and the illumination is not as uniform as in a series circuit.

In choosing a system, here are a few suggestions that may aid in your selection.

- If the total wattage of the circuit exceeds 2 kilowatts or more than 15 lights, consider a series lighting system.

- When extending an existing system, use the existing circuit.

- If low-voltage capacity exists at the proposed location, use a multiple system, even though the load exceeds 2 kilowatts.

- When several small lights are to be spaced rather far apart and no low-voltage secondary exists along the route, use the series system regardless of the load size or the number of lights.

- When estimates show that one type of system will save money and time, use the more economical system.

Series Circuits

Let us consider a series streetlight system. The power for the circuit will be supplied from the base primary distribution lines, through fuse cutouts, to an oil switch, and from the oil switch to a constant-current regulator (fig. 6-16). The constant-current regulator will supply power to the series loops and, thus to the individual lamps. While the current (normally 6.6 amperes) remains constant, the voltage of the circuit is equal to the sum of the voltages of all the lamps plus the voltage drop in the wire. With enough lamps connected in series, the circuit can become a **high-voltage circuit.**

The series circuit is easily controlled, but any break, such as a burned-out filament in a lamp, interrupts the

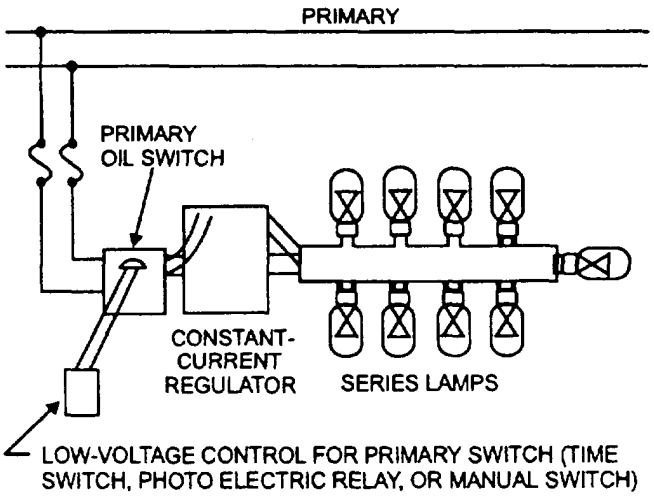


Figure 6-16.—Series street-lighting circuit.

entire circuit. The use of film-disk cutouts (fig. 6-17) in the lamp socket prevents lamp failure from interrupting the circuit. The cutouts consist of two metal disks separated by a thin film of insulating material. The insulating film is held in place by the spring pressure of the contact disks. When the filament of the lamp burns out, the entire circuit voltage appears across the film disk. This is more than sufficient to puncture the film and close the circuit between the two metallic disks, thereby bypassing the burned-out filament. In later series circuits, an isolation transformer is used to eliminate the need for the film disk fixture. The primary winding of the isolation transformer is connected in series with the power source and the secondary winding provides power to the light bulb. Since the primary winding is isolated from the secondary winding, a burned out bulb will not interrupt the continuity of the lighting circuit.

A series circuit is installed using only one wire, as shown in figure 6-18(a). Some of the lamps are connected in the outgoing wire, and the rest are connected in the return wire. This is called an "open-loop" series circuit. An open-loop circuit is less expensive initially, but troubleshooting is difficult, time consuming, and costly.

To make it possible to locate a fault like an open circuit or a ground, it is desirable to bring the outgoing and return conductors close together in numerous places so that the circuit can be easily short-circuited. Such a circuit is called a “closed-loop” circuit, as shown in figure 6-18(b). Sometimes the circuit is arranged to combine the open- and closed-circuit features, as shown in figure 6-18(c). The use of the closed-loop or the combination circuit makes troubleshooting easier.

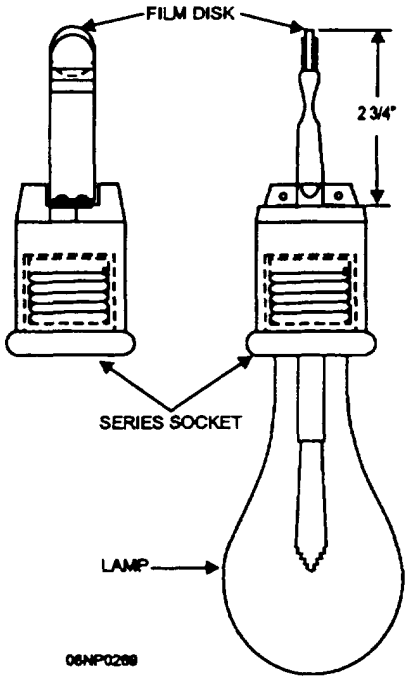


Figure 6-17.—Series lamp, socket, and film-disk cutout.

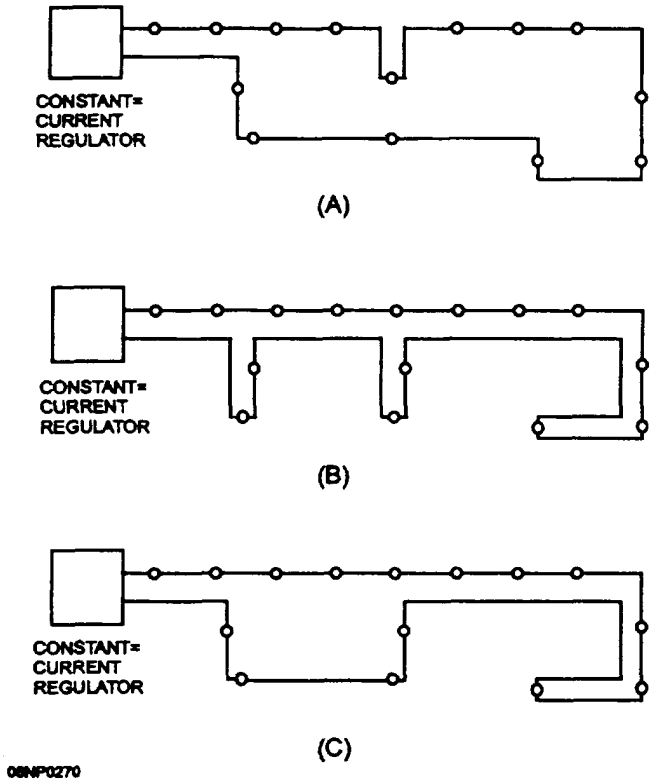


Figure 6-18.—Diagrams of (a) open loop, (b) closed bop, and (c) combined open and closed loop series circuits.

Installing the series circuit on the same crossarm as the primary-distribution conductor is usually the most economical. When two primary crossarms are used, the streetlight wires should be carried on the lower arm in the end-pin position. When two separate single-conductor street circuits are on the same crossarm, they should not be placed in adjacent pin positions because of confusion in troubleshooting.

Insulator sizes should be based on the open-circuit voltage of the largest regulator used and are usually the same size as those used for primary distribution. White insulators should be used on a series street circuit to distinguish them from the primary distribution insulators and to assist in identifying the circuits for operating and maintenance work. Small strain insulators should be used for cutting in individual lamps or loops of five lamps or fewer. Equivalent voltage insulators with automatic line splices may also be used. If the loop consists of more than five lamps, a primary disk insulator is used. The insulator is usually cut in after the conductors have been strung.

The conductor size should be No. 6 medium hard-drawn copper or its mechanical equivalent. Although No. 8 hard-drawn copper is usually too weak for longer spans, the use of copperweld or similar conductors of

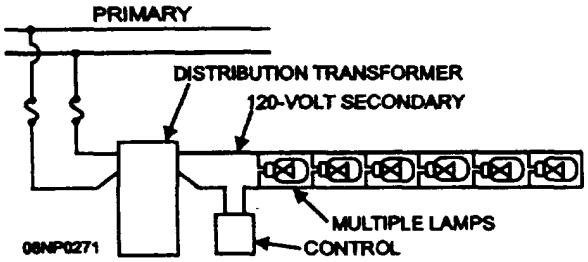


Figure 6-19.—Multiple street-lighting circuit.

high-mechanical strength overcomes the difficulty. Conductor sag should be the same as for primary distribution.

Constant-current regulators should be protected on overhead circuits by lightning arresters on both the primary and secondary sides.

Multiple Circuits

The multiple streetlight system uses a distribution transformer of the proper size as service equipment. (See fig. 6-19.) Notice that the transformer is fed directly through fuse cutouts from the base primary distribution system. The control for the circuit is connected into one line of the secondary side. The selection of output voltage of the transformer depends on the voltage required for the individual lamps that are installed. Depending on the types of lamps selected, this voltage may be from 120 volts to 480 volts. You must know the type of lamp that will be used in the circuit before you can properly select the transformer to feed the streetlight system.

COMPONENTS AND CONTROLS

There are many components required to construct an area lighting system. These include constant-current transformers, relays, controls, fixtures, wiring, and lamps. Controls can be manual, automatic, or a combination.

Constant-Current Transformer

The constant-current transformer, usually called a regulator, has a movable secondary winding that automatically changes position to provide constant current for any load within its full-load rating. The balance point between coil weight and magnetic force may be adjusted to provide the desired output current.

A moving-coil regulator is recommended because of the close regulation required for streetlighting work. It consists of a fixed primary coil and a movable secondary coil on a laminated core. Voltage applied to the primary winding causes voltage to be induced in the secondary winding. When the secondary circuit is closed, the magnetic field in the secondary reacts with the primary-coil field to push the movable coil up. The balance point between coil weight and magnetic force is designed to provide the desired secondary current (usually 6.6 amperes).

On most existing installations, the constant-current regulator is of the outdoor type. Three main types of installation are used for these regulators: two-pole platform, timber or steel construction single-pole platform, and pole mounted. Any regulator larger than 20 kilovolt amperes should be mounted on a platform.

Constant-current regulators should be loaded as near 100 percent as possible since both efficiency and power factor are best at this load. Specifications of the American Institute of Electrical Engineers (AIEE) require constant-current transformers to deliver the rated secondary current at lo-percent overload. A larger size regulator should not be installed before this 10-percent overload is reached. When larger regulators must be installed and are not readily available, a booster transformer may be used with its secondaries connected into the series street circuit and its primaries connected to the primary feeder supplying the regulator (fig. 6-20).

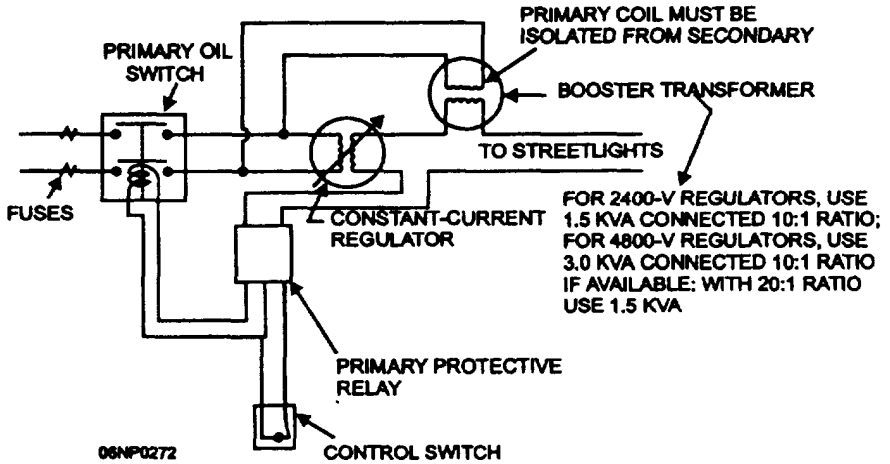


Figure 6-20.—Method of relieving slightly overloaded regulators with a distribution or booster transformer.

Since transformers used for this purpose should have secondary bushings insulated for the high voltage of the series street circuit, a special booster transformer is preferred to an ordinary distribution transformer for use with constant-current regulators of 10 kilowatts and larger. In using a booster transformer, the primary coil must be isolated from the secondary coil that necessitates removing any internal lead connecting the two coils. The additional load handled by this device equals the product of the street-circuit current and the secondary voltage of the transformer. Thus, if a 2,400/240-volt transformer is used, the additional load

STRAIGHT-SERIES LAMPS WITH FILM CUTOUT

REGULATOR RATING (kW)	CIRCUIT RATING IN AMPERES											
	6.6						15	20				
	600 LUMENS	800 LUMENS	1,000 LUMENS	2,500 LUMENS	4,000 LUMENS	6,000 LUMENS		4,000 LUMENS	6,000 LUMENS	10,000 LUMENS	15,000 LUMENS	25,000 LUMENS
1	21	17	14	6	4	2	4	3	3			
2	42	34	28	12	8	5	8	7	6	3	2	1
3	64	51	43	18	12	8	12	11	9	5	3	2
5	107	86	72	30	18	13	20	19	13	9	6	3
7.5	161	129	108	45	30	20	30	29	21	12	9	5
10	214	172	144	60	40	26	40	39	28	16	11	7
15	321	258	216	90	60	40	60	58	47	25	16	10
20	428	344	288	120	80	55	80	78	56	34	22	13
25	535	430	360	150	100	66	100	97	70	42	28	17
30	642	516	432	180	120	80	121	117	85	50	34	21
UNIT kW*	.047	.058	.069	.167	.250	.375	.249	.256	.354	.600	.880	1.43

LAMPS WITH AUTO TRANSFORMERS AND LAMPS WITH ISOLATION TRANSFORMERS

REGULATOR RATING (kW)	CIRCUIT RATING IN AMPERES											
	15	20				6.6		15	20			
	4,000 LUMENS	6,000 LUMENS	10,000 LUMENS	15,000 LUMENS	25,000 LUMENS	1,000 LUMENS	25,000 LUMENS	4,000 LUMENS	6,000 LUMENS	10,000 LUMENS	15,000 LUMENS	25,000 LUMENS
1	3	2	1	1	0	12	5	3	2	1	1	0
2	7	5	3	2	1	24	10	7	5	3	2	1
3	11	7	4	3	2	32	15	10	7	4	3	2
5	18	13	8	5	3	53	25	17	12	7	5	3
7.5	27	19	12	8	5	80	38	26	18	11	7	5
10	37	26	16	11	6	107	51	35	25	15	10	6
15	55	39	24	16	10	160	76	52	37	23	15	10
20	74	52	32	22	12	215	102	70	50	30	20	12
25	92	65	40	27	16	268	127	87	62	38	25	16
30	110	78	48	32	20	322	152	104	74	46	30	20
UNIT kW*	.273	.384	.625	.935	1,500	.093	.197	.288	.405	.650	1.000	1.500

HIGH-INTENSITY DISCHARGE LAMPS

LAMP CAPAFITY OF REGULATORS IS LIMITED BY STARTING CURRENT. DETERMINE UNIT kW BY MULTIPLYING LAMP WATTAGE BY THE FOLLOWING FACTORS: 2.1 FOR AMBIENT TEMPERATURES NOT BELOW +35°F (+2°C)
2.5 FOR AMBIENT TEMPERATURES TO -30°F (-34°C)

THE PROPER SIZE REGULATOR TO SELECT IS THE SMALLEST RATING WHICH EXCEEDS THE SUM OF THE UNIT kW FOR ALL LAMPS ON THE CIRCUIT, REGARDLESS OF TYPE.

*UNIT kW IS THE APPROXIMATE kW CAPACITY REQUIRED FOR A SPECIFIC LAMP AND ITS ASSOCIATED TRANSFORMER OR BALLAST AS APPLICABLE.

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Figure 6-21.—Approximate lamp capacity for street-lighting regulators.

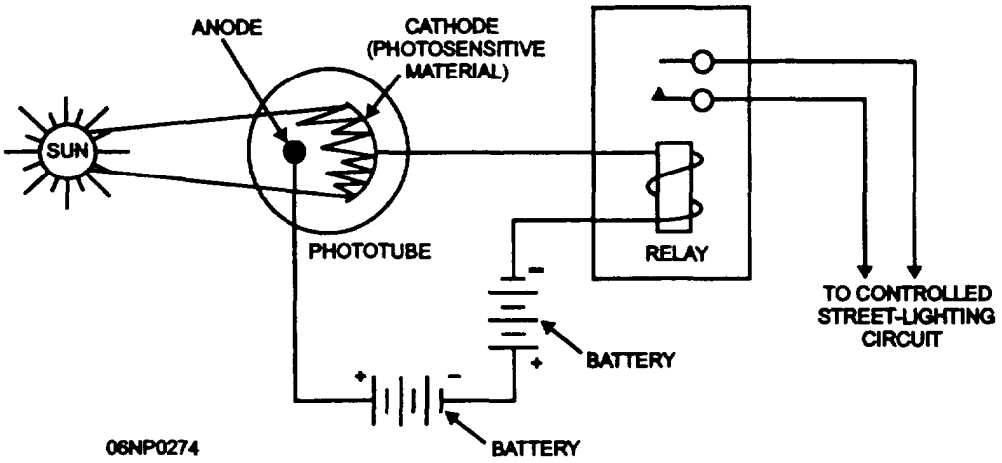


Figure 6-22.—Photoelectric cell control circuit.

that the street circuit can carry is 240 volts times 6.6 amperes or 1.584 kilowatts.

Figure 6-21 shows the maximum number of series lamps in the various sizes that may be used for full-load rating on a regulator. The average number of watts of energy consumption for each size lamp may be computed since the regulator ratings are based on their output. In this manner, the load of a circuit consisting of different size lamps may be computed.

Example: What size regulator would be required to supply the following lamps?

25—1,000-lumen, 6.6-ampere, straight-series lamps

50—2,500-lumen, 6.6-ampere, straight-series lamps

10—6,000-lumen, 20-ampere lamps with isolating transformer

Solution: Figure 6-21 shows that the average energy consumption of a 1,000-lumen, 6.6-ampere, straight-series lamp with film cutout is 69 watts per lamp. In a similar manner, the average energy consumption of a 2,500-lumen lamp is 167 watts, and a 6,000-lumen, 20-ampere lamp with isolating transformer is 405 watts. Totaling the combined load shows the following:

25 x 69 = 1,725 watts

50 x 167 = 8,350 watts

10 x 405 = 4,050 watts

14,125 watts or 14.1 kilowatts

Therefore, a 15-kilowatt regulator would be required.

NOTE: The table makes allowances for line losses in the average series street circuits.

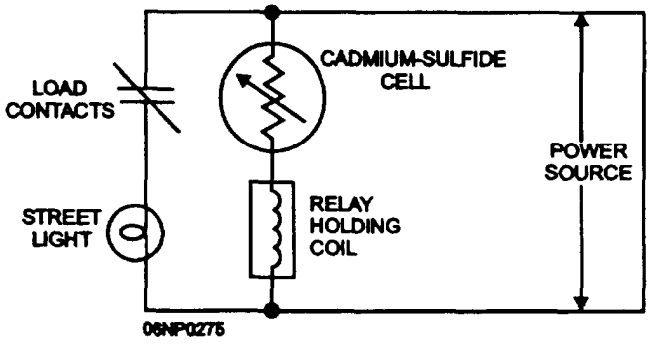


Figure 6-23.—Cadmium-sulfide cell control circuit,

Control Circuits

Several methods are used to control the operation of area lighting systems. For recreational lighting, only a manual switch is required. On the other hand, streetlights and security lights have more sophisticated *controls.*

Lights normally are on during the hours of darkness or when unusual weather conditions indicate the need for artificial light. Although lights could be activated by assigning an individual to operate the controls manually, they are usually turned on and off by a combination of controls.

Most control circuits that you will encounter in the field use one of the following devices to control the lighting system: photoelectric cell (fig. 6-22), cadmium-sulfide cell (fig. 6-23), time clock, pilot wire relay (fig. 6-24), or cascading relays (fig. 6-25).

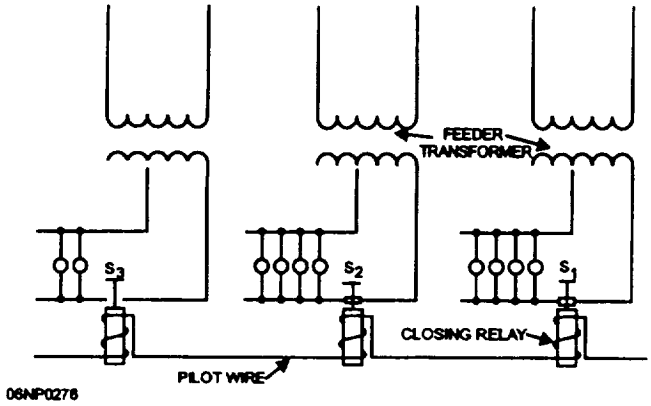


Figure 6-24.—Pilot wire control of multiple-lighting circuits supplied from several feeder transformers.

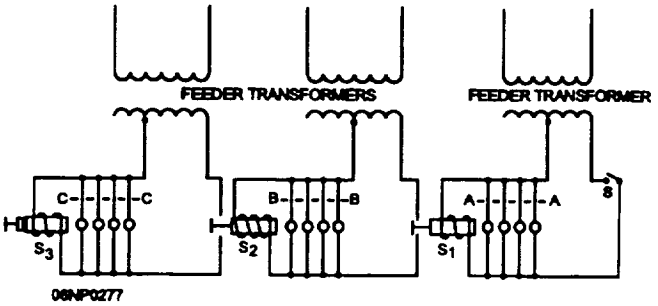


Figure 6-25.—Cascade control of multiple-lighting circuits supplied from several feeder transformers.

CHAPTER 7

ELECTRICAL APPLIANCES, TEST EQUIPMENT, MOTORS, AND CONTROLLERS

In this chapter we will discuss the installation, principles of operation, troubleshooting, and repair of electrical appliances, motors, and controllers. We will also discuss the principles of operation and use of test equipment. Some of the appliances that we will discuss are washing machines, clothes dryers, electric ranges, and hot-water heaters. No matter what type of command you are assigned to, whether it be a mobile construction battalion, public works, or construction battalion unit, you, as a Construction Electrician (CE), will be called upon to install, troubleshoot, and repair various appliances.

The information on various representative appliances applies generally to a number of different makes and models. You can use the repair procedures for other appliances that you will service. To troubleshoot and repair appliances effectively, you must understand the principles of operation that apply to them.

Throughout this chapter you will see references to the National Electrical Code© (NEC©). Look up each article and read it. More specific information is contained there than will be discussed in this chapter. You will need this specific information to do your job properly.

Appliances are of three types: fixed, portable, and stationary. Fixed appliances are installed at a specific location. Once installed, they become permanent. Examples of fixed appliances are hot-water heaters and central air-conditioning units. Portable appliances can be moved from place to place. Examples of these are food mixers and toasters. Stationary appliances are not easily moved from place to place in normal use. Examples of these are window air-conditioning units and refrigerators.

The components of appliances range from a simple ON/OFF switch to more essential components, such as motors, pumps, and temperature control switches. There are components in similar appliances that work on the same principle and, in many cases, the majority of the parts from one type of appliance can be interchanged with another. The only difference in many appliances is the housing and brand name. The important point to remember is when a particular brand name appliance is inoperative because of a broken component, you may be able to use a component from another brand name appliance to get the appliance back into operation.

APPLIANCE INSTALLATION REQUIREMENTS

Many factors affect the installation of appliances. We will discuss some of the more important of factors in this section, to include; connection to power, means of disconnection, branch circuits, and installation by type of appliance

Generally, appliances may be connected only to a receptacle with the same rating as the appliance. A standard 110-volt, 15-ampere duplex outlet may supply a single 15-ampere fixed or a 12-ampere branch circuit. On new construction projects all 15- and 20-ampere receptacles must be of the grounding type. (Refer to NEC©, Article 250.) Most household appliances, such as toasters, flat irons, waffle irons, refrigerators, and portable ovens, are rated at less than 12 amperes, so they may be used in the standard outlet on a 110-volt, 15-ampere circuit.

Each appliance should have a means for disconnection from all ungrounded conductors. Since there are different types of appliances, naturally there are different disconnecting means.

For fixed or stationary appliances that are not rated 300 voltamperes or 1/8 horsepower (93.3 watts), the branch-circuit overcurrent device can serve as the disconnecting means. For an appliance rated greater than 300 voltamperes or 1/8 horsepower (93.3 watts), the circuit breaker may serve as the disconnecting means if it is within sight from the appliance or is capable of being locked in the open position. On portable appliances, an attachment plug and receptacle may serve as a disconnecting means; this disconnection arrangement may include household ranges and clothes dryers. The amperage rating of the receptacle should not be less than the rating of the appliance, unless so authorized by the NEC©. Attachment plugs and connectors should conform to Article 422 of the NEC©.

Unit switches that are part of an appliance that disconnect all ungrounded conductors are permitted as the disconnecting means. Refer to Article 422 of the NEC© for other means of disconnection on the various types of occupancies. When you are grounding an appliance, refer to the NEC©, Article 250. Any part of an appliance that may be energized must be grounded except for those mentioned within this article.

SMALL APPLIANCE BRANCH CIRCUIT

A circuit that supplies electrical energy to one or more outlets to which appliances are to be connected is called an appliance branch circuit. These circuits are not to have any permanently connected lighting fixtures that are not a part of an appliance.

The NEC© states special requirements for appliance branch circuits. We will go over a few of these requirements.

In dwelling occupancies, small appliance loads, including refrigeration equipment, dining areas, kitchens, family rooms, pantries, and breakfast rooms, should have two or more 20-ampere branch circuits installed (referred to as special-purpose outlets) in addition to the branch circuits previously mentioned. These circuits will have no other outlets except for clock outlets.

At least two appliance receptacle branch circuits will be installed in the kitchen for receptacle outlets. In the laundry room at least one 20-ampere branch circuit will be provided. Again, always refer to the NEC© before installing any circuit or equipment to ensure you have the proper number of circuits needed and the correct size wiring and disconnecting means necessary for each branch circuit, appliance, and piece of equipment that you are to install,

TYPES OF APPLIANCES

We will discuss various appliances that you will encounter throughout the Naval Construction Force (NCF). You may be called upon to install, troubleshoot, and repair all appliances mentioned here, plus others not covered within this chapter.

Washing Machines

The purpose of a washing machine is to clean clothes by forcing a mixture of water and a cleaning compound through the clothing regardless of how the machine is constructed.

Washing machines can be classified in various ways, but generally they are divided into the agitator and tumbler types. Each type has advantages over the other and may have certain disadvantages, but each will give years of service if properly operated and maintained.

COMPONENTS.—Before attempting any troubleshooting or repairs, you have to understand the components of the washer and their functions. Washers vary in construction, but their operating principles are similar.

Electrical Supply.—Before connecting any washer to a power source, look at the motor nameplate or the manufacturer's manual to determine the correct electrical supply for the washer. Normally, a 120-volt, 60-cycle, 15- to 20-ampere circuit is required. Most machines come with a three-prong power cord that is to be inserted into a grounded duplex convenience outlet according to NEC© requirements. UNDER NO CIRCUMSTANCES SHOULD YOU REMOVE THE GROUND PRONG FROM THE PLUG. This prong is a ground that protects the user from electrical shock and possible electrocution.

Timer.—-The timer is the heart of the electrical system. It has a motor, an escapement, and multiple-circuit cam switches, all assembled into one unit. The timer (being a synchronous type of motor, like those in clocks) has a small pinion gear that drives the escapement. The escapement is a spring-powered mechanism that advances the time interval. The motor winds up a spring that unwinds abruptly to advance the camshaft the correct number of degrees. A ratchet mechanism in the escapement output gear permits the timer to be advanced manually. The camshaft opens and closes smaller switches in the multiple-circuit cam switch case. These switches control the operation of the washer. All electrical circuits come through the timer. The main ON/OFF switch, operated by a push-pull action of the timer shaft, also is located within the timer housing.

Motor.—The most essential component of a washer is the motor, which is usually a 1/3-horsepower, 120-volt unit. The motor supplies the power that operates the agitator, spins the tub, and operates the water pump. The motor is protected by a thermal overload protector connected in series with both the main and starting windings. The overload protector opens if the windings overheat. Some washers are equipped with two-speed motors and others have reversible motors.

Belts from the motor to the transmission drive the agitator and the tub. Figure 7-1 shows a typical washer

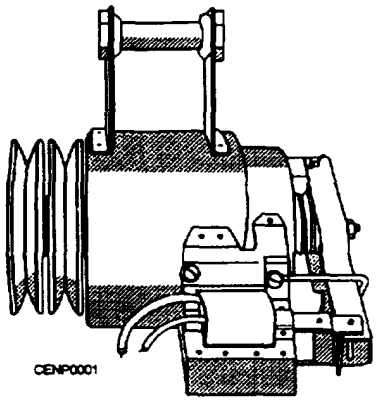


Figure 7-1.—Typical washer motor.

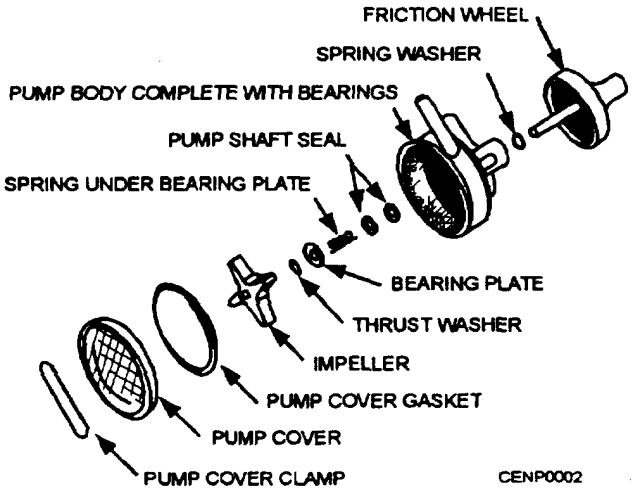


Figure 7-2.—Pump assembly.

motor with pulleys, mounting bracket, and high-speed solenoid.

Pump.—The pump removes water from the tub after each cycle. Normally, the pump is located next to the motor and is engaged by the electrical solenoid. The solenoid engages the friction wheel of the pump (fig. 7-2) with the friction wheel on the motor, causing the shaft to turn the impeller and extract water from the tub. The discharge hose of the pump must be mounted above the water level of the tub, or the water will dram without the operation of the pump. In some cases, the pump is belt-driven and the solenoid tightens the belt to make the pump operate.

One of the major causes of pump failure is foreign objects lodged in the pump impeller. To correct this situation, you remove the cover clamp (fig. 7-2) and the cover and remove the lodged item from the pump. Other causes are slippage between the friction wheels of the pump and motor and failure of the solenoid. Also, check for clogged hoses leading to and from the pump.

Inlet Valves.—Water inlet valves equipped with two solenoids are called mixing valves. They have two water inlets: one hot and one cold. They actually mix hot and cold water. When the temperature control switch is set in the HOT position, the solenoid on the hot-water side of the valve is energized. That permits only hot water to enter the machine. Conversely, when the temperature control switch is set in the COLD position, the solenoid on the cold-water side of the valve is energized, and only cold water is permitted to enter. Positioning the switch in the WARM position energizes both solenoids, allowing hot and cold water to mix.

When water fails to enter the machine naturally, check the water supply first. Then check the screen at the inlet valve. At the hose connection to the inlet valve, there is a fine screen: make sure it is free of any foreign objects. Ensure that you have power to the inlet valve solenoid. Remember the electrical power must come through the water-level control switch, water-temperature selector switch, and timer.

As a last resort, disassemble the valve and check for foreign objects. Also, ensure that the plunger inside the valve is free to operate; there must be at least 10 pounds of water pressure to overcome the spring pressure of the plunger in the solenoid valve.

Water-Level Switch.—The water-level switch, normally actuated by pressure, controls the amount of water that enters the tub. The switch has an adjustment screw to set the level of the water. The tighter the screw, the more pressure is required to operate the switch, and the higher the water level required The water-level switch has two sets of contacts, one normally opened and the other normally closed. As the correct water level is reached, the switch opens one set of contacts, de-energizing the water fill valve. The other set of contacts closes and completes a circuit to the timer, allowing the timer to operate and start the next cycle. The timer will not operate during the fill cycle.

Safety Switches.—Most washers have at least two safety switches. One is an off-balance switchthat opens a circuit to the motor if the clothes shift to one side. Moving the tub to the center and rearranging the clothes will close the switch, allowing the washer to operate. This switch prevents damage to the machine from the vibration of operating with an unbalanced load The other safety switch is located near the door of the machine. Opening the door will stop the machine from operating. Some machines do not have this switch but have a locking solenoid. When the machine goes into the spin cycle, the solenoid latches the door to keep it from being opened during the spin cycle.

ELECTRICAL OPERATION.—Let's look at the electrical operation of a washer. With the plug connected to the outlet, the timer is turned to WASH and the dial is pushed in or pulled out, depending on the type of switch. The operational cycle continues as follows:

1. From the ON/OFF switch, power flows through the temperature control switch and the water-level switch to the inlet solenoid valve. That energizes the inlet valve, allowing the tub to fill.

2. The timer motor is de-energized during the fill cycle because of the open set of contacts in the water-level control switch.

3. Once the water reaches the proper level, one set of contacts opens to shut off the fill solenoid. The other contacts close, sending power to the timer and, at the same time, energizing the motor for the wash cycle.

4. At the end of the wash cycle, power is fed from the timer to the solenoid on the pump, engaging the pump and removing water from the tub.

5. Once the tub is empty, the solenoid for the spin cycle is energized. Its power is fed through the door switch to the solenoid so that, if the door is opened, the machine shuts down

6. During the spin cycle, the water pump is running, and the tub is operating at high speed The timer has provided a bypass circuit around the now open set of contacts in the water-level control switch

7. Once the cycle is completed, the pump, the high-speed solenoid, and the motor are de-energized because there is no water in the tub.

8. The water-level switch closes, energizing the inlet water solenoid to fill the tub for the rinse cycle.

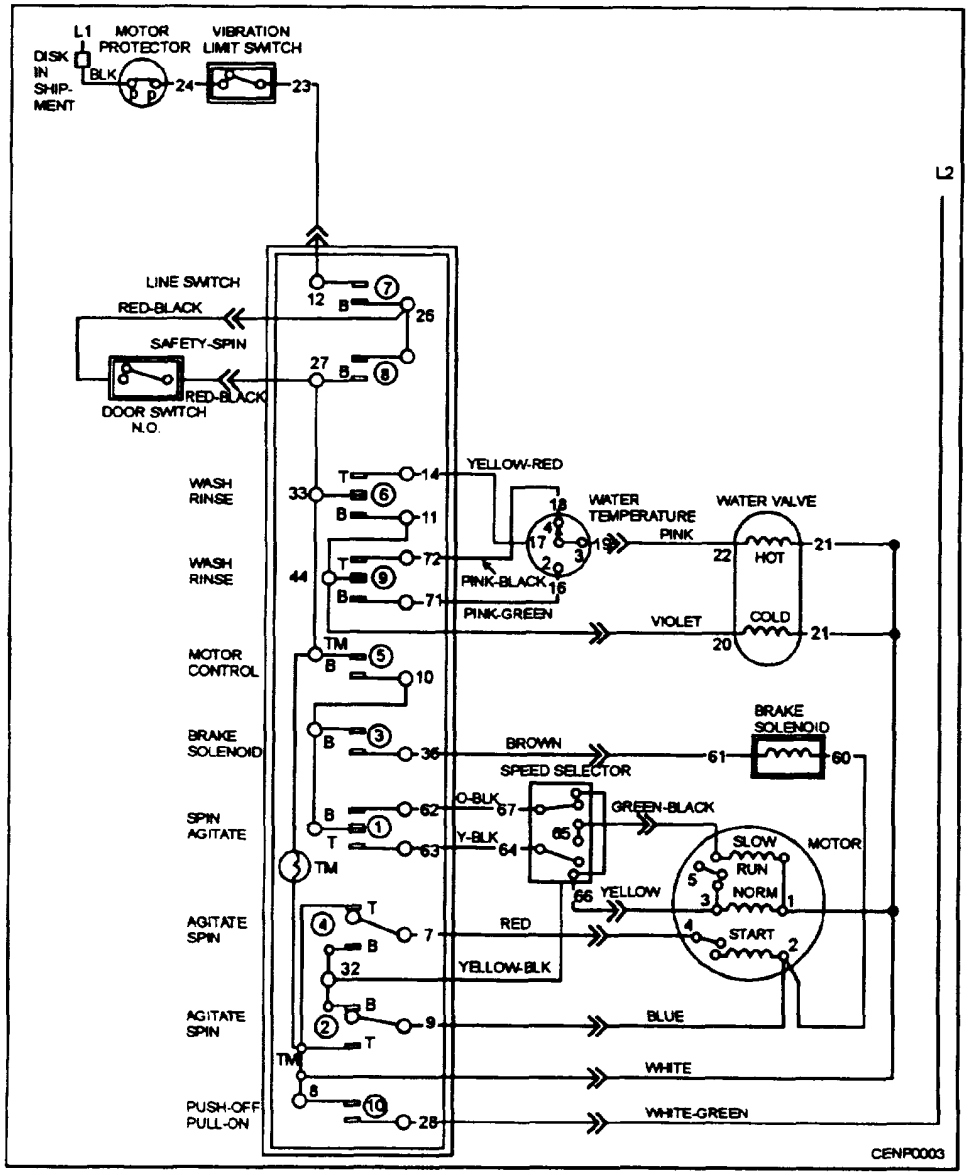


Figure 7-3.—Typical wiring diagram of a washing machine.

9. The rinse cycle is completed in the same manner as the wash cycle, and after this cycle, the timer shuts down, completing the operation.

TROUBLESHOOTING.—Before attempting any repair or replacement of any washing machine component, you must locate the trouble. Eliminate any guesswork. Guesswork can result in time-consuming repair. When troubleshooting a washer, you need to have the wiring diagram for that particular washer. Normally, it is pasted to the back panel. Try starting the machine and observing its operation. Run the machine through its cycles so you can trace the trouble to one circuit or component. Figure 7-3 shows a typical wiring diagram of a washing machine. The information shown in table 7-1 should help you troubleshoot a washing

Table 7-1.—Washing Machine Troublesbooting Chart

TROUBLE	PROBABLE CAUSE	REMEDY
Motor will not start. (No power at motor.)	Blown fuse.	Replace fuse.
	Broken wiring.	Repair wiring.
	Loose connections.	Tighten connections.
	Inoperative timer.	Repair timer.
	Defective motor.	Replace motor.
Motor will not turn. (Motor has power.)	Jammed water pump due to foreign matter.	Clean pump.
	Transmission jammed.	Repair transmission.
	Low voltage.	Correct voltage.
Motor runs but agitator does not.	Belt broken.	Replace belt.
	Loose pulleys.	Tighten pulleys.
	Belt off pulleys.	Replace belt on pulleys.
	Faulty timer.	Replace timer.
	Inoperative clutch.	Adjust clutch.
	Broken gear in transmission.	Repair transmission.
	Loose connection at time or clutch solenoid.	Tighten connection.
Washer washes but does not spin.	Water in tub.	Check operation of water pump.
	Faulty timer.	Replace timer.
	Faulty clutch or transmission.	Replace clutch or transmission.
	Loose connection in spin circuit.	Tighten connection.
No water enters tub.	Clogged screen at water valve.	Clean screen.
	Loose connection in water valve solenoid circuit.	Tighten connection.
	Defective solenoid.	Replace solenoid.
	Water valve stuck.	Repair valve.
	Defective timer.	Replace timer.
Water does not drain.	Clogged drain valve screen.	Clean screen.
	Defective water pump.	Replace water pump.
	Drain hose plugged.	Unplug hose.
	Defective timer.	Replace timer.
	Pump belt broken.	Replace belt.
Noisy operation.	Loose pulleys.	Tighten pulleys.
	Cracked belt.	Replace belt.
	Worn transmission.	Replace transmission.
	Worn pump.	Replace pump.
	Loose cabinet parts.	Tighten parts.
Agitator operates when basket spins.	Improper electrical connection at timer.	Correct condition.
	Defective clutch.	Repair clutch.
Washer stalls when running.	Frozen bearing.	Replace bearing.
	Transmission jammed.	Replace transmission.
	Off-balance load.	Distribute clothes evenly in tub.
	Improper adjustment of vibration switch.	Adjust switch.
Washer leaks water.	Poor door or lid gasket.	Replace gasket.
	Pump seal defective.	Replace seal.
	Hose connection loose.	Tighten connection.
	Machine overloaded.	Remove part of load.
	Too much water in tub.	Check operation of water shutoff.
Washer does not cycle.	Faulty timer.	Replace timer.
	Inoperative solenoids.	Replace solenoids.
	Faulty wiring.	Repair wiring.
	Loose circuit connections.	Tighten connections.
	Crossed circuit wires.	Check circuits with manufacturer's diagram.
	Broken transmission parts.	Replace transmission.

machine. It lists some of the troubles that can develop in a washer along with the probable causes and remedies for each.

Clothes Dryers

An electric clothes dryer is not as complicated as a washing machine; therefore, we will not go into as much detail on its operation as we did with the washing machine.

The main electrical parts of a dryer are as follows: electric-heating elements, thermostats to control heat, a motor to turn the drum assembly, and a timer to select cycle operations. Most dryers have a cutoff switch on the door that stops the dryer when the door is opened. Many dryers have a 40-watt ozone bulb to help condition the air. This bulb requires either a ballast coil or a ballast bulb. Both high-limit and low-limit operating thermostats are used in dryers to control the air temperatures that pass through the clothes. These are located in the exhaust housing and can be easily checked during operation by a voltage check. Your tester will indicate a voltage each time the contact is opened. Safety thermostats should show continuity between terminals at normal room temperature. Holding a small flame close to the thermostat should cause it to open, indicating an open circuit across its contacts.

Dryer timers are fairly simple to troubleshoot. Some timer drive motors and switching mechanisms can be replaced, but in most cases, it is more practical to replace the timer. Again, before attempting any repair or replacement of any parts, run the dryer through its cycles, eliminating any guesswork. Always refer to the wiring diagram for the particular dryer on which you are working. Figure 7-4 is a wiring diagram for a typical electric dryer.

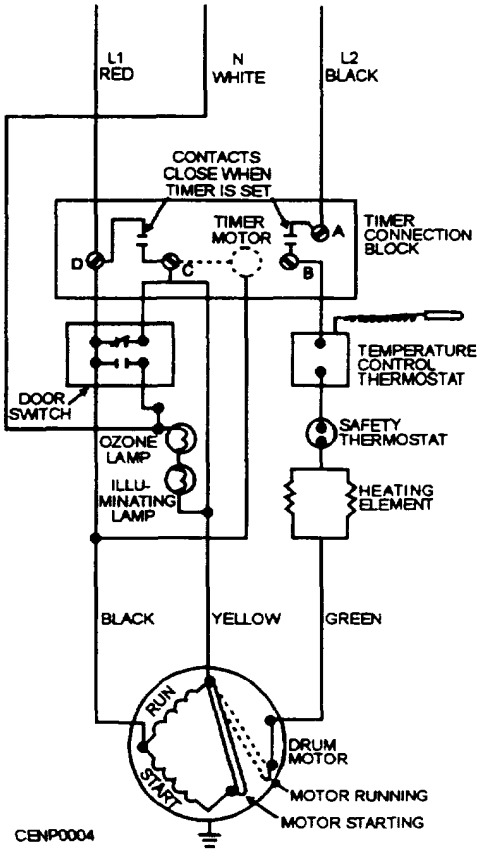


Figure 7-4.—Schematic of an automatic dryer.

Electric Ranges

Electric ranges cook food by surface- and oven-heating elements. The surface elements, or burners, are on the top of the range, and the oven elements are within the oven. Electric ranges differ in size, but most standard ranges have four surface burners, a deep-well cooker, and an oven. Electric ranges vary in width from the 20-inch apartment size to the 40-inch full-size range. The approximate height of the surface burners from the floor is 35 inches.

The primary components of an electric range are the surface burners, deep-well cooker, oven, timer, and individual switches that control the temperatures of the heating units. The range usually has a convenience outlet to supply electricity for a coffee percolator, waffle iron, or toaster, which you can operate on the top of the range. The range is usually automatic. The oven control keeps the temperature of the oven at a set point, and an electric clock and timer shut off the oven at a predetermined time. The individual switches that control the temperatures of the surface burners are usually located on the front of the range.

The principle of operation of an electric range is simply that of an electric current passing through a resistance, thereby producing heat. The resistance is usually nichrome wire.

Heating elements used in ranges may be of the open or the enclosed types. The surface burners usually have enclosed tubular or cast-in elements. Each element is controlled by an individual switch that can control the element for as many as 10 different heat positions. The electrical power supply to each element is either 120 volts or 240 volts or both, depending upon the heat position of the switch Each surface burner is connected to a signal light that indicates when the unit is in the ON position. In the wiring schematic shown in figure 7-5, you can see the wiring of a typical electric range.

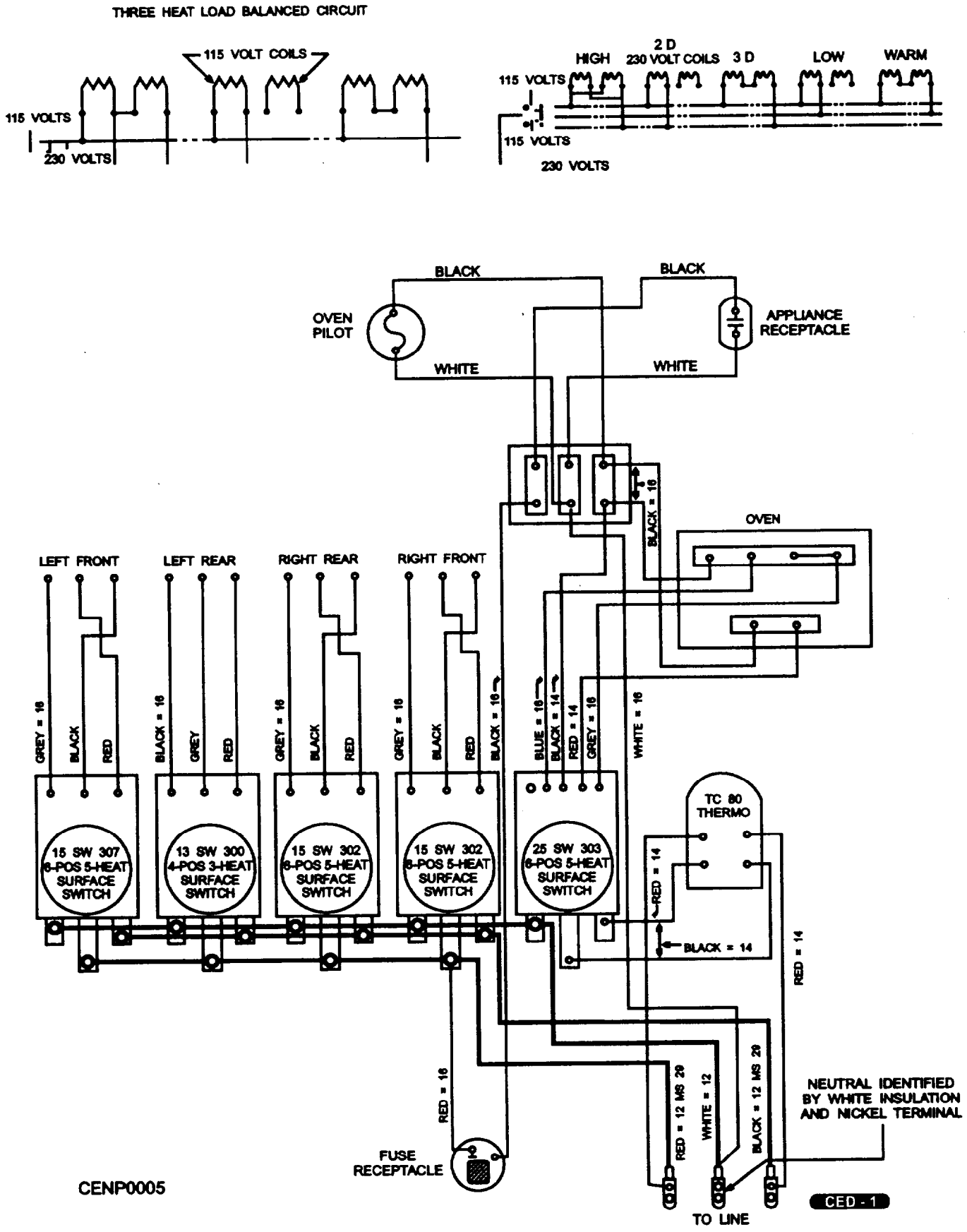


Figure 7-5.—Typical electric range wiring schematic.

OVEN-HEATING ELEMENTS.—The ovens of electric ranges are equipped with open or enclosed elements. These include the rod and coil, suspended coil, spiral-wound, or tubular types. Ovens have two heating elements. One is located in the upper part of the oven and the other in the lower part. Oven elements work off a thermostat to control heat temperature and a timing device for automatic shutoff, as shown in figure 7-6.

TROUBLESHOOTING.—In troubleshooting, start by checking to ensure that proper voltage is going to the unit; then check each element and control device. The heating element, though ruggedly constructed, might become open-circuited. That can be checked with an ohmmeter. Normal resistance is somewhat less than 100 ohms. If elements are opened, replacement is necessary.

If the heating element checks normal but the unit does not heat up, the controls should be checked. Voltage measurement is the most reliable test for a switch. When turned off, the measurement across the switch terminals should read "FULL-LINE VOLTAGE," 120 or 240 volts. When the switch is ON, the reading should be zero across the terminals. Any voltage reading across the terminal of a closed switch indicates a fault. Replacing a faulty switch involves the disconnection and replacement of many wires. A sketch or identifying tags should be used to ensure the correct relocation of the wires.

Oven thermostats control temperature and are factory-calibrated for that unit. Some units can be recalibrated but most must be replaced. When replacement is necessary, the exact type is preferred; however, universal type replacement is available. The manufacturer's instructions that come with a thermostat will give you the exact method for installing and calibrating the device.

Faulty wiring is the final check. Unless arcing damage is evident, test a wire by disconnecting both ends from the circuit; then check it with an ohmmeter. A good wire checks 0 ohms; a faulty one, infinity (∞). Table 7-2 is a guide that should help you when troubleshooting electric ranges; it lists the trouble, probable cause, and remedy.

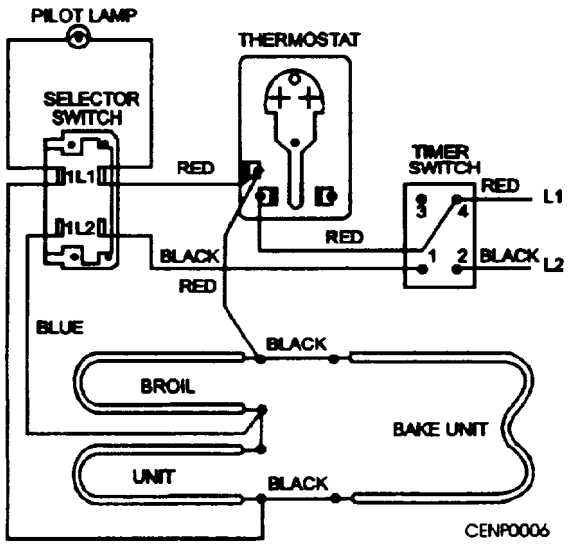


Figure 7-6.—Oven-heating circuit with two heating units.

Hot-Water Heaters

A hot-water heater is nothing more than a metal water-storage tank with one or two electric heating elements, thermostatically controlled to heat water in the tank. Some of the electrical problems you may encounter are as follows: no power, defective thermostat, thermostat out of calibration, or a defective heater element or elements.

The hookup for a hot-water heater will vary depending on the size and application of each unit. Always refer to the manufacturer's manual for wiring instructions and the NEC© for any special requirements. Most hot-water heaters that you will be installing will have a wiring diagram similar to the one shown in figure 7-7. The thermostat is in series with the

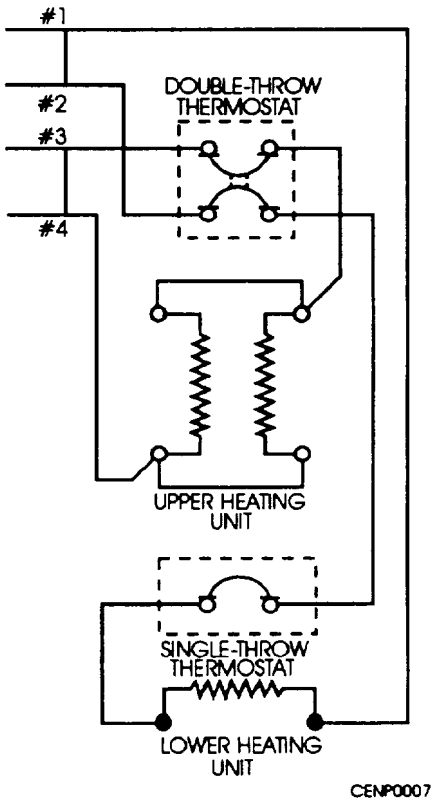


Figure 7-7.—Wiring connections for an electric water beater, having two heating units

Table 7-2.—Troubleshooting Guide for Electric Ranges

TROUBLE	PROBABLE CAUSE	REMEDY
Range will not heat.	No voltage at outlet.	Correct voltage.
	Blown fuse.	Replace fuse.
	Open breaker.	Reset breaker.
	Broken wire in power cord.	Check continuity of cord.
	Faulty wall outlet.	Check for voltage at outlet.
	Faulty prongs on male plug.	Replace if necessary.
	Faulty slots in wall outlet.	Replace if necessary.
No heat at one surface burner.	Loose terminal connections at burner unit.	Clean and tighten connections.
	Corroded contacts in control switch.	Clean contacts with sandpaper.
	A burned-out element.	Replace element.
	Open in burner circuit.	Replace wires if necessary.
Surface burner too hot.	Incorrect or reverse connections.	Switch wires as required.
No heat in oven.	Element connections loose and corroded.	Clean and tighten connections.
	Burned-out element or elements.	Replace elements.
	Inoperative oven control.	Adjust or replace control.
Oven too cool.	Inoperative oven control.	Adjust and replace control.
	Improper voltage at element.	Check and increase voltage.
	Open in one section of element.	Check and replace element if necessary.
	Loose and corroded element connections.	Clean and tighten connections.
Oven too hot.	Inoperative oven control.	Adjust or replace control.
	Wrong element.	Install proper element.
Uneven baking.	Range tilted.	Level range.
	Oven racks not on proper supports.	Place racks on proper supports.
Appliances fail to heat when plugged into appliance outlets.	Blown fuse.	Replace fuse.
	Loose and corroded circuit connections.	Clean and tighten connections.
	Broken circuit wires.	Replace wires.
	Faulty outlet.	Replace if necessary.

heating element and has only one set of contacts that open and close in response to the temperature at the bottom of the water-heater tank. The double-throw thermostat controls both the upper and lower heating elements. The switch closes the circuit in the upper heating unit whenever the water temperature in the top of the tank becomes lower than the thermostatic switch setting. When the top part of the tank reaches a preset temperature, the switch opens the contacts to the upper unit and, by toggle action, closes the contacts to the lower unit. The lower unit comes on and remains on until its preset temperature is reached and the thermostat is satisfied.

APPLIANCE CONTROLS

Appliance controls, as the name implies, regulate the use of electrical appliances used everyday. They allow us to turn appliances on and off. There are two general classes of controls: manual and automatic.

MANUAL CONTROLS

Manual controls turn the appliance on and off, and some types set the appliance at a desired temperature by controlling the current flow to the unit. The automatic control, in addition to turning the unit on and off, maintains an even heat in the unit; for example, the automatic controls on kitchen appliances result in better

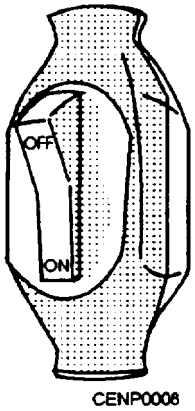


Figure 7-8.—In-line toggle switch.

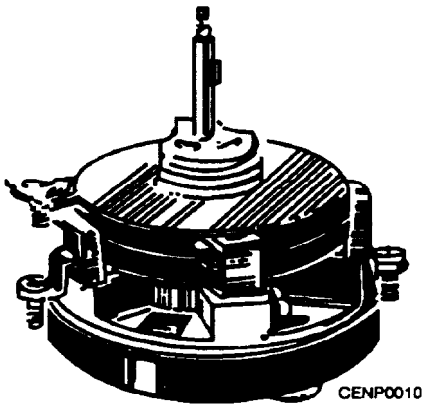


Figure 7-10.—Typical rotary switch.

food preparation and allow more time for the food preparer to accomplish other tasks.

Manual controls turn the heating unit on and off by making or breaking the electrical circuit. Manual controls consist of the toggle switch and different types of rotary switches.

Toggle Switches

Toggle switches are used to make and break the electrical circuit on many small appliances. Figure 7-8 shows one type of toggle switch that is installed in an appliance cord. This type of switch cannot be repaired. You must replace it. Figure 7-9 shows a typical wall-mounted toggle switch used to control appliances. New switches are usually so inexpensive that repairing an old one is not economical.

Rotary Switches

Rotary switches have fast make-and-break action and usually have three or more heat settings. The spring action contained in this type of switch enables it to operate extremely fast and eliminates the usual pitting and burning of its contacts.

Rotary switches are normally used to control the top elements of an electric range. Changing the position of the switch changes the connection to the element and varies the voltage; for example, the LOW position connects the elements in series to a 120-volt Rower source, and the HIGH position connects the elements in parallel to a 240-volt power source. Various combinations of these connections deliver different heat from the unit, all controlled by the rotary switch. Figure 7-10 shows a typical rotary switch.

Repair of this switch is recommended only as a temporary measure. Repair consists of cleaning and adjusting contacts, replacing worn and inoperative parts, and lubricating the contacts and switch mechanism with nonoxide grease for smoother operation. The switch should be replaced as soon as a replacement is available.

The pull-to-turn switch, as shown in figure 7-11, is constructed to carry the higher loads connected with

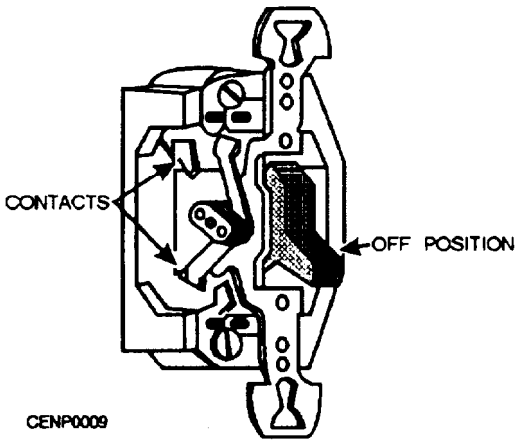


Figure 7-9.—Typical wall-mounted toggle switch.

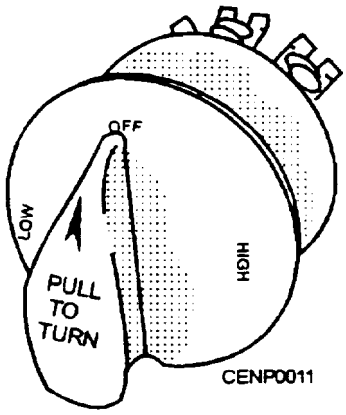


Figure 7-11.—Pull-to-turn switch.

commercial ranges and oven installations in galleys. The current is interrupted ahead of the make-and-break action of the switch contacts. That eliminates the usual pitting and burning of contacts. This switch cannot be repaired; you must replace it.

AUTOMATIC CONTROLS

The basic function of an automatic control is turning current on and off as required to maintain a desired temperature.

Bimetallic Blade Control Switch

The bimetallic blade control switch, as shown in figure 7-12, is operated by the expanding and contracting effect caused by heating two pieces of dissimilar metals that are welded together. Repair of this control is limited to an adjustment in its temperature setting.

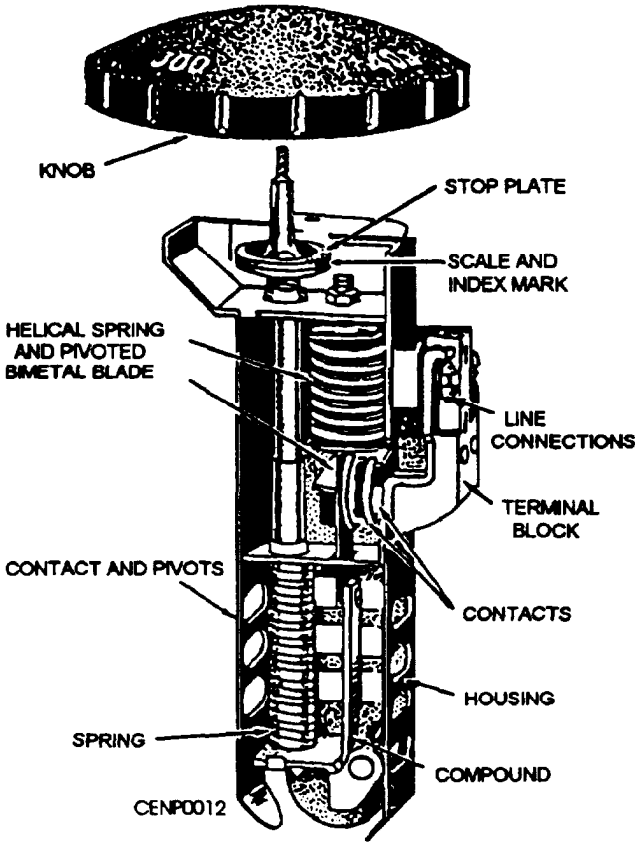


Figure 7-12.—Bimetallic blade control switch.

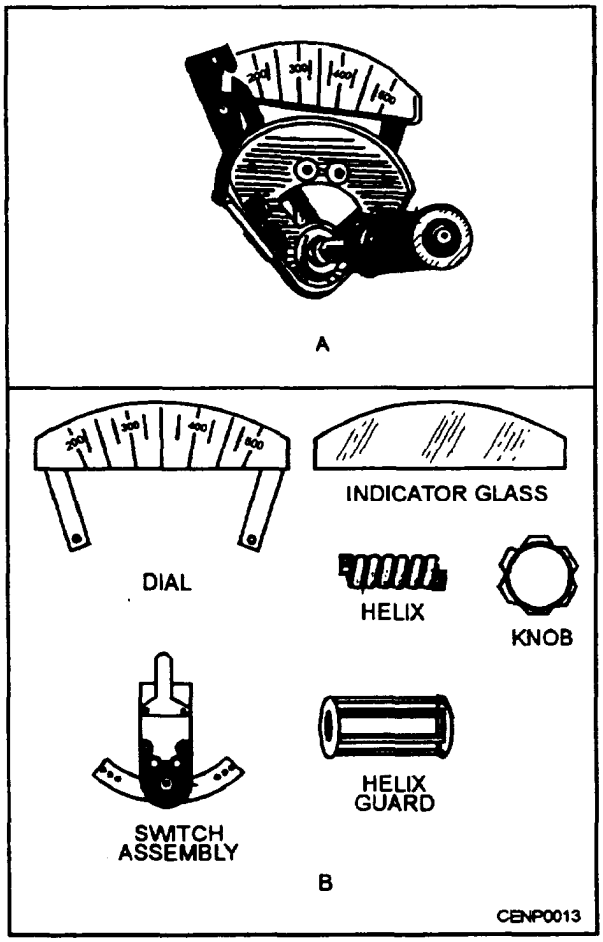


Figure 7-13.—A. Helix control; B. Helix components.

Helix Control

A helix control (fig. 7-13, view A) is used in some domestic, semi-commercial, and commercial installations. It is operated by thermostatic metal that coils and uncoils when heat is applied, regulating a switch to make and break the electric circuit. Repairing this unit consists of replacing miscellaneous parts, such as the dials, switch assembly, helix, helix guard, and so on (fig. 7-13, view B).

Hydraulic Control

A hydraulic control is probably the most frequently used control for automatically regulating the temperature of cooking appliances. In this control, a capillary tube filled with fluid is connected to hydraulic

bellows (fig. 7-14). A bulb located on one end of the capillary tube is filled with fluid and then is put in the heat zone. It transfers heat-created pressure through the capillary to the diaphragm. The expanding diaphragm presses a system of levers that snap the electrical contacts open, thus cutting off electrical current to the controls. Automatic recycling takes place with slight temperature drops, maintaining a constant set temperature.

Certain types of hydraulic controls have a safety device, normally set at 450°F, that trips upon reaching the set temperature and requires manual resetting. It may take several hours before the appliance has cooled down enough to allow the operator to reset the unit.

Repairing a hydraulic control is usually limited to adjusting the temperature setting to correspond with the temperature recorded in the appliance. You can adjust the temperature control by loosening, but not removing, the two small, slotted lock screws (fig. 7-14) that are behind the dial. Now, with one hand, hold the main center hub of the control and move the slotted adjusting plate to the right to raise the temperature or to the left to lower the temperature. That is a delicate adjustment, so move the dial a little at a time.

If you find that the circular slots in the adjusting plate prevent you from turning the plate for the desired temperature change, remove the two lock screws carefully so you can move the adjusting plate a full 180 degrees. Replace the two adjusting screws and continue the calibration process as before.

A timer is used to control a circuit to an appliance automatically or give a warning to the operator that a predetermined time has lapsed. Figure 7-15 shows a typical wiring diagram of an electric range single-pole oven timer.

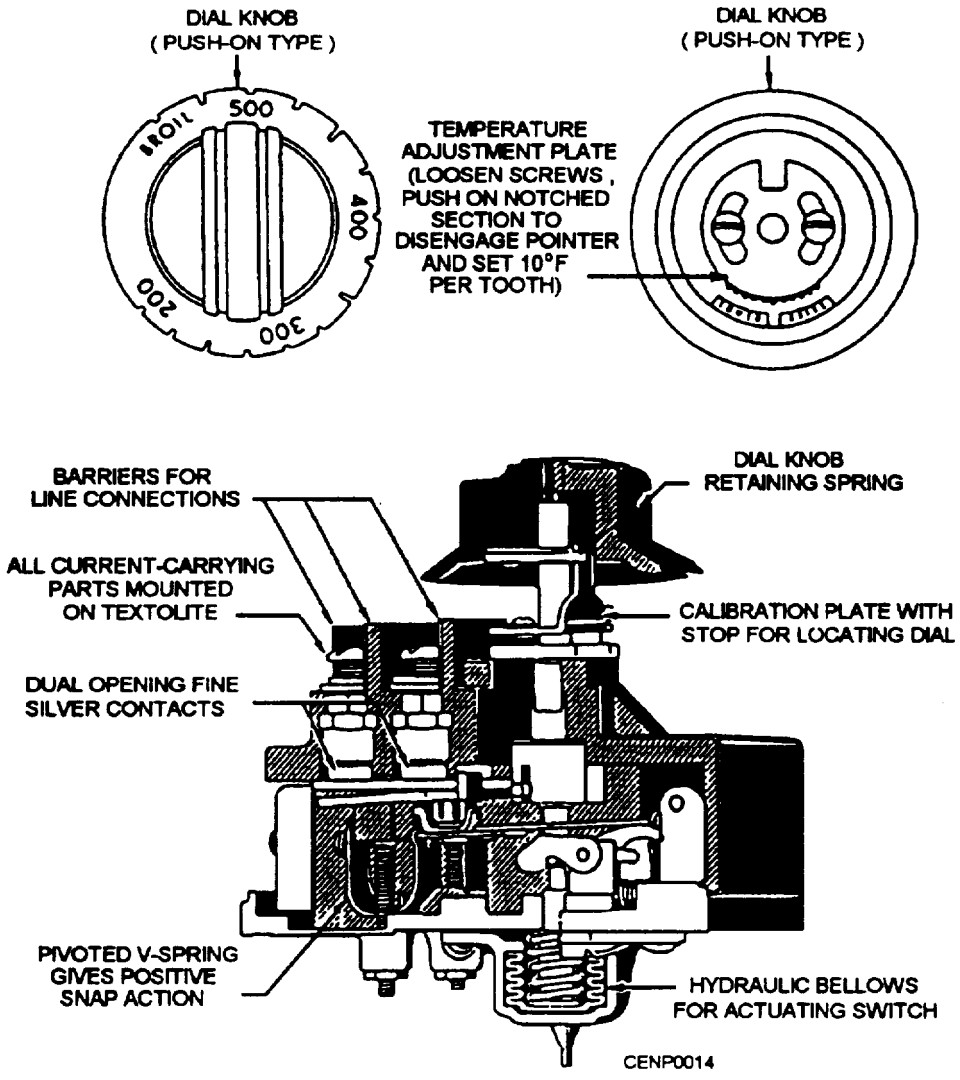


Figure 7-14.—Hydraulic control.

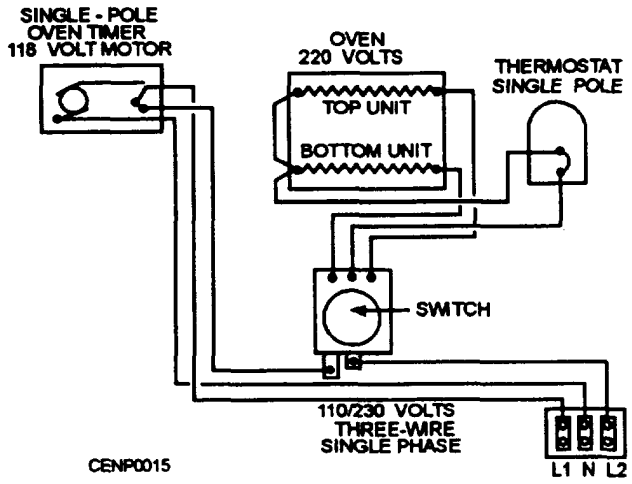


Figure 7-15.—Single-pole oven timer wiring schematic.

APPLIANCE AND EQUIPMENT MAINTENANCE, REPAIRS, AND TROUBLESHOOTING

Identifying and locating problems within circuits, appliances, and equipment is a challenging job. This phase of your rating as a Construction Electrician (CE) working within a maintenance shop is where much of your career will be spent.

INSPECTION

To locate faulty conditions in circuits, you need to perform some inspecting, some calculating, and some instrument testing. A few moments spent studying the schematic or drawing of a particular circuit before the actual troubleshooting begins often simplifies the task of isolating the trouble. THINK! If a circuit fails to operate properly, apply some logical reasoning when you check for the fault. The trial-and-error method is inefficient and time-consuming.

When you troubleshoot a circuit, the first thing you want to do is study the schematic; the next step is to inspect the circuit visually. Check for loose connections, loose wires, burnt wires, and burnt components, and check the type of wiring.

Careful inspection of electrical components and equipment is essential to preventing fire hazards caused by defects or dangerous conditions. These inspections include checking for cleanliness, normal operation, operation under load, tight connections, adjustment, and lubrication Always perform a visual inspection first. In this inspection, examine the general condition of the equipment, determine whether it was abused, dropped, or overloaded or is inoperative because of continued use. The general condition of a unit can help you to determine the fault within it.

Testing and maintaining equipment is best accomplished at the time of inspection. Completing everything without returning to the area saves time. Tools and test equipment should be taken to the job site when the inspection is performed.

PREVENTIVE MAINTENANCE

One of the primary responsibilities of a CE is to ensure proper operation of switches and elements used in appliances and equipment. That can be done by developing and following a good inspection and maintenance program. Periodically, you should check all equipment for loose connections, burned or pitted contacts, and the improper mounting of switches. You should also check for bad connections, improper mounting, and loose or broken insulators on coils or ribbon elements.

The inspection and maintenance of switches and elements on appliances and equipment go hand in hand, and, in most cases, a problem discovered during inspection is corrected on the spot and requires no further work until the next inspection.

TROUBLESHOOTING

A bad appliance should first be checked visually. If you fail to find the trouble by visual inspection, you will find that a meter is an indispensable device in testing electrical circuits of appliances.

Power Supply and Cord

When you attempt to repair an inoperative appliance, do not be in a hurry to disassemble it to find the trouble. You should first pull the power cord from the outlet and determine if there is current at the outlet. If the outlet is energized, inspect the power cord. Next, examine the plug connections for cleanliness and tightness. Finally, inspect the power cord for any broken wires. If the condition of the cord makes it unserviceable, replace it before going any further in your troubleshooting procedure.

Checking the power supply and the condition of the power cord should be the first thing you do when you attempt to find an electrical fault in an appliance. In a number of cases, electrical faults are found in the power cord, rather than in the appliance itself. Only when you have determined that the fault is not with the power supply or cord, should you consider troubleshooting the internal units. To troubleshoot these units effectively, you have to disassemble part of the appliance.

WARNING

When you are troubleshooting and doing repair work, TREAT ELECTRICITY WITH RESPECT. Working with electricity is hazardous, and you must take every precaution to avoid electrical shocks, burns, and electrocution. Regard all circuits as live until you have opened the switches or have made voltage tests and know that the circuit is dead. Lock and tag all switches in the OPEN position to keep other personnel from tampering with them and creating a safety hazardous condition. Remove protective devices, such as fuses, from their holders. REMEMBER, YOU WILL BE WORKING ON THAT CIRCUIT.

Controls and Elements

Controls and elements on appliances or equipment will most likely be your biggest problem. Check switches and controls with an ohmmeter for the making or breaking of contacts. If the switch is ON, the ohmmeter should read "0." The operation of a switch can be checked with a voltmeter. Check for voltage input and output.

New switches are usually inexpensive, so repairing an old one is not economical. The contacts may be reformed as a temporary measure to ensure a positive contact for completing the circuit. Lubricating the contacts and spring mechanics with a nonoxide grease reactivates the switch operation.

Repair of the bimetallic blade control switch is limited to an adjustment in the temperature setting of the control to agree with the temperature recorded in the appliance or equipment being tested. Temperature of equipment should be tested by a reliable temperature tester or a good thermometer.

Repair of the helix control is limited to adjusting the temperature setting of the control to agree with the temperature recorded in the appliance or equipment being tested. If the control cannot be adjusted, the complete control assembly must be replaced.

If a timer fails to operate, use the following procedures to locate the trouble:

- Test the electrical circuit for a blown fuse.
- Check for friction between the hands of the timer and timer crystal.
- Check all wire connections.

To repair an inoperative electric timer, perform the following steps:

- Replace the blown fuse with a fuse of the proper rating.
- Replace the complete rotor if the rotor is inoperative.
- Replace the complete coil assembly if the field coil is burned out.
- Repair the timer switch assembly by cleaning contacts or reforming the contact arm to ensure positive contact. If the contact shows excessive wear, replace the switch assembly.
- Adjust the hands of the timer if they are binding.
- Check all connections at the back of the timer for positive contact to ensure a complete circuit.

Elements can be checked using a -voltmeter or ohmmeter. If a voltmeter is being used remove one wire from the element and check for voltage between the empty terminal and ground. A voltage reading indicates a good element, and no voltage indicates an open or defective element.

If an ohmmeter is used, first ensure that the power is disconnected. Remove both conductors to prevent a false reading. Connect the two leads of the ohmmeter to the two terminals of the element. A reading of zero indicates a good element. A reading of infinity symbol indicates an open element.

PORTABLE ELECTRIC TOOL TESTERS

If you have ever had an encounter with an ungrounded electric drill while working in the rain, you have a feel for the importance of tool testing. You will also have gained a healthy respect for the person who tests tools at the battalion central tool room (CTR) or the Public Works Department (PWD) when he or she fmds and corrects the problem with portable electric power tools.

The tool tester shown in figure 7-16 is an example of a tool tester that personnel from CTR or PWD might use.

The tool tester consists of a transformer, sensing relays, indicator lights, an audible warning buzzer, and leads suitable for tool or appliance connections.

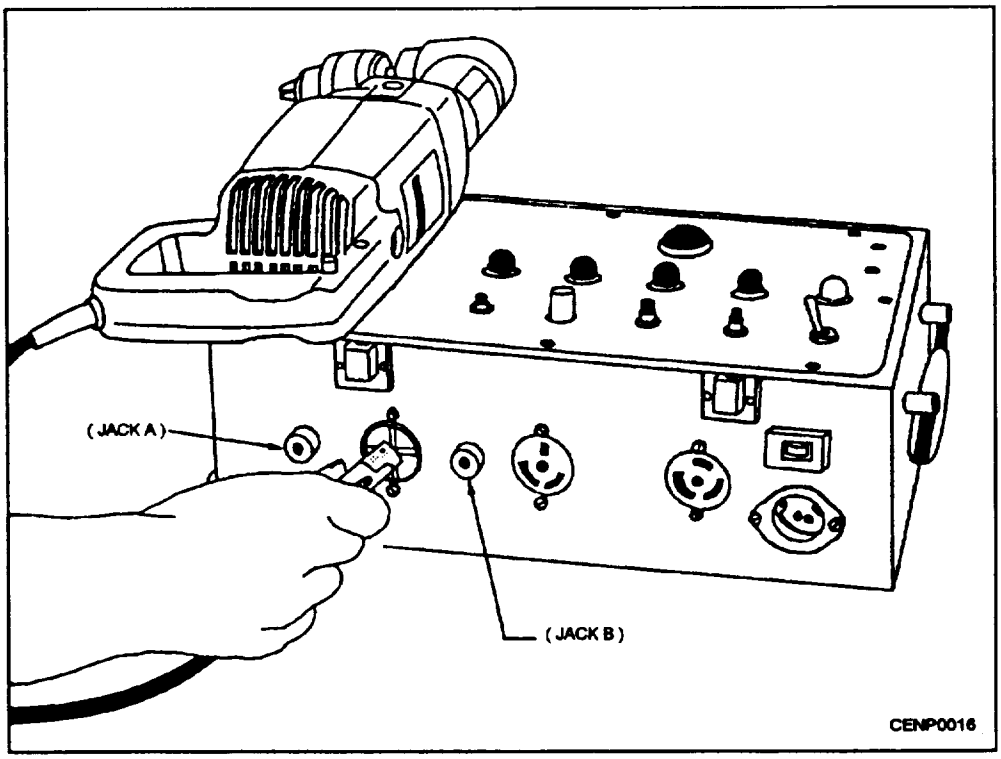


Figure 7-16.—Typical tool tester.

The transformer passes approximately 30 amperes through the tool cord equipment ground, burning away any "whiskers" that may be causing a poor equipment ground If there is no equipment ground, the OPEN EQUIPMENT GROUND sensing relay is activated, and appropriate warnings are given (the OPEN EQUIPMENT GROUND light glows).

If the resistance of the ground on the equipment under test is approximately 0.2 to 1.5 ohms, the FAULTY EQUIPMENT GROUND sensing relay is activated Resistance in excess of this amount activates the OPEN EQUIPMENT GROUND sensing relay.

The range in length of extension cords that can be tested is from approximately 6 feet to 100 feet of 16-gauge wire. These lengths will be longer or shorter in other gauges. The sensing circuit can be adjusted for different sensitivities.

The presence of a dangerous POWER GROUND, caused by carbon, moisture paths, or insulation breakdown, is checked at a 500-volt potential or at a 120-volt potential when the RF TEST button is pressed. The equipment, line cord, and switch are tested for SHORT CIRCUIT.

Faulty conditions are indicated by the corresponding light (red) and buzzer. One faulty condition must be corrected before another one will be indicated.

Tests proceed only when the equipment ground is in a safe condition. All tests (except the power ground) are conducted at potentials less than 10 volts.

If no electrical defects are found, the tool operates at its proper voltage to reveal any mechanical faults.

Optional features are installed to simplify two-wire and double-insulated tool tests and provide for safely testing double-insulated tools for power grounds.

WARNING

The tool operates at the end of the test cycle. Be sure moving parts are faced away from the operator and have proper clearance to operate. Remove any removable cutting blade or bit before the tool is tested Do not come in physical contact with the tool during the test.

MAINTENANCE OF POWER TOOLS

It is the task of a CE to ensure the proper operation of all power tools within his or her realm of responsibility. The program itself will be formulated by higher authority. The best way to perform this task is to develop a good inspection and maintenance program. Periodically, you should check all power tools for loose connections, pitted contacts, improper mounting of switches, and so forth.

The inspection and maintenance of power tools go hand in hand, and, in most cases, a problem discovered during inspection is corrected on the spot and requires no further work until the next inspection.

TEST EQUIPMENT

Test equipment and experienced Construction Electricians are not always needed to locate problems. Anyone who sees a ground wire dangling beneath a lightning arrester might suspect a problem. Little skill is required to consider an electrical service problem as a possible reason for the lack of power in a building.

Arcing, loud noises, and charred or burned electrical equipment sometimes indicate electrical faults; however, hidden, noiseless circuit problems are much more common and usually much harder to locate.

The right test equipment and the Construction Electrician who knows how to use it are a valuable combination for solving electrical circuit problems.

No attempt will be made in this chapter to explain the internal workings of test equipment, such as meter movement or circuitry. Information on these subjects is covered in Navy Electricity and Electronics Training Series (NEETS) modules, published by the Naval Education and Training Program Management Support Activity. Test equipment is discussed in Modules 3 and 16. Your education services officer (ESO) should stock the NEETS modules. If not, he or she can order them for you. Other information on the use of test and circuit measuring equipment is included in modules throughout the NEETS series. This section introduces to you the types of test equipment used by the Construction Electrician in the field.

WARNING

Naval Facilities Command (NAVFAC) requires that tests of electrical equipment be performed under the supervision of qualified electrical personnel. If in-house personnel are not available for these tests, the services of a qualified electrical testing contractor may be used. If you do not know how to do certain tests that must be performed, go to your seniors (crew leader and/or project chief). Be certain that you can perform the test safely before starting the test procedure.

AMMETERS

A meter used to measure the flow of electric current is a current meter. Current meters that measure current in amperes are called ammeters. The ammeter is connected in series with the circuit source and load. Panel-mounted ammeters, such as those used in power plants, are permanently wired into the circuit. Figure 7-17 shows two typical panel-mounted ammeters.

Portable ammeters are temporarily connected into a wiring system at whatever point in the system a current reading is desired; for example, feeder current is measured by opening the feeder and wiring the meter in series with the feeder source and load. Circuits branching off the feeder may be opened and an ammeter inserted into the branch.

Using a clamp-on ammeter (fig. 7-18) is an exception to the rule previously stated requiring ammeters to be series-connected. The clamp-on ammeter consists in part of clamp-on transformer jaws that can be opened and placed around a conductor. The

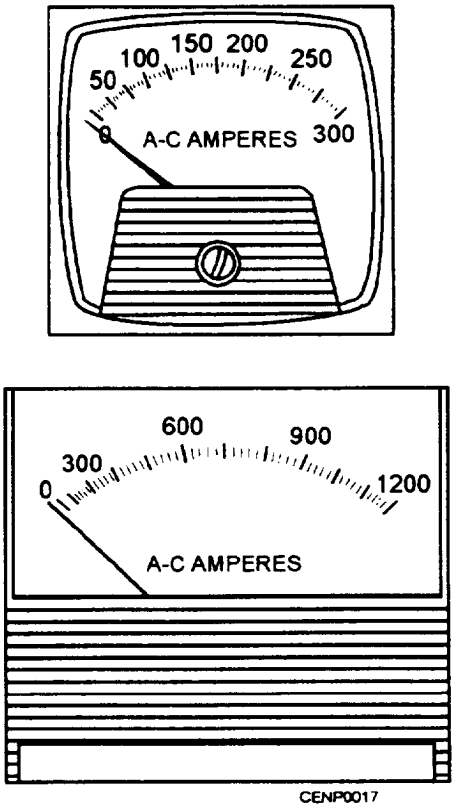


Figure 7-17.—Typical panel ammeters.

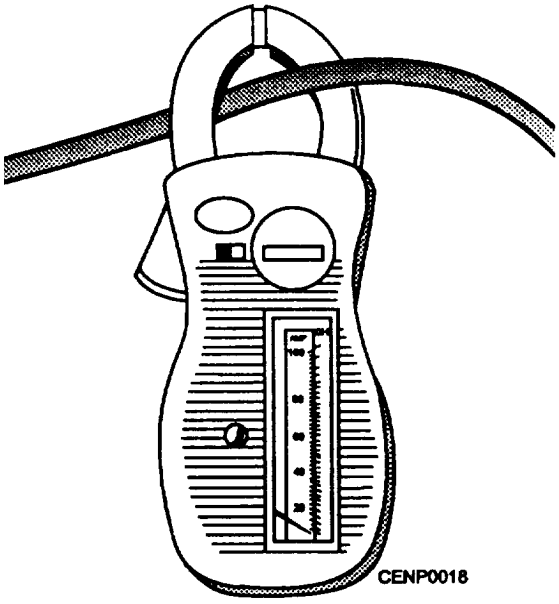


Figure 7-18.—Clamp-on ammeter.

jaws are actually part of a laminated iron core. Around this core, inside the instrument enclosure, is a coil winding that connects to the meter circuit. The complete core (including the jaws) and the coil winding are the core and secondary of a transformer. The conductor, carrying the current to be measured, is like a primary winding of a transformer. The transformer secondary is the source of power that drives the meter movement. The strength of the magnetic field surrounding the conductor determines the amount of secondary current. The amount of secondary current determines the indication of current being measured by the meter.

All ammeters will have an adjustable scale. The function and range of the meter are changed as the scale is changed.

To take a current measurement, turn the selector until the AMP scale you wish to use appears in the window. To take measurements of unknown amounts of current, you should rotate the scale to the highest amperage range. After taking the reading at the highest range, you may see that the amount of current is within the limits of a lower range. If so, change the scale to that lower range for a more accurate reading.

After choosing the scale you want, depress the handle to open the transformer jaws. Clamp the jaws around only one conductor. The split core must be free of any debris because it must close completely for an accurate reading.

To measure very low currents in a small flexible conductor, you may wrap the conductor one or more times around the clamp-on jaws of the meter. One loop will double the reading. Several loops will increase the reading even more. After taking the measurement, divide the reading by the appropriate number of loops to determine what the actual current value is.

The clamp-on ammeter is convenient and easy to use. To measure the current of a single-phase motor, for example, simply rotate the selector until the desired amp scale appears, clamp the jaws around one of the two motor conductors, and take the reading.

Some clamp-on instruments are capable of more than one function; for example, they are designed for use as an ohmmeter or a voltmeter when used with the appropriate adapter or test leads.

VOLTMETERS

The meter component (or voltage indicator) of a voltmeter is actually a milliammeter or a micrometer. This instrument is series-connected to a resistor (called a voltage multiplier) to operate as a voltmeter. The series resistance must be appropriate for the range of voltage to be measured. The scale of an instrument designed for use as a voltmeter is calibrated (marked off) for voltage measurements.

Panel voltmeters are similar in appearance to the ammeters shown in figure 7-17, except for the calibration of the scale. Examples of typical panel voltmeters are shown in figure 7-19. Voltmeters are

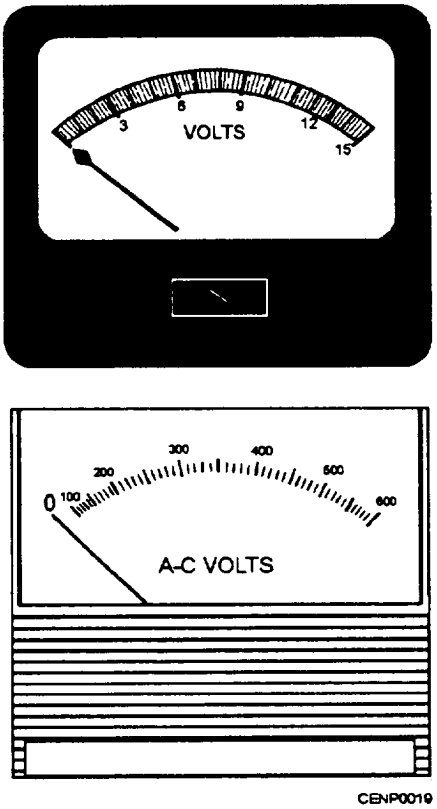


Figure 7-19.—Typical panel voltmeters.

connected across a circuit or voltage source to measure voltage. Panel-mounted voltmeters are permanently wired into the circuit in which they are to be used.

Portable voltmeters are designed to measure one or more ranges of voltage. Those intended for measurement of more than one voltage range are provided with range selector switches. The range selector switch internally connects the appropriate multiplier resistor into the meter circuit for the range of voltage to be measured; for example, a voltmeter may be designed to use a O-l milliampere milliammeter as a voltage indicator. For each setting of the selector switch, a different multiplier resistor is connected into the meter circuit. For each selection, a particular resistor value is designed to limit the current through the milliammeter to a maximum of 1/1,000 of an ampere (1 milliampere) for a full-scale reading.

In a similar way, voltmeters designed to use a micrometer, for example, a 50-microampere meter, include multiplier resistors that limit the meter current to a maximum value of 50 microamperes. In this case, 50 microamperes are flowing through the meter for a full-scale deflection of the needle.

Voltmeters that use either a milliammeter or micrometer to indicate voltage have a scale calibrated to read directly in volts. The flow of current in either type of meter represents the electrical pressure (voltage) between two points in an electrical circuit; for example, the two points may be the hot (ungrounded) conductor and the neutral (grounded) conductor of a 125-volt circuit. In this case, the voltmeter is said to be connected across the line.

LINE VOLTAGE INDICATORS

The line voltage indicator (fig. 7-20) is much more durable than most voltmeters for rough construction work. Its durability is mainly due to its simple design and construction. It has no delicate meter movement inside the case as do the analog meters previously mentioned. The two test leads are permanently connected to a solenoid coil inside the molded case.

CAUTION

Do not use the line voltage indicator on voltages exceeding the capabilities of the indicator.

An indicator, attached to the solenoid core, moves along a marked scale when the leads are connected across a voltage source. The movement of the core is

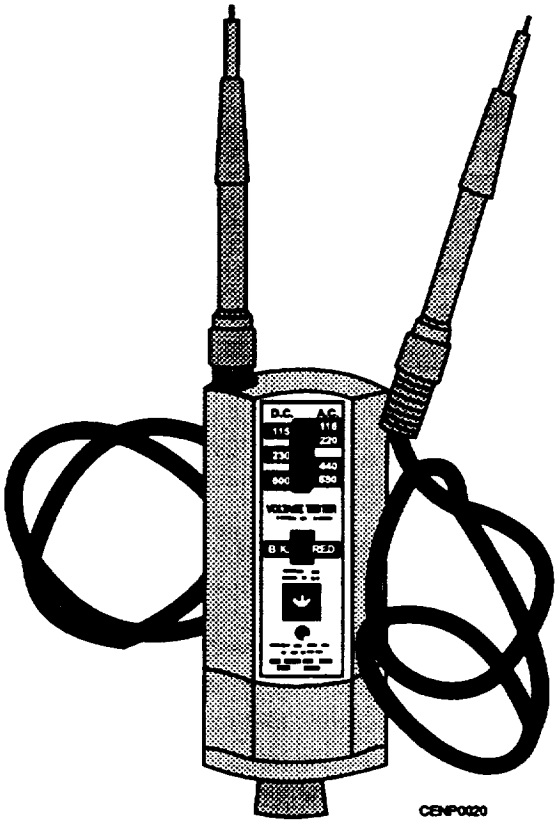


Figure 7-20.—Line voltage indicator.

resisted by a spring. The indicator comes to rest at a point along the scale that is determined by both the strength of the magnetic field around the solenoid and the pressure of the opposing spring. The strength of the magnetic field is in proportion to the amount of voltage being measured.

In the center of the tester is a neon lamp indicator. The lamp is used to indicate whether the circuit being tested is ac or dc.

When the tester is operated on ac, it produces light during a portion of each half-cycle, and both lamp electrodes are alternately surrounded with a glow. The eye cannot follow the rapidly changing alternations so that both electrodes appear to be continually glowing from ac current. Two other indications of ac voltage are an audible hum and a noticeable vibration that can be felt when the instrument is hand-held.

When the tester is operated on dc, light is produced continuously, but only the negative electrode glows; therefore, the tester will indicate polarity on dc circuits. Both the test probes and the glow lamp enclosure are colored red and black. If, while you are testing a dc circuit, the electrode of the glow lamp on the side colored black is glowing, this glow indicates the black

probe of the tester is on the negative side of the circuit; likewise, the opposite electrode glows when the red probe of the tester is on the negative side of the circuit.

The neon lamp is not the only method used on line voltage indicators to indicate dc polarity; for example, the Wigginton voltage tester, manufactured by the Square D Company, uses a permanent magnet mounted on a rotating shaft The ends of the magnet are colored red and black. The magnet is viewed from a transparent cap located on top of the tester. When the red portion of the magnet is up, the red test prod is positive. When the black portion of the magnet is up, the black prod is positive. Neither type of line voltage indicator vibrates when measuring dc.

Be certain to read and understand the instructions for the particular instrument you use. As you can see from this example about polarity indicators, because of variations in similar instruments, you could easily misunderstand an indication from one instrument when thinking of the instructions for another.

The line voltage indicator is not used to determine the exact amount of circuit voltage. That presents no problem for most of the work done by Construction Electricians. As you become proficient in the use of the solenoid type of voltage indicator, you can tell approximately what the voltage is by the location of the indicator within a voltage range on the scale.

OHMMETERS

The resistance of a component or circuit, in ohms, can be determined by using Ohm's law. With the instruments we just discussed, you can find circuit current and voltage. From electrical theory you already know that voltage divided by amperage equals resistance. But the fastest method of determining resistance is by taking a resistance reading directly from an ohmmeter.

The simplest type of ohmmeter consists of a housing that includes a milliammeter, a battery, and a resistor connected in series, as shown in figure 7-21. The ohmmeter is designed so that the resistor R_1 limits the current though the milliammeter to a value that results in a full-scale deflection of the meter needle. The scale (fig. 7-22) is calibrated in ohms. By using several resistors, more than one battery, and a selector switch (to select one of the several resistors and batteries), you can make the ohmmeter include more than one resistance range.

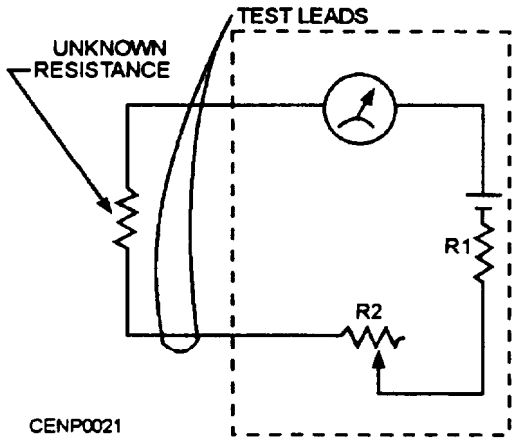


Figure 7-21.—A simple series ohmmeter circuit.

You may use a variable resistor in the meter circuit (R_2 in fig. 7-21) to compensate for variations in battery voltage. Before using an ohmmeter for a precise resistance measurement, short the leads together and set the needle to zero by rotating the "zero ohms" (variable resistor) knob. The result is a full-scale reading at zero ohms.

CAUTION

Be certain not to place the ohmmeter leads across an energized circuit or a charged capacitor. Ignoring this rule will likely result in damage to the test equipment. Always turn off the power on a circuit to be tested before making continuity or resistance tests. Before you test with an ohmmeter, bleed any capacitors that are included in the circuits under test. Use extreme care in testing solid-state components and equipment with an ohmmeter. The voltage from the internal batteries of the ohmmeter will severely damage many solid-state components. Always turn an ohmmeter off after you have completed your test to lengthen the life of the batteries.

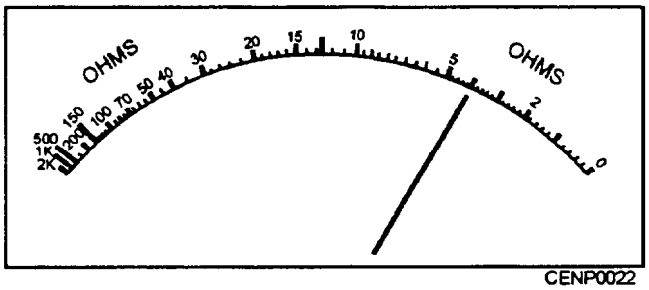


Figure 7-22.—Typical scale of a series type of ohmmeter.

After you zero the meter, place the leads across the circuit or component under test. The resistance of the unknown resistor between the ohmmeter leads limits the current through the meter, resulting in less than a full-scale deflection of the needle. The resistance reading may then be taken from the point along the scale at which the needle comes to rest

Accurate readings become progressively more difficult to take toward the high-resistance end of the scale. When the needle comes to rest at the high end of the scale and the ohmmeter has several resistance ranges, you may simply switch to a higher range for a reading closer to center scale. The resistance is read directly from the scale at the lowest range (for example, the R x 1 range on some ohmmeters). At the higher ranges the reading may be multiplied by 100 or 10,000 (as on the R x 100 or R x 1,000 ranges). The higher resistance ranges in a multirange ohmmeter use a higher voltage battery than do the lower ranges.

We will discuss multimeters (meters that perform more than one function) later in this chapter, but since we have already discussed the ammeter as a clamp-on ammeter, we will look at the same instrument as an ohmmeter.

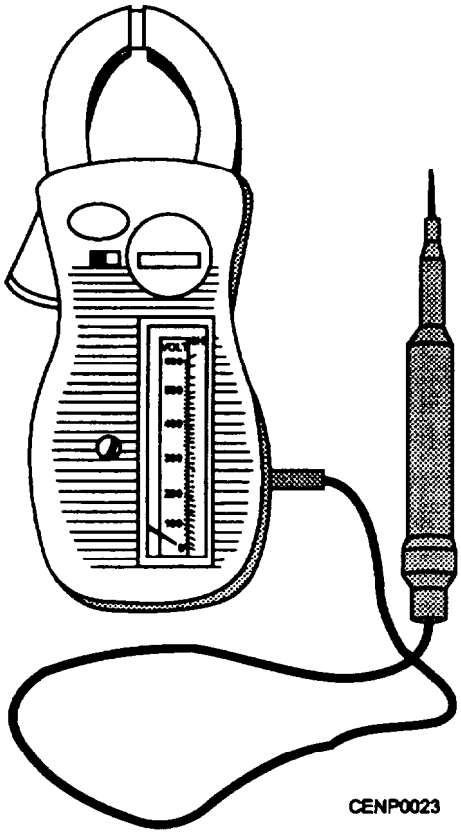


Figure 7-23.—Clamp-on ammeter with ohmmeter battery adapter.

To use the ammeter as an ohmmeter, you should plug a battery adapter into the jack on the side of the case (fig. 7-23). The battery in the adapter powers the ohmmeter function of this instrument. One of two test leads that may be plugged into the instrument (for voltage measurements) is used for the second lead of the ohmmeter. This test lead is plugged into the jack marked “COMMON.” The ohmmeter scale is a fixed scale at the right side of the scale window opening. It is not part of the rotating scale mechanism. The rotating mechanism has no effect on the ohmmeter operation. The leads are applied to the circuit or component, and the reading is taken as with any ohmmeter.

The series type of ohmmeter is only one type of instrument used for resistance measurements, but it is common in the design of ohmmeters used by Construction Electricians.

MULTIMETERS

Up to this point, each of the instruments we have discussed, for the most part, performs only one function. The exception was the clamp-on ammeter/ohmmeter. In a similar way the analog meters and digital meters perform several (or multiple) functions and are therefore referred to as multimeters.

An analog instrument usually makes use of a needle to indicate a measured quantity on a scale. Digital meters indicate the quantity directly in figures. We will discuss both types here because you will use both types.

Notice that each multimeter in figure 7-24 (A, B, C, and D) consists of a case to enclose the indicating device, one or more functions and/or range switches, and internal circuitry and jacks for external connections.

Voltage Measurements

Before plugging the test leads into the jacks, set the switches for the measurement. Let’s look at anexample. You are about to measure the voltage at a standard wall outlet in an office. You already know from experience that the voltage should be in the area of 115 to 125 volts ac. You have one of two types of multimeters-an analog meter or a digital meter. Because you do know the voltage to be tested, you would set the function switch to AC and the voltage to 250V. For the operation of the range and function switches on the particular meter, you should check the manufacture’s literature.

What should you do if you have no idea what the voltage is? There are times when you should not get

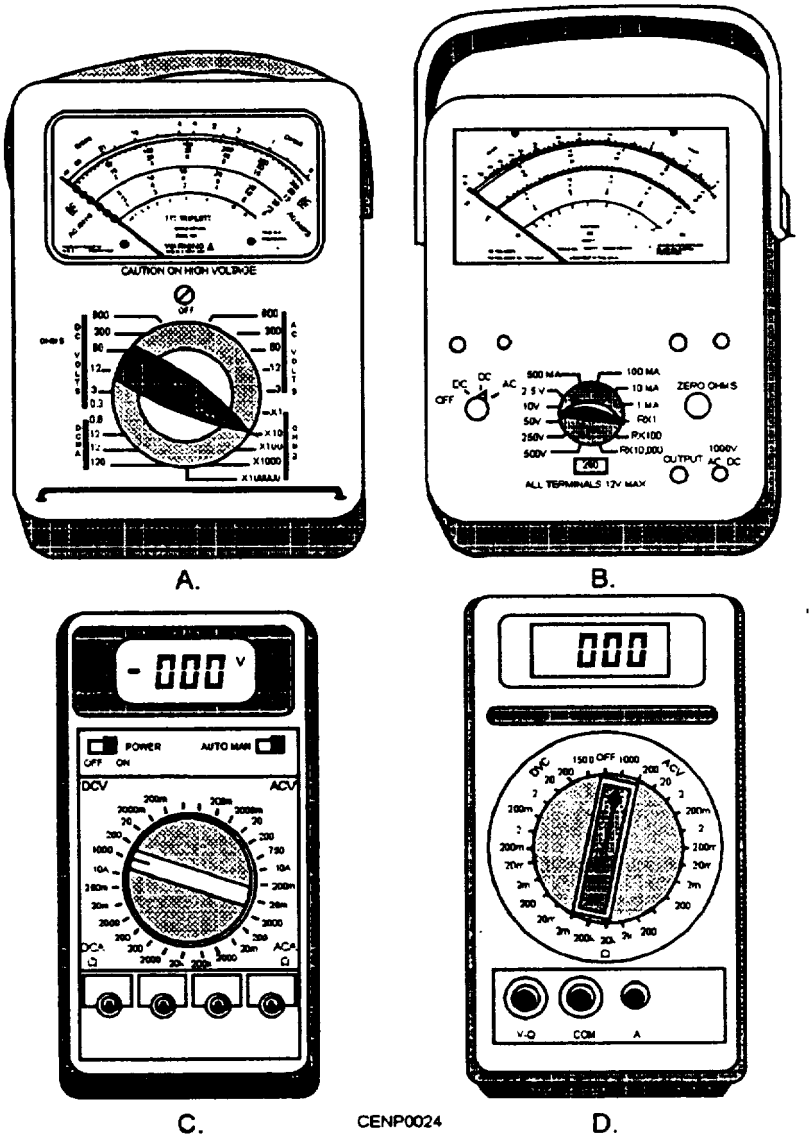


Figure 7-24.—Typical multimeters (analog types A and B and digital types C and D).

near the equipment; in this case, you should check with someone who knows (for example, a public works engineer or line crew supervisor). Check the highest range on your instrument. If you have a meter and you know the voltage value should not exceed 1,000 volts ac, then set the range/function switch to 1,000 ACV.

Plug the test leads into the appropriate jacks for the test you are about to perform. When you have red and black test leads, get into the habit of using the black lead with the common or - (negative) jack, even when measuring ac volts. For either analog meter, plug the red lead into the + (positive) jack. With either of the digital meters, use the jack marked "V-O" (volts-ohms).

WARNING

The following sequence of steps is important for your safety. Stay alert and follow them carefully.

Connect the two test leads to the two conductors/terminals of the wall outlet while holding the insulated protectors on the test leads. Do not touch the probes or clips of the test leads. Take the reading. If you have the meter range switch at the highest setting and see that the voltage value is within a lower voltage range, set the range switch to the lower range that is still higher than the voltage reading you remember. When you take a reading at a higher range and switch to a lower range, the reading at the lower range will be more accurate. Be certain to read from the scale that matches

the range setting of the switch; for example, when using the multimeter with the switch set to 300 AC VOLTS, read from the scale that has a maximum reading of 300 ac. Simply take the reading directly from either of the digital multimeters.

WARNING

Always be alert when taking voltage or amperage measurements if it is necessary to move the meter. If the instrument is moved in a way that causes tension on the test leads, one or both leads may be pulled Tom the jack(s). The leads will be energized just as the circuit to which they are connected, and they can be dangerous.

The positions of the jacks may differ for a particular measurement, from one meter to another. Notice how the jacks are labeled on the instrument you use, and follow the instructions from the manufacturer of the instrument.

Amperage Measurements

It is possible that you may never use a multimeter for amperage measurements. Most multimeters are designed with quite low current ranges. The clamp-on ammeter (discussed earlier) is the most convenient portable instrument for measuring ac amperes.

Resistance Measurements

As mentioned earlier, ohmmeters have their own voltage source. This circumstance is also true of the ohmmeter function of multimeters. The size and number of batteries for different instruments vary. Usually one or more 1 1/2- to 9-volt batteries are used for resistance measurements.

As you must set up the meter to measure voltage accurately, so you must set it up for measuring resistance. If you are to measure a 120-ohms resistor, for example, set the selector switch to ohms at the appropriate range. For the analog instruments, set the switch to the R x 1 or x 1 as appropriate. Read the value from the ohms scale directly. For higher values of resistance like 1,500 ohms, for example, use the R x 100 or x 100 range. In this case, multiply the reading from the ohms scale by 100.

For all critical resistance measurements, always touch the leads together and set the indicator needle to zero with the appropriate adjustment knob. Do not let the leads touch your fingers or anything else while you are zeroing the meter.

On multimeters, use the common – (negative) and + (positive) jacks for resistance measurements.

Be certain that there is no power on the circuit or component you are to test when measuring resistance. Be sure also to discharge any capacitors associated with the circuit or component to be tested before connecting the instrument to the circuit or component

For critical measurements, make sure that only the circuit or component you are to test touches the leads while you take the reading; otherwise, the reading may be inaccurate, especially on the higher resistance ranges.

Many times you will use the ohmmeter for continuity tests. All you will want to know is whether the circuit is complete or not. You will not have to zero the meter for noncritical continuity tests. You will want to touch the leads together to see where the needle comes to rest. If the needle stops at the same place when you place the leads across the circuit, you will know the path has a low resistance. In other words you will know there is continuity through the circuit.

Construction Electricians also use other instruments for different types of resistance measurements. We will discuss these instruments next.

MEGOHMMETERS

The megohmmeter is a portable instrument consisting of an indicating ohmmeter and a source of dc voltage. The dc source can be a hand-cranked generator, a motor-driven generator, a battery-supplied power pack, or rectified dc.

The megohmmeter is commonly called a "megger" although Megger© is a registered trademark. The megger tester shown in figure 7-25 is an example of a dual-operated megohmmeter. having both a hand-cranked generator and a built-in line power supply in the same module.

Any one of the ohmmeters shown in figure 7-24 will measure several megaohms. You may wonder why they are not called megohmmeters. What is the difference between the megger and the typical ohmmeter? Does not each of them have an indicator and a dc voltage source within the instrument enclosure? The megger is capable of applying a much higher value of dc voltage to the circuit or component under test than is the typical ohmmeter. Meggers that will supply a test potential of 500 volts are common in

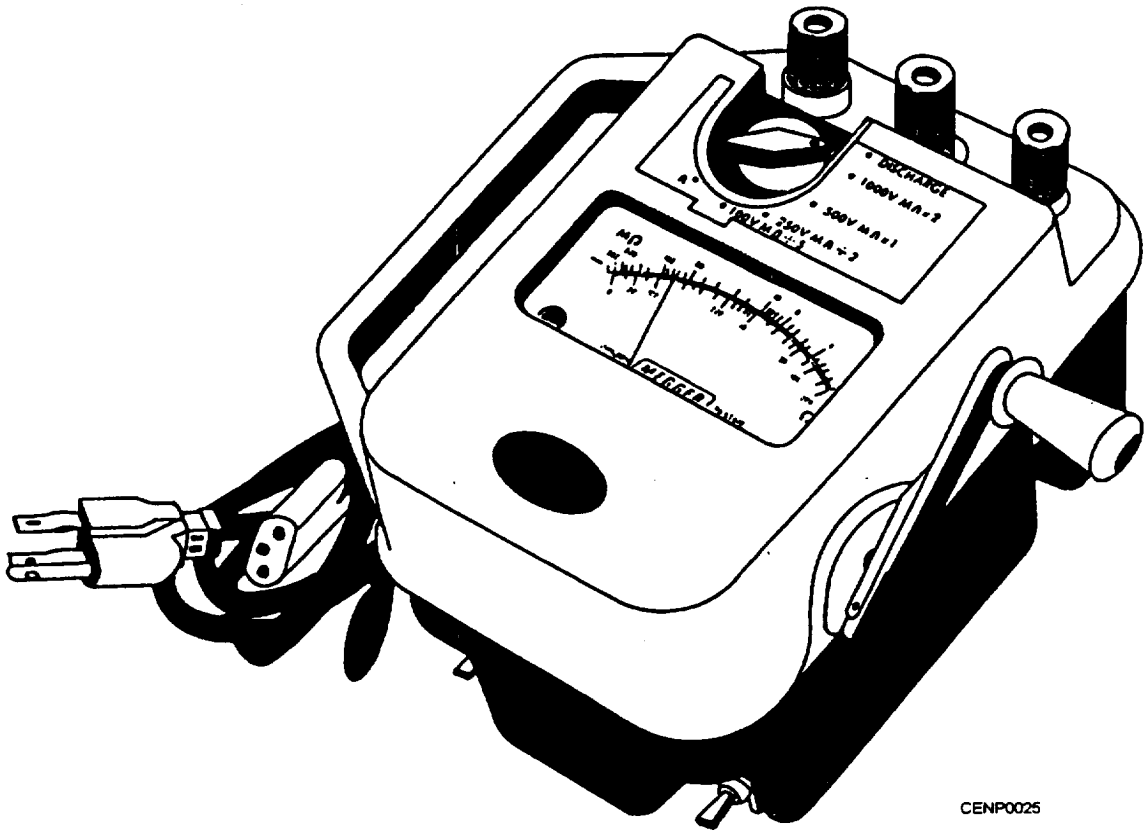


Figure 7-25.—Typical megohmmeter tester.

the Navy. The megger (fig. 7-25) is capable of several test voltages up to 1,000 volts, depending on the setting of the selector switch. Ohmmeters are generally designed to include batteries as voltage sources. These batteries apply approximately 1/2 to 9 volts to the circuit under test.

The design of the megger is such that the needle floats freely until the generator is operated. When the generator is not operating, the needle may come to rest at any point on the scale. This characteristic is due to internal design, unlike that used in the typical ohmmeter.

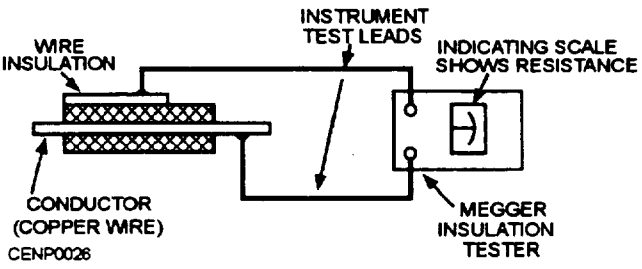


Figure 7-26.—Typical megger test instrument hooked up to measure insulation resistance.

INSULATION RESISTANCE TESTERS

The megger is used to measure high-insulation resistance. The high resistance may be between windings of a transformer or motor or between the conductor in a cable and the conduit or sheath surrounding the cable (fig. 7-26).

If the test leads connected to the line and earth terminals are open-circuited (as when they are not allowed to touch anything) and the hand-cranked generator is operated, the needle is deflected to infinity (fig. 7-27). “Infinity” means that the resistance is too high for the instrument to measure. The symbol for

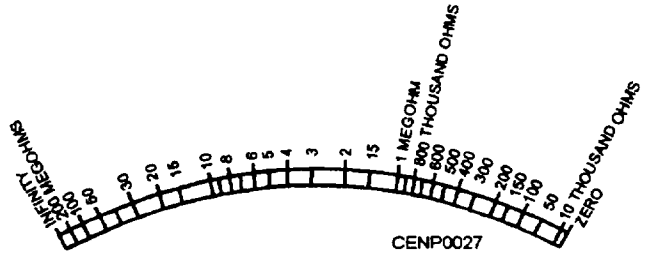


Figure 7-27.—Typical indicating scale on the megger insulation tester.

infinity on the scale of the megger (fig. 7-25) is similar to a horizontal figure eight. During a test, a reading at or near infinity means either that the insulation is in excellent shape or the test leads are not making contact with the component being tested.

If the test leads are connected to each other while the hand crank is turned, the pointer will deflect to zero, indicating no resistance between the test leads. A zero deflection in the above-mentioned test (fig. 7-26) can mean that the conductor under test is touching the sheath or conduit surrounding it. This deflection could also be an indication that the insulation is worn or broken somewhere close to the test point. Any reading near the low end of the scale may mean faulty or wet insulation.

The megger serves well as an insulation tester because of the high-test voltage it produces. The low voltage of an ohmmeter may not produce enough leakage current through poor insulation to cause the meter to indicate a problem even when one exists. But the relatively high voltage of the megger will likely cause enough leakage current to reveal an insulation problem by a lower than normal resistance indication on the meter scale.

How low is the resistance of bad insulation? How high must the insulation resistance reading be before you can be sure the insulation is good?

Here are some general observations about how you can interpret periodic insulation resistance tests, and what you should do with the results.

CONDITION	WHAT TO DO
1. Fair to high values and well maintained.	No cause for concern.
2. Fair to high values, but showing a constant tendency towards lower values.	Locate and remedy the cause and check the downward trend.
3. Low but well maintained.	Condition is probably all right, but the cause of the low values should be checked.
4. So low as to be unsafe.	Clean, dry out, or otherwise raise the values before placing equipment in service (test wet equipment while drying it out).
5. Fair or high but showing sudden lowering.	Make tests at frequent intervals until the cause of well maintained low values is located and remedied or until the values become steady at a level that is lower but safe for operation or until values become so low that it is unsafe to keep the equipment in operation.

Short-Time or Spot-Reading Tests

Several test methods are commonly used. We will discuss the short-time or spot-reading tests.

In this method, you simply connect the megger across the insulation to be tested and operate it for a short, specific time period (60 seconds usually is recommended). As shown in figure 7-28, you have picked a point (to take the reading) on a curve of increasing resistance values; quite often the value will be less for 30 seconds, more for 60 seconds. Bear in mind also that temperature and humidity, as well as condition of the insulation, affect your reading.

If the apparatus you are testing has low capacitance, such as a short run of type NM cable (Romex), the spot-reading test is all that is necessary; however, most equipment is capacitive, so your first spot reading on equipment in your work area—with no prior tests—can be only a rough guide as to how "good" or "bad" the insulation is. For many years, maintenance personnel have used the 1-megohm rule to establish the allowable lower limit for insulation resistance. The rule may be

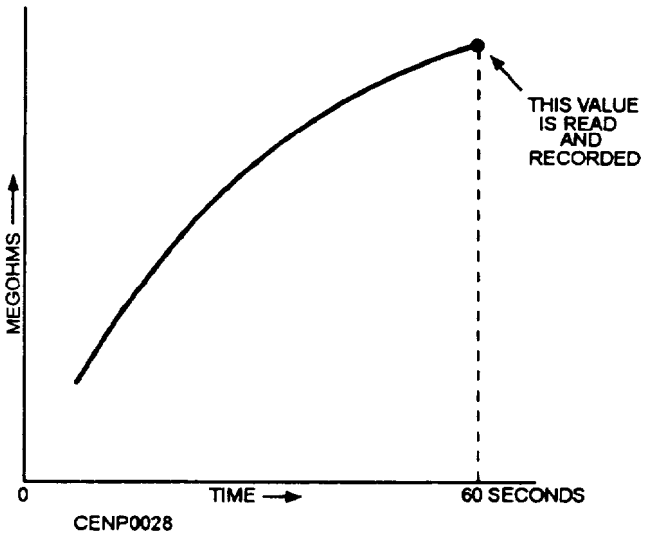


Figure 7-28.—Typical curve of insulation resistance (in megohms) with time.

stated thus: Insulation resistance should be approximately 1 megohm for each 1,000 volts of operating voltage with a minimum value of 1 megohm. For example, a motor rotated at 2,400 volts should have a minimum insulation resistance of 2.4 megohms. In practice, megohm readings normally are considerably above this minimum value in new equipment or when insulation is in good condition.

By taking readings periodically and recording them, you have a better basis for judging the actual insulation condition, Any persistent downward trend is usually fair warning of trouble ahead, even though the readings may be higher than the suggested minimum safe values. Equally true, as long as your periodic readings are consistent, they may be all right even though lower than the recommended minimum values.

Common Test Voltages

Commonly used dc test voltages for routine maintenance are as follows:

EQUIPMENT AC RATING	DC TEST VOLTAGE (See selector switch settings on Megger© in fig. 7-25.)
up to 100 volts	100 and 250 volts
440 to 550 volts	500 and 1,000 volts
2,400 volts	1,000 to 2,500 volts or higher
4,160 volts and above	1,000 to 5,000 volts or higher

CAUTION

Use care in applying test voltage to the component to be tested. Do not use a high-test voltage on low-voltage equipment or components.

Do not exceed the commonly used test voltages mentioned above unless you are following the equipment manufacturer's instructions to do so. On the other hand, a test voltage lower than the operating voltage of the component to be tested may not reveal a problem that the test should indicate. If the test voltage is too low, you may get no more than a resistance reading such as you would get with an ohmmeter.

Causes of Low Insulation Resistance Readings

Insulation resistance varies with the temperature. The effect of temperature depends on the type of insulation, the amount of moisture in and on the insulation surface, and the condition of the surface.

The amount of moisture in insulation has a great effect on its resistance. For meaningful results, tests of insulation resistance should be made under as nearly similar conditions as practical. Long cables can be exposed to a variety of conditions along the cable route at the same time. A comparison of readings may not indicate a change in insulation condition.

An accumulation of things like dust, dirt, and moisture can cause low-resistance readings. A motor stored or kept idle for a while may have to be cleaned and dried out before being installed and placed in service.

Record Keeping

Records should be kept where tests are performed periodically. The frequency of the tests should be based on the importance of the circuit. One test each year is usually adequate. Records of each circuit or component may be compared. Trends may indicate a future problem, and corrections may be made in time to prevent future problems in cables or components, like motors or transformers.

Effects of Temperature

If you want to make reliable comparisons between readings, you should correct the readings to a base temperature, such as 20°C (68°F), or take all your readings at approximately the same temperature (usually not difficult to do). We will cover some general guidelines to temperature correction.

One rule of thumb is that for every 10°C (50°F) increase in temperature, you halve the resistance; or for every 10°C (50°F) decrease, you double the resistance; for example, a 2-megohm resistance at 20°C (68°F) reduces to 1/2 megohm at 40°C (104°F).

Each type of insulating material will have a different degree of resistance change with temperature variation. Factors have been developed, however, to

simplify the correction of resistance values. Table 7-3 gives such factors for rotating equipment, transformers, and cable. You multiply the reading you get by the factor corresponding to the temperature (which you need to measure).

For example, assume you have a motor with Class A insulation and you get a reading of 3.0 megohms at a temperature (in the windings) of 131°F (55°C). From table 7-3 you read across at 131°F to the next column (for Class A) and obtain the factor 15.50. Your correct value of resistance is then

3.0 megohms	x	15.50	= 46.5 megohms
(reading at 131°F)		(Correction factor for Class A insulation at 131°F)	(Corrected reading for 68°F or 20°C)

Note that the resistance is 14.5 times greater at 68°F (20°C) than the reading taken at 131°F. The reference temperature for cable is given as 60°F (15.6°C), but the important point is to be consistent-correcting to the same base before making comparisons between readings.

Effects of Humidity

We mentioned in this chapter about the presence of moisture in insulation and its marked effect upon resistance values. You might expect that increasing humidity (moisture content) in the surrounding (ambient) air could affect insulation resistance. And it can, to varying degrees.

If your equipment operates regularly above what is called the "dew-point" temperature (that is, the temperature at which the moisture vapor in air condenses as a liquid), the test reading normally will not be affected much by the humidity. This stability is true even if the equipment to be tested is idle, so long as its temperature is kept above the dew point. In making this point, we are assuming that the insulation surfaces are free of contaminants, such as certain lints and acids or

Table 7-3.—Temperature Correction Factors (Corrected to 20°C for Rotating Equipment and Transformers; 15.6° for Cable)

TEMP.		ROTATING EQUIP.			CABLES							
°C	°F	CLASS A	CLASS B	OIL-FILLED TRANSFORMERS	CODE NATURAL	CODE GR-S	PERFORMANCE NATURAL	HEAT RESIST. NATURAL	HEAT RESIST. & PERFORM GR-S	OZONE RESIST. NATURAL GR-S	VARNISHED CAMBRIC	IMPREGNATED PAPER
0	32	0.21	0.40	0.25	0.25	0.12	0.47	0.42	0.22	0.14	0.10	0.28
5	41	0.31	0.50	0.36	0.40	0.23	0.60	0.56	0.37	0.26	0.20	0.43
10	50	0.45	0.63	0.50	0.61	0.46	0.76	0.73	0.58	0.49	0.43	0.64
15.6	60	0.71	0.81	0.74	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
20	68	1.00	1.00	1.00	1.47	1.83	1.24	1.28	1.53	1.75	1.94	1.43
25	77	1.48	1.25	1.40	2.27	3.67	1.58	1.68	2.48	3.29	4.08	2.17
30	86	2.20	1.58	1.98	3.52	7.32	2.00	2.24	4.03	6.20	8.62	3.20
35	95	3.24	2.00	2.80	5.45	14.60	2.55	2.93	6.53	11.65	18.2	4.77
40	104	4.80	2.50	3.95	8.45	29.20	3.26	3.85	10.70	25.00	38.5	7.15
45	113	7.10	3.15	5.60	13.10	54.00	4.15	5.08	17.10	41.40	81.0	10.70
50	122	10.45	3.98	7.85	20.00	116.00	5.29	6.72	27.85	78.00	170.00	16.00
55	131	15.50	5.00	11.20			6.72	8.83	45.00		345.00	24.00
60	140	22.80	6.30	15.85			8.58	11.62	73.00		775.00	36.00
65	149	34.00	7.90	22.40				15.40	118.00			
70	158	50.00	10.00	31.75				20.30	193.00			
75	167	74.00	12.60	44.70				26.60	313.00			

salts that have the property of absorbing moisture (chemists call them "hygroscopic" or "deliquescent" materials). Their presence could unpredictably affect your readings; they should be removed before tests are made.

In electrical equipment we are concerned primarily with the conditions on the exposed surfaces where moisture condenses and affects the overall resistance of the insulation. Studies show, however, that dew will form in the cracks and crevices of insulation before it is visibly evident on the surface. Dew-point measurements will give you a clue as to whether such invisible conditions may exist, altering the test results.

As a part of your maintenance records, it is a good idea to make note at least of whether the surrounding air is dry or humid when the test is made and whether the temperature is above or below the ambient. When you test vital equipment, record the ambient wet- and dry-bulb temperatures from which dew point and percent relative or absolute humidity can be obtained

Preparation of Apparatus for Test

NOTE: Before interrupting any power, be certain to check with your seniors (crew leader, project chief, or engineering officer, as appropriate) so that any necessary notification of the power outage may be made. Critical circuits and systems may require several days or even weeks advance notice before authorization for a power outage may be granted.

TAKE OUT OF SERVICE.—Shut down the apparatus you intend to work on. Open the switches to de-energize the apparatus. Disconnect it from other equipment and circuits, including neutral and protective (workmen's temporary) ground connections. See the safety precautions that follow in this section.

MAKE SURE OF WHAT IS INCLUDED IN THE TEST.—Inspect the installation carefully to determine just what equipment is connected and will be included in the test, especially if it is difficult or expensive to disconnect associated apparatus and circuits. Pay particular attention to conductors that lead away from the installation. That is important, because the more equipment that is included in a test, the lower the reading will be, and the true insulation resistance of the apparatus in question may be masked by that of the associated equipment.

WARNING

Care should be taken in making electrical insulation tests to avoid the danger of electric shock. Read and understand the manufacturer's safety precautions before using any megohmmeter. As with the ohmmeter, never connect a megger to energized lines or apparatus. Never use a megger or its leads or accessories for any purpose not described in the manufacturer's literature. If in doubt about any safety aspects of testing, ask for help. Other safety precautions will follow in this section.

Safety Precautions

WARNING

Observe all safety rules when taking equipment out of service.

- Block out disconnect switches.
- Be sure equipment is not live.
- Test for foreign or induced voltages.
- Ensure that all equipment is and remains grounded—both equipment that you are working on and other related equipment.
- Use rubber gloves when required.
- Discharge capacitance fully.
- Do not use the megger insulation tester in an explosive atmosphere.

When taking equipment out of service, be sure to observe all rules for safety. Block out the disconnect switches. Test for foreign or induced voltages. Apply workmen's grounds. (Workmen's grounds are grounds you or others use to ground equipment while you are working on it;)

When you are working around high-voltage equipment, remember that because of proximity to energized high-voltage equipment, there is always a possibility of voltages being induced in apparatus under test or lines to which it is connected; therefore, rather than removing a workmen's ground to make a test, you should disconnect the apparatus, such as a transformer or circuit breaker, from the exposed bus or line, leaving the latter grounded. USE RUBBER GLOVES WHEN CONNECTING THE TEST LEADS TO THE APPARATUS AND WHEN OPERATING THE MEGGER.

APPARATUS UNDER TEST MUST NOT BE LIVE.—If neutral or other ground connections have to be disconnected, make sure that they are not carrying current at the time and that when they are disconnected,

no other equipment will lack protection normally provided by the ground.

Pay particular attention to conductors that lead away from the circuit being tested and make sure that they have been properly disconnected from any source of voltage.

SHOCK HAZARD FROM TEST VOLTAGE.—Observe the voltage rating of the megger and regard it with appropriate caution. Large electrical equipment and cables usually have sufficient capacitance to store up a dangerous amount of energy from the test current. Make sure this capacitance is discharged after the test and before you handle the test leads.

DISCHARGE OF CAPACITANCE.—It is very important that capacitance be discharged, both before and after an insulation resistance test. It should be discharged for a period about four times as long as test voltage was applied in a previous test.

Megger instruments are frequently equipped with discharge switches for this purpose. If a discharge position is not provided, a discharge stick should be used. Leave high capacitive apparatus (for instance, capacitors, large windings, etc.) short circuited until you are ready to re-energize it.

EXPLOSION AND FIRE HAZARD.—So far as is known, there is no fire hazard in the normal use of a megger insulation tester. There is, however, a hazard when your test equipment is located in a flammable or explosive atmosphere. Slight sparking may be encountered (1) when you are attaching the test leads to equipment in which the capacitance has not been completely discharged, (2) through the occurrence of arcing through or over faulty insulation during a test, and (3) during the discharge of capacitance following a test. Therefore:

WARNING

Do NOT use the megger insulation tester in an explosive atmosphere.

Suggestions: For (1) and (3) in the above paragraph, arrange permanently installed grounding facilities and test leads to a point where instrument connections can be made in a safe atmosphere.

For (2): Use low-voltage testing instruments or a series resistance.

For (3): To allow time for capacitance discharge, do not disconnect the test leads for at least 30 to 60 seconds following a test.

MOTORS AND CONTROLS

As a Construction Electrician, you must understand the principles of operation and construction of electrical motors and controllers. This knowledge is necessary so you can perform troubleshooting, maintenance, and repair of this equipment. You must be able to determine why the motor or controller is inoperative, if it can be repaired without removing it from service, or if it must be replaced. You must know what equipment substitutions or replacements to make and how to make the proper lead connections. The various types of motors and controllers have many elements in common; therefore, maintenance is fairly uniform. Once a motor or controller has been installed and the proper maintenance performed, you will have very little trouble. However, if something should go wrong, you must understand motors and controllers and how they operate to determine what troubleshooting steps to take and repairs to make. Remember, YOU are the repairman.

MOTORS

Motors operate on the principle that two magnetic fields within certain prescribed areas react upon each other. Pole pieces, frame, and field coils form one field; and as current is sent through the armature windings, another magnetic field is set up. The units of a motor, then, are the poles and the armature. The poles are ordinarily the static part, and the armature is the rotating Part

The poles are formed by placing magnetized bars so that the north pole of one is placed directly opposite of the south pole of the other. The air gap between these poles contains the magnetic field Just as a conductor must be insulated to prevent its electrical charge from being grounded, so the magnetic field must be shielded from the earth's magnetic field, or from the field of nearby generators or motors. This shielding is usually accomplished by surrounding the field with a shell of soft iron. The armature carries the coils which cut the lines of force in the field.

DC MOTORS AND CONTROLS

Direct-current motors and controls are seldom installed, maintained, or serviced by CEs unless they are assigned to special units, such as the State Department, where they will receive special training on this type of equipment. Therefore, we will not go into the depth on dc motors and controls as we will with ac. For information on direct-current motors and controls refer to the Navy Electricity and Electronics Training

Series (NEETS) modules and the *Electrician's Mate* Training Manual, NAVEDTRA 12164.

AC MOTORS

Most of your work with motors, at shore stations especially, will be with a-c motors. Dc motors have certain advantages but a-c power is more widely used and a-c motors are less expensive and on the whole, more reliable.

For example, sparking at the brushes of a dc motor can be very dangerous if there is explosive gas or dust in the surrounding air. On most a-c motors, brushes and commutators are not used and little maintenance is required. They are suited to constant speed applications and are designed to operate at a different number of phases and voltages.

A-c motors are designed in various sixes, shapes, and types such as the induction, series, and synchronous, but as a Construction Electrician in the U. S. Navy, you will be concerned primarily with the induction motors. This type of motor includes, among others, the split-phase, capacitor, repulsion-induction, and the polyphase motors.

SPLIT-PHASE MOTORS

A split-phase motor is usually of fractional horsepower. It is used to operate such devices as small pumps, oil burners, and washing machines. It has four main parts. These are the rotor, the stator, the end plates (or end bells, as they are sometimes called), and a centrifugal switch

The rotor consists of three parts. One of these parts is the core which is made up of sheets of sheet steel called laminations. Another part is a shaft on which these laminations are pressed. The third part is a squirrel-cage winding consisting of copper bars which are placed in slots in the iron core and connected to each other by means of copper rings located on both ends of the core. In some motors the rotor has a one-piece cast aluminum winding.

The stator of a split-phase motor consists of a laminated iron core with semiclosed slots, a steel frame into which the core is pressed, and two windings of insulated copper wire that are placed into the slots and are called the running and starting windings.

End bells, which are fastened to the motor frame by means of bolts or screws, serve to keep the rotor in perfect alignment. These end bells are equipped with bores or wells in the center, and are fitted with either sleeve or ball bearings to support the weight of the rotor and thus permit it to rotate without rubbing on the stator.

The centrifugal switch is located inside the motor on one of the end bells. It is used to disconnect the starting winding after the rotor has reached a predetermined speed, usually 75 percent of the full load speed. The action of the centrifugal switch is as follows: the contacts on the stationary part of the switch (the stationary part is mounted on the end bell) are closed when the motor is not in motion and make contact with the starting winding. When the motor is energized and reaches approximately 75 percent of full load speed, the rotating part of the switch (mounted on the rotor) is forced by centrifugal force against the stationary arm, thereby breaking the contact and disconnecting the starting winding from the circuit. The motor is then operating on the running winding as an induction motor. Figure 7-29 shows the two major parts of a centrifugal switch.

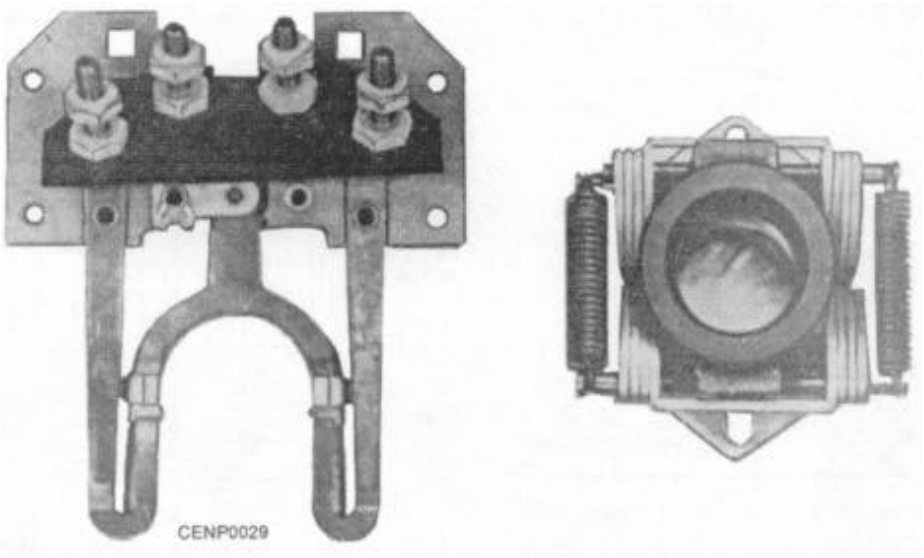


Figure 7-29.—Two major parts of a centrifugal switch.

The direction of rotation of a split-phase motor may be reversed by reversing the connections leading to the starting winding. This action can usually be done on the terminal block in the motor. Figure 7-30 shows a diagram of the connections of a split-phase motor.

Troubleshooting and Repair

Motors require occasional repairs, but many of these can be eliminated by following a preventive maintenance schedule. Preventive maintenance, in simple terms, means taking care of the trouble before it happens. For example, oiling, greasing, cleaning, keeping the area around the equipment clean, and seeing that the equipment has the proper protective fuses and overload protection are preventive maintenance steps that eliminate costly repairs.

To analyze motor troubles in a split-phase motor, the first check is for proper voltage at the terminal block. If you have the proper voltage, check the end bells for cracks and for alignment. The bolts or screws may be loose and the ends may be out of line. The next check is for a ground With the motor disconnected, check the connections from the terminal block to the frame with an ohmmeter or megger. If you find a ground in this test, remove the end bell with the terminal block and centrifugal switch and separate the starting winding and running winding and make another ground check on each of these windings. In many cases you will find the ground in the loops where the wires are carried from one slot to the next one. This situation can sometimes be repaired without removing the winding. In some cases, the ground may be in the centrifugal switch due to grease that has accumulated from over-greasing.

If the first test does not show a ground in the motor, check to see that the rotor revolves freely. If the rotor turns freely connect the motor to the source of power and again check to see that the rotor turns freely when energized. If the rotor turns freely with no voltage applied, but locks when it is applied, you will know that the bearings are worn enough to allow the iron in the rotor to make contact with the iron in the pole pieces.

If the trouble is a short, either the fuse will blow or the winding will smoke when the motor is connected to the line. In either event the motor will have to be disassembled A burned winding is easily recognizable by its smell and the burned appearance. The only remedy is to replace the winding. If the starting winding is burned, it can usually be replaced without disturbing the running winding, but check closely to be sure that the running winding is not damaged. In making a check for a shorted coil, the proper procedure is to use an ohmmeter to check the resistance in the coil that you suspect to be bad. Then check this reading against a reading from a coil that is known to be good.

An open circuit can be caused by a break in a wire in the winding, or by the centrifugal switch not closing properly when the motor is at a standstill. Too much end play in the rotor shaft may cause the rotating part of the centrifugal switch to stop at a point where it allows the contacts on the stationary part of the switch to stand open. Should the rotor have more than 1/64-inch end play, place fiber washers on the shaft to line the rotor up properly.

If the motor windings are severely damaged, the motor must be sent to a motor shop for repairs. The repairs will usually be done in a shop operated by Public Works or the motor may be sent outside the base to a civilian operated motor shop. For this reason only the basic principles of the winding procedure will be covered.

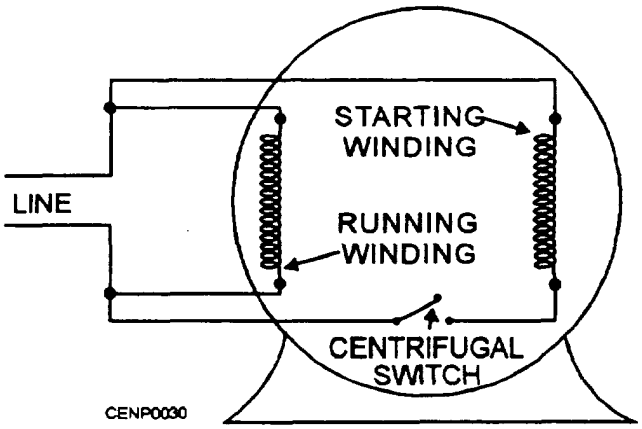


Figure 7-30.—Diagram of the connections of a split-phase motor.

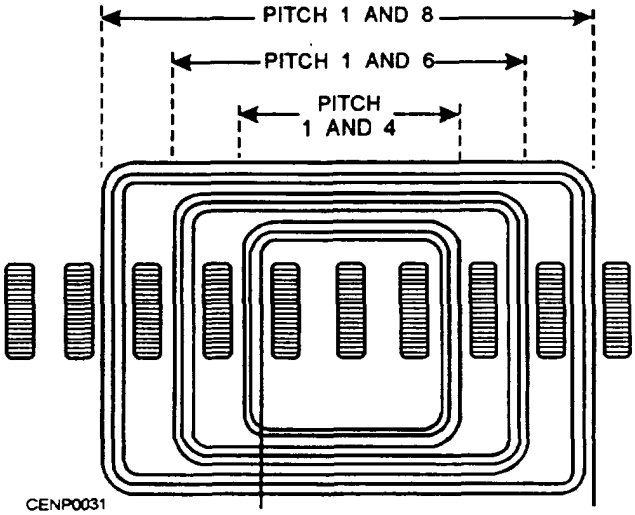


Figure 7-31.—The pitch of a coil.

Repair of a split-phase motor with a damaged winding consists of several operations: taking the winding data, stripping the old windings, insulating the slots, winding the coils and placing them in the slots, connecting the windings, testing, varnishing and baking the winding.

Before the motor is taken apart, the end plates should be marked with a center punch so that they may be reassembled properly. One punch mark should be put on the front end plate and a corresponding mark made on the frame. Two marks should be made on the opposite end plate and also on the frame at that point.

Taking the winding data is one of the most important parts of the operation This action consists of obtaining and recording information concerning the old winding; namely, the number of poles, the pitch of the coil (the number of slots that each coil spans), (fig. 7-31), the number of turns in each coil, the size of the wire in each winding, the type of connection (series or parallel), the type of winding, and slot insulation. See figure 7-32.

This data is taken while removing the old winding from the motor frame. One coil should be cut at a place where the number of turns may be counted. The size of the wire and other data is then entered on the data sheet.

SPLIT PHASE MOTOR DATA

MAKE					
HP	RPM	VOLTS	AMPS		
CYCLE	TYPE	FRAME	STYLE		
TEMP	MODEL	SERIAL NO	PHASE		
NO OF POLES	END ROOM	NO OF SLOTS			
LEAD PITCH	COMMUTATOR PITCH				
WIRE INSULATION	WINDING (HAND, FORM, AND SKEIN)				
SLOT INSULATION	TYPE	SIZE	THICKNESS		
TYPE CONNECTIONS	SWITCH	LINE			
WINDING	TYPE	SIZE AND KIND WIRE	NO OF CIRCUITS	COIL PITCH	TURNS
RUNNING					
STARTING					
SLOT NO	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				
RUNNING					
STARTING					
ROTATION	CLOCKWISE	COUNTER CLOCKWISE			

CENP0032

Figure 7-32.—Split-phase motor data sheet.

Clean the old insulation and varnish from the slots before installing the new slot insulators. This cleaning is usually done with a torch. The slot insulators are formed from one of several types of material available for this purpose. The best procedure is to reinsulate the slots with the same type and size insulation that was used in the original winding.

The coils are then wound according to the data sheet and replaced in the slots in the same position as the windings that were removed. The starting windings are ALWAYS placed 90 electrical degrees out of phase with the running windings.

When all the connections between the poles of the windings have been completed and tested and the leads attached, the stator should be placed in a baking oven at a temperature of about 250°F and baked for three hours to remove any trace of moisture. Heating the windings also helps the varnish to penetrate the coils.

The stator is then dipped in a good grade of insulating varnish, allowed to drip for about an hour and then placed in the oven and baked for several hours.

When the stator is removed from the oven, the inner surface of the core of the stator should be scraped to remove the varnish so that the rotor will have sufficient space to rotate freely.

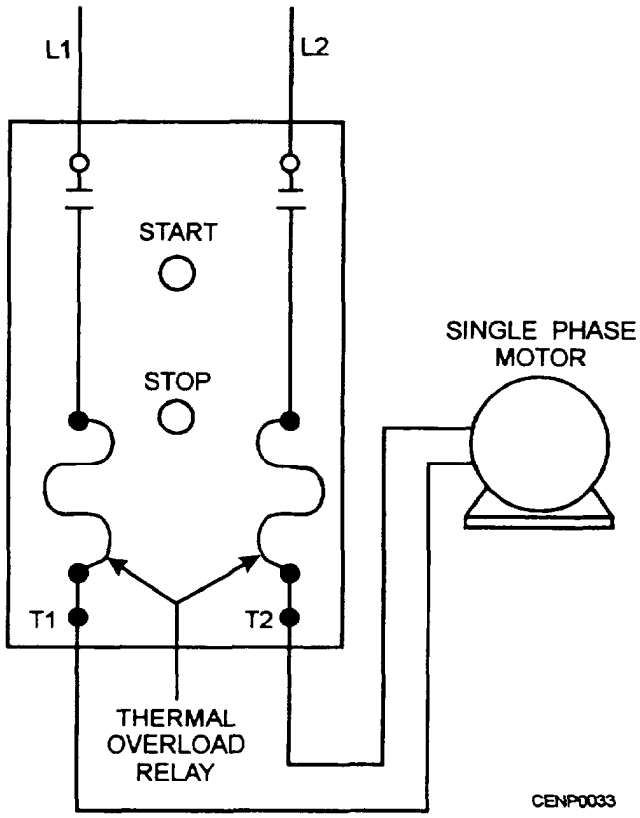


Figure 7-33.—Starting switch for a single-phase motor.

Control for a Split-Phase Motor

The control switch for a split-phase motor is usually a simple OFF and ON switch if the motor is equipped with an overload device. If the motor does not have this overload device, the switch will be of a type illustrated in figure 7-33. This type of switch has two push buttons; one to start and one to stop the motor. It uses interchangeable thermal overload relay heaters for protection of various size motors. In some cases, a 30-ampere safety switch with the proper size fuse may be used.

CAPACITOR MOTORS

The capacitor motor is similar to the split-phase motor, but an additional unit, called a capacitor, is connected in series with the starting winding, These motors may be of capacitor-start or the capacitor-run type.

The capacitor is usually installed on top of the motor; but it may be mounted on the end of the motor frame, or inside the motor housing, or remote from the motor. Acapacitor acts essentially as a storage unit. All capacitors have this quality and all are electrically the same. The only difference is in the construction The type of capacitor usually used in fractional-horsepower motors is the paper capacitor. This type of capacitor has strips of metal foil separated by an insulator, usually waxed paper. The strips are rolled or folded into a compact unit which is placed in a metal container either rectangular or cylindrical in shape. ‘Iwo terminals are provided for connections.

The capacitor-start motor has, like the split-phase motor, a centrifugal switch which opens the starting winding when the rotor has reached the predetermined speed, while the capacitor-run motor does not have the centrifugal switch and the starting winding stays in the circuit at all times. Figure 7-34 shows a capacitor-start motor winding circuit. The capacitor motor provides a higher starting torque with a lower starting current than the split-phase motor.

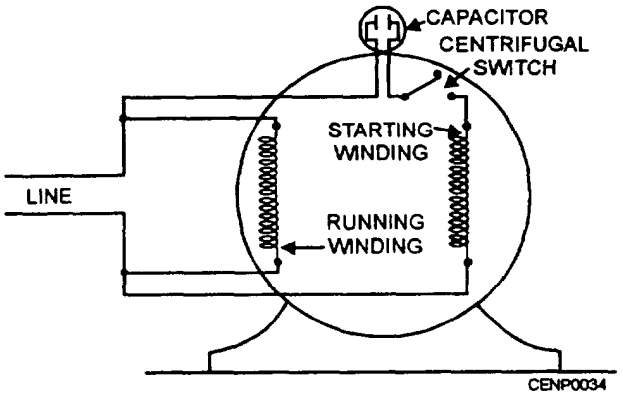


Figure 7-34.—Capacitor start motor winding circuit.

TROUBLESHOOTING AND REPAIR

The procedure for troubleshooting and repair for the capacitor motor is the same as for the split-phase motor except for the capacitor. Capacitors are rated in microfarads and are made in various ratings, according to the size and type. Acapacitor may be defective due to moisture, overheating or other conditions. In such a case it must be replaced with another one of the same value of capacity. To test a capacitor, remove the motor leads from the capacitor and connect the capacitor in series with a 10-amp fuse across a 110- volt line. If the fuse burns out, the capacitor is short-circuited and must be replaced. If the fuse does not burn out, leave the capacitor connected to the line for a few seconds to build up a charge. Do not touch the terminals after the charging process as serious injury may result from the stored charge.

Short the terminals with an insulated handle screw driver. A strong spark should show if the capacitor is good. If no spark or a weak spark results, the capacitor must be replaced.

The procedure for rewinding a capacitor motor is the same as for the split-phase motor except for the capacitor.

UNIVERSAL MOTORS

A universal motor is one that operates on either single-phase ac or dc power. These motors are normally made in sizes ranging from 1/200 to 1/3 horsepower. You can get them in larger sizes for special conditions. The fractional horsepower sizes are used on vacuum cleaners, sewing machines, food mixers, and power hand tools.

The salient-pole type is the most popular type of universal motor. The salient-pole type consists of a stator with two concentrated field windings, a wound rotor, a commutator, and brushes. The stator and rotor windings in this motor are connected in series with the power source. There are two carbon brushes that remain on the commutator at all times. These two brushes are used to connect the rotor windings in series with the field windings and the power source (fig. 7-35). The universal motor does not operate at a constant speed. The motor runs as fast as the load permits; i.e., low speed with a heavy load and high speed with a light load. Universal motors have the highest horsepower-to-weight ratio of all the types of electric motors.

The operation of a universal motor is much like a series dc motor. Since the field winding and armature are connected in series, both the field winding and armature winding are energized when voltage is applied to the motor. Both windings produce magnetic fields which react to each other and cause the armature to rotate. The reaction between magnetic fields is caused by either ac or dc power.

SHADED-POLE MOTORS

The shaded-pole motor is a single-phase induction motor that uses its own method to produce starting torque. Instead of a separate winding like the split-phase and capacitor motors, the shaded-pole motor's start winding consists of a copper band across one tip of

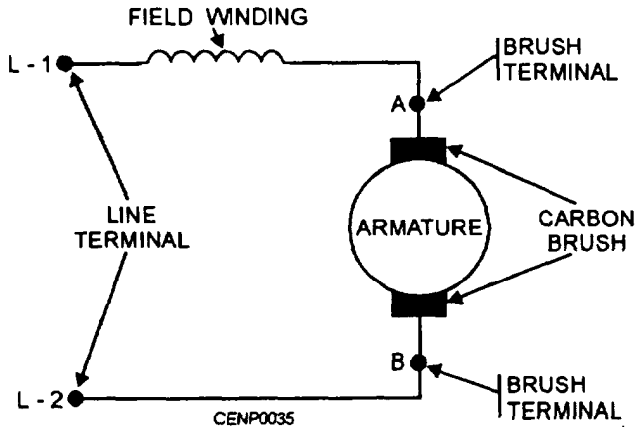


Figure 7-35.—Universal motor schematic.

each stator pole (fig. 7-36). This copper band delays the magnetic field through that portion of the pole. When ac power is applied, the main pole reaches its polarity before the shaded portion of the pole. This action causes the shaded poles to be out of phase with the main poles and a weak rotating magnetic field is produced. Because of the low-starting torque, it isn't feasible to build motors of this type larger than 1/20 horsepower. They are used with small fans, timers, and various light-load control devices.

Remember, all single-phase induction motors have some auxiliary means to provide the motor with starting torque. The method used for this starting torque depends on the application of the motor.

FAN MOTORS

A wide variety of motors are used for fans and blowers. Here we will discuss the different methods of varying the speed of common fan motors.

Different manufacturers use different methods for varying the speed. On some motors only the running-winding voltage is varied while the voltage in the starting winding is constant On others the running winding consists of two sections connected in series across 230 volts for high speed. If low speed is required, the two sections are connected to 155 volts through an auto-transformer. Usually, these motors are connected for three speeds.

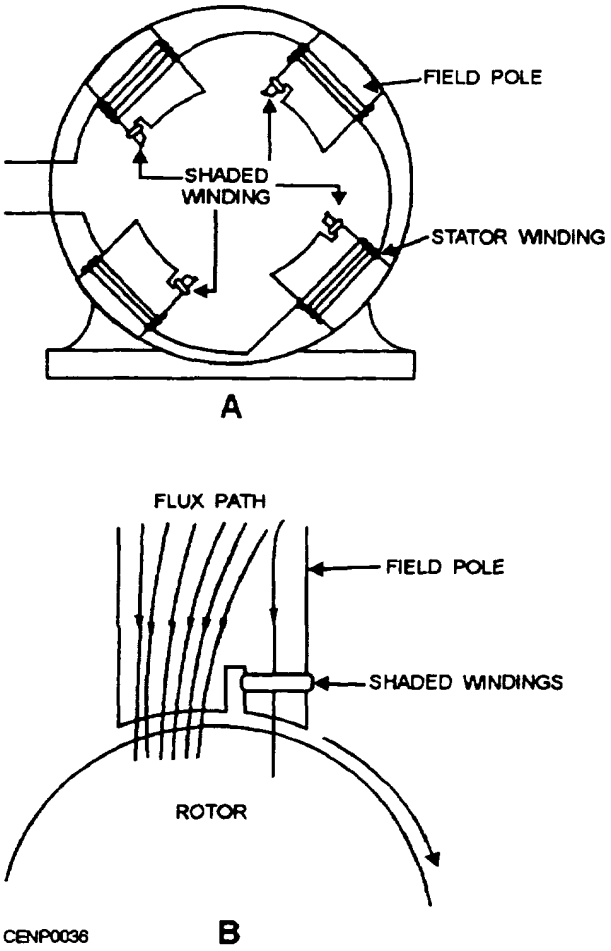


Figure 7-36.—Shaded-pole stator.

SPEED CONTROL OF SHADED POLE MOTORS

Many fans have a shaded-pole type motor. The speed of these motors is varied by inserting a choke coil in series with the main winding. Taps on the choke coil provide the different speeds.

SPEED CONTROL OF SPLIT-PHASE AND CAPACITOR MOTORS

Split-phase and capacitor motors are commonly used in floor and wall fans. Two-speed, split-phase, motors are normally made with two run windings and either one or two start windings, depending on the manufacturer. In a three-speed, split-phase motor, the speeds are obtained with only three windings: one running, one auxiliary, and one starting winding. For high speed, the running winding is connected across the line, and the starting winding is connected in series with the auxiliary winding across the line. For medium speed, the running winding is connected in series with half the auxiliary winding, and the starting winding is connected in series with the other half of the auxiliary winding. For low speed, the running and auxiliary windings are in series across the line, and the starting winding is connected across the line. Actually, a tap at the inside point of the auxiliary is brought out for medium speed. A centrifugal switch is connected in series with the starting winding.

The capacitor motor used for two-speed floor fans is a permanent-split capacitor motor. This motor does not use a centrifugal switch. For three speeds, the auxiliary winding is tapped at the center point, and a lead is brought out for medium speed. This motor is similar to the three-speed, split-phase motor, except that the centrifugal switch is removed and a capacitor substituted. This motor is used extensively for blowers in air-conditioning systems.

Split-phase motors used on wall fans are wound like the ordinary split-phase motor, but many do not have a centrifugal switch. A special type of autotransformer, located in the base of the fan, is used to change the speed and also to produce an out-of-phase current in the starting winding. The primary of the transformer is

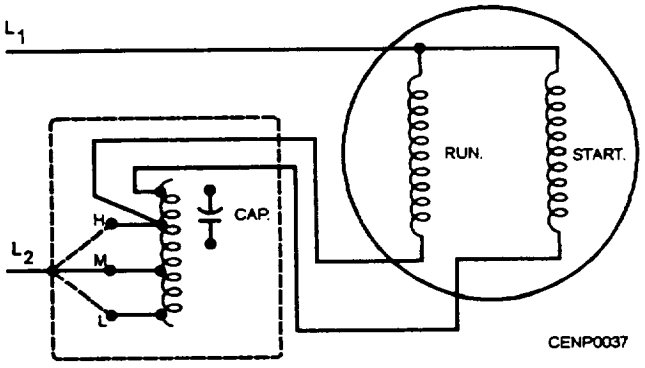


Figure 7-37.—Capacitor motor used for a wall fan.

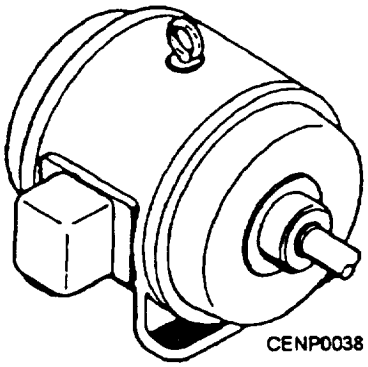


Figure 7-38.—Three-phase motor.

tapped for different speeds and is connected in series with the main winding. The starting winding is connected across the transformer secondary.

Acapacitor motor for a wall fan (fig. 7-37) contains a capacitor of approximately 1 microfarad (µf) in the starting-winding circuit. To increase the effective capacity and consequently the starting torque of this motor, connect the capacitor. across an autotransformer. The taps on the transformer permit a choice of various speeds.

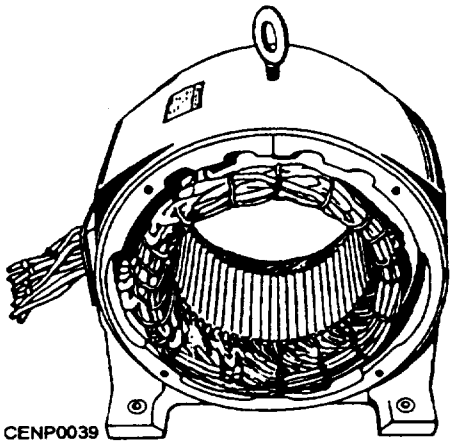


Figure 7-39.—Three-phase stator.

SPEED CONTROL OF UNIVERSAL FAN MOTORS

The universal fan motor has a resistance unit in the base to vary the speed. A lever that extends outside the base is used to insert the resistance in the circuit.

CONSTRUCTION OF THREE-PHASE MOTORS

Construction of a three-phase motor consists of three main parts: stator, rotor, and end bells. Its construction is similar to a split-phase motor, but the three-phase motor has no centrifugal switch (fig. 7-38).

STATOR

The stator, as shown in figure 7-39, consists of a frame and a laminated steel core, like that used in split-phase and repulsion motors, and a winding formed of individual coils, placed in slots.

ROTOR

The rotor may be a die-cast aluminum squirrel-cage type or a wound type. Both types contain a laminated core pressed onto a shaft. The squirrel-cage rotor (fig. 7-40) is like the rotor of a split-phase motor. The wound

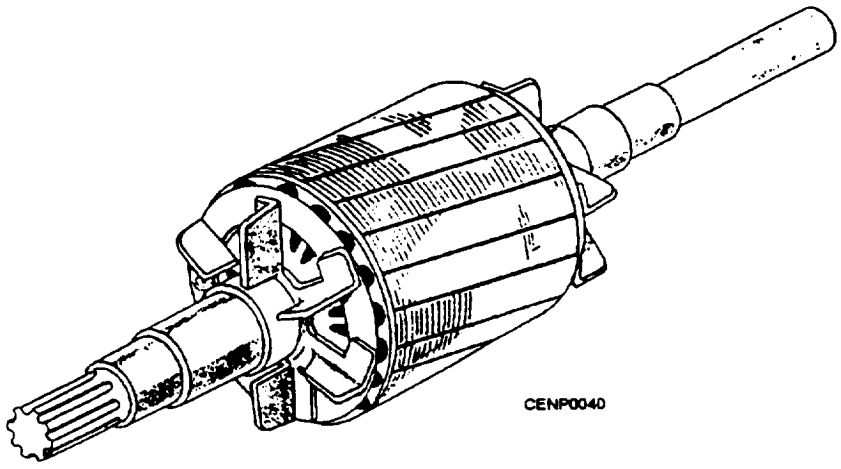


Figure 7-40.—Squirrel-cage rotor.

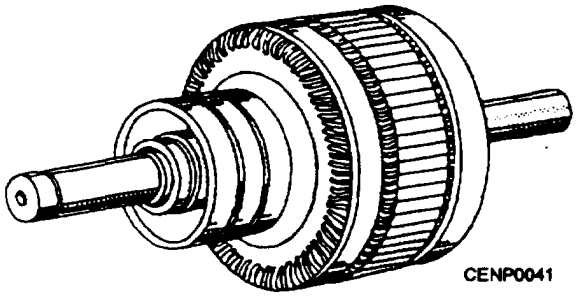


Figure 7-41.—Three-phase wound rotor.

rotor (fig. 7-41) has a winding on the core that is connected to three slip rings mounted on the shaft.

END BELLS

The end bells, or brackets, are bolted to each end of the stator frame and contain the bearings in which the shaft revolves. Either ball bearings or sleeve bearings are used for this purpose.

CONNECTING THREE-PHASE MOTORS

Connecting a three-phase motor is a simple operation. All three-phase motors are wound with a number of coils, with a 2-to-1 ratio of slots to coils. These coils are connected to produce three separate windings called phases, and each must have the same number of coils. The number of coils in each phase must be one-third the total number of coils in the stator. Therefore, if a three-phase motor has 36 coils, each phase will have 12 coils. These phases are usually called Phase A, Phase B, and Phase C. All three-phase motors have their phases arranged in either a wye connection or a delta connection.

WYE CONNECTION

A wye-connected three-phase motor is one in which the ends of each phase are joined together paralleling the windings. The beginning of each phase is connected to the line. Figure 7-42 shows the wye connection.

DELTA CONNECTION

A delta connection is one in which the end of each phase is connected in series with the next phase. Figure 7-43 shows the end of Phase A connected to the beginning of Phase B. The end of Phase B is connected to the beginning of Phase C, and the end of Phase C is connected to the beginning of Phase A. At each connection, a wire is brought out to the line.

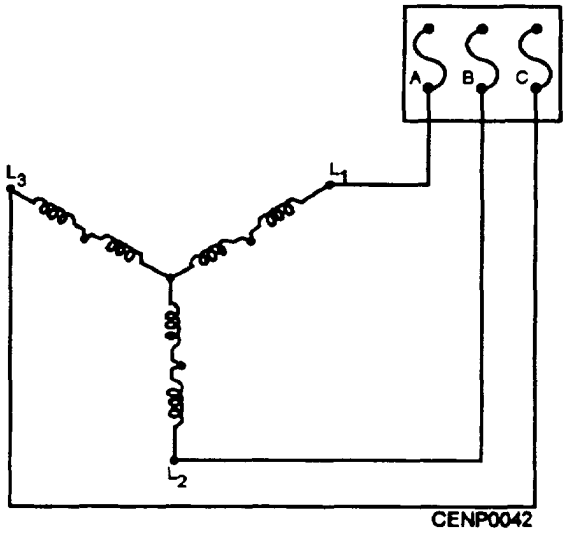


Figure 7-42.—Star, or wye, connection.

VOLTAGES

Most small- and medium-sized three-phase motors are made so that they can be connected for two voltages. The purpose in making dual-voltage motors is to enable the same motor to be used in facilities with different service voltages. Figure 7-44 shows four coils which, if connected in series, may be used on a 460-volt ac power

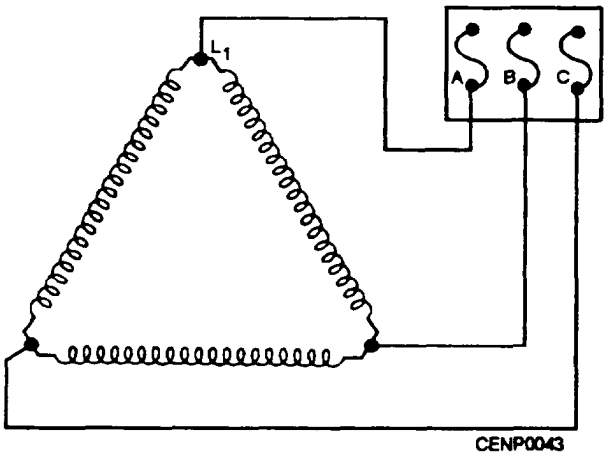


Figure 7-43.—Delta connection.

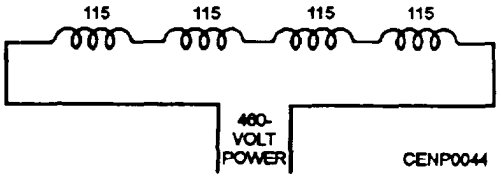


Figure 7-44.—Four 115-volt coil connected in series to produce 460 volts.

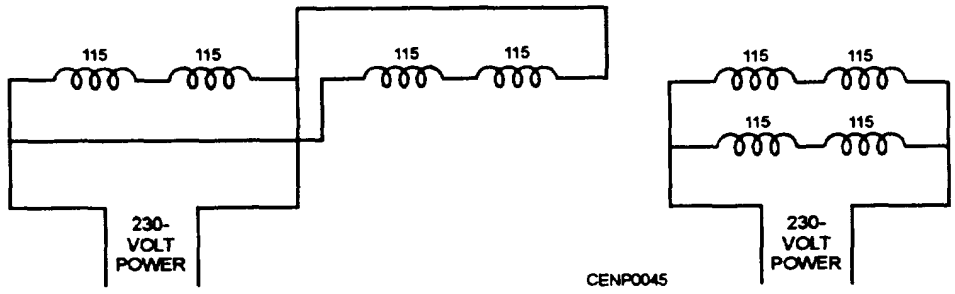


Figure 7-45.—Four 115-volt coil connected in parallel for 230 volts; each coil still receives only 115 volts.

supply. Each coil receives 115 volts. If the four coils were connected in two parallel sets of coils to a 230-volt line, as shown in figure 7-45, each coil would still receive 115 volts. So, regardless of the line voltage, the coil voltage is the same. This is the principle used in all dual-voltage machines. Therefore, if four leads are brought out of a single-phase motor designed for 460/230 or 230/115-volt operation, the motor can be readily connected for either voltage.

Dual-Voltage Wye Motor

When you are connecting a dual-voltage wye motor, remember practically all three-phase dual-voltage motors have nine leads brought out of the motor from the winding. These are marked TI through T9, so that they may be connected externally for either of the two voltages. These are standard terminal markings and are shown in figure 7-46 for wye-connected motors.

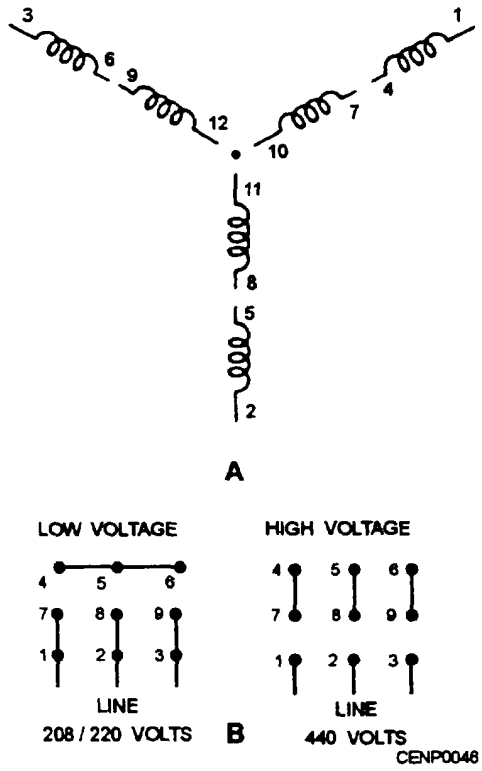


Figure 7-46.—Terminal markings and connection for a wye-connected dual-voltage motor.

HIGH VOLTAGE.—to connect for high voltage, you should connect groups in series, as shown in figure 7-47. Use the following procedure:

1. Connect T6 and T9; twist and wire nut.
2. Connect leads T4 and T7; twist and wire nut.
3. Connect T5 and T8; twist and wire nut.
4. Connect leads TI, T2, and T3 to the three-phase line.

LOW VOLTAGE.—This same motor can be connected for low voltage. Use the following procedure:

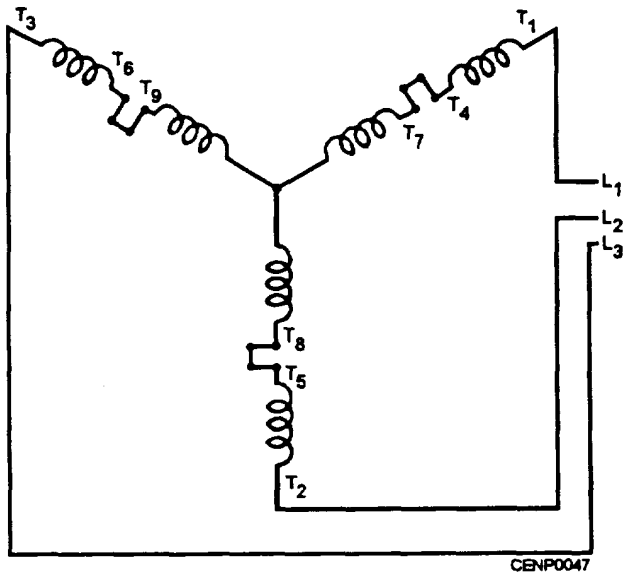


Figure 7-47.—Two-voltage wye motor windings connected in serifs for high-voltage operations.

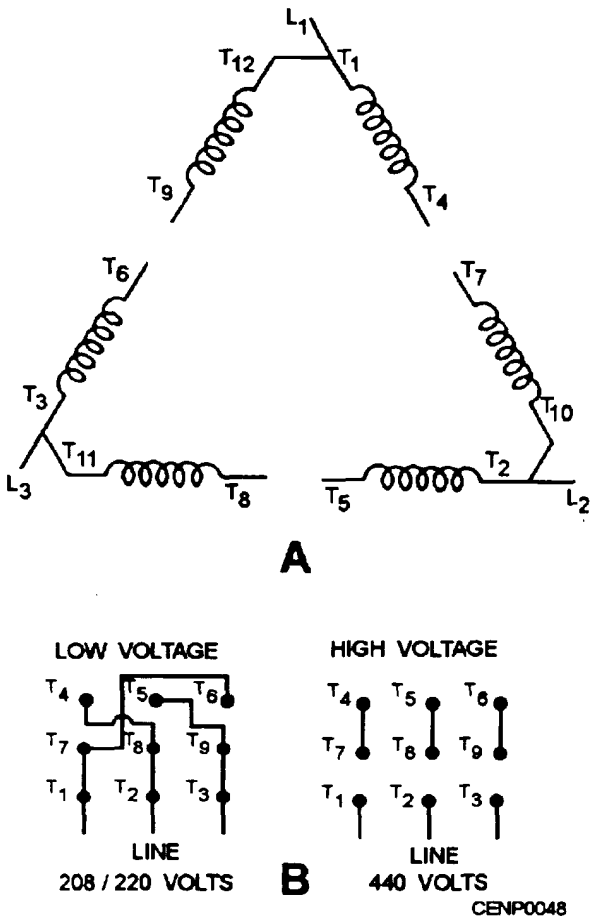


Figure 7-48.—Standard markings and connections for a delta-connected dual-voltage motor.

1. Connect lead T7 to TI and to line lead LI.
2. Connect lead T8 to T2 and to line lead L2.
3. Connect lead T3 to T9 and line lead L3.
4. Connect T4, T5. and T6 together.

Dual-Voltage Delta Motor

For connecting a dual-voltage delta motor, refer to figure 7-48 for the standard terminal markings of a dual-voltage, delta-connected motor

HIGH VOLTAGE.—For high-voltage operation, connect lead T4 to T7; connect lead T5 to T8; connect lead T6 to T9; connect T1, T2, and T3 to LI, L2, and L3, respectively.

LOW VOLTAGE.—For low-voltage operation, connect leads Tl, T7, and T6 to the line lead LI. Connect leads T2, T4, and T8 to line lead L2. Connect leads T3, T5, and T9 to line lead L3.

Reversing Three-Phase Motors

For reversing three-phase motors, figure 7-49 shows the three leads of a three-phase motor connected to a three-phase power line for clockwise rotation. To reverse any three-phase motor, interchange any two of the power leads.

AC MOTOR CONTROLLERS

This section covers common electric controllers. The term controller includes any switch or device normally used to start or stop a motor.

Controllers are classified as either manual or magnetic. The manual controller uses a toggle mechanism, moved by hand, to open or close the circuit. It may be a switch, a disconnect, or even an attachment plug. Magnetic controllers use a magnetic coil to move the mechanism which opens or closes the circuit. Magnetic controllers are operated manually by pressure on a button or automatically by a pressure switch or a similar device. The controller must be within sight of the motor, unless the disconnect device or the controller can be locked in the open position, or the branch circuit can serve as a controller. A distance of more than 50 feet is considered equivalent to “out of sight.”

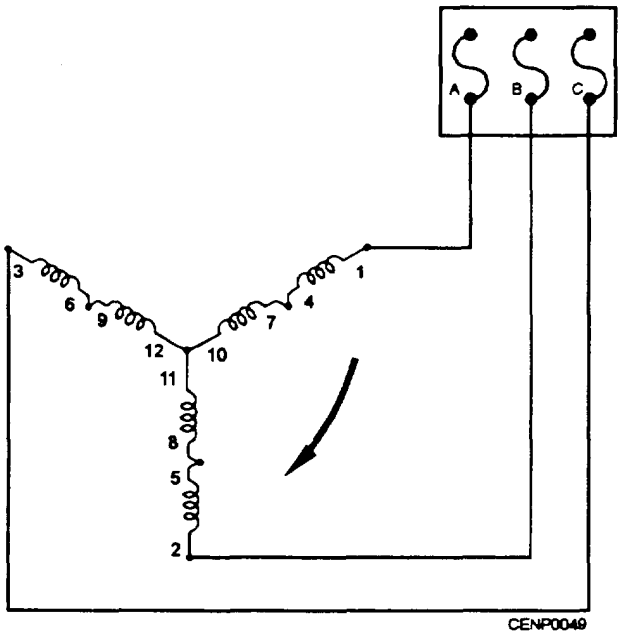


Figure 7-49.—Wye-connected motor to three-phase power for clockwise rotation.

CONTROLLER CAPABILITIES

Each controller must be capable of starting and stopping the motor which it controls and, for an alternating-current motor, it must be capable of interrupting the stalled-rotor current of the motor.

Horsepower Ratings

The controller must have a horsepower rating not lower than the horsepower rating of the motor. Exceptions are indicated below.

- For a stationary motor rated at 1/8 horsepower or less, normally left running and so constructed that it cannot be damaged by overload or failure to start (such as clock motors), the branch-circuit overcurrent device may serve as the controller.

- For a stationary motor rated at 2 horsepower or less and 300 volts or less, the controller may be a general-use switch with an ampere rating of at least twice the full-load current rating of the motor.

- For a portable motor rated at 1/3 horsepower or less, the controller may be an attachment plug connector and receptacle.

- A branch-circuit circuit breaker, rated in amperes only, may be used as a controller. Branch-circuit conductors must have an amperage capacity (ampacity) not less than 125 percent of the motor full-load current rating.

Single Controller Serving a Group of Motors

Each motor must have an individual controller, except for motors of 600 volts or less; a single controller can serve a group of motors under any one of the following conditions:

- A number of motors drive several parts of a single machine or piece of apparatus, such as a metal and woodworking machine, crane, hoist, and similar apparatus.

- A group of motors is under the protection of one overcurrent device.

- A group of motors is located in a single room within sight of the controller location.

Conductors supplying two or more motors must have an ampacity equal to the sum of the full-load current rating of all motors plus 25 percent of the highest rated motor in the group.

CONTROLLER MARKINGS

Controllers are marked with the maker's name or identification, the voltage, the current or horsepower rating, and other data as may be needed to properly indicate the motors for which it is suitable. A controller that includes motor running overcurrent protection or is suitable for group motor application is marked with the motor running overcurrent protection and the maximum branch-circuit overcurrent protection for such applications. Be extremely careful about installing unmarked controllers into any circuit. Controllers should be properly marked.

CONTROLLER CIRCUITRY

Before you condemn a motor, make sure that the fault does not lie within the controller. The only way to be sure the fault is not in the controller is to understand the circuitry of the controller. As previously mentioned, there are two general types of motor controllers: manual and magnetic.

Manual Controllers

Manual controllers (motor starters) are available up to 7 1/2 horsepower at 600 volts (three-phase) and to 3 horsepower at 220 volts (single-phase).

TOGGLE SWITCHES OR CIRCUIT BREAKERS.—A toggle switch or circuit breaker can serve as a controller, provided its ampere rating is at least twice the full-load current rating of the motor and the motor rating is 2 horsepower or less. It must be connected in a branch circuit with an overcurrent device that opens all ungrounded conductors to the switch or circuit breaker. These switches or circuit breakers may be air-brake devices operable directly by applying the hand to a lever or handle. An oil switch can be used on a circuit with a rating which does not exceed 600 volts or 100 amperes, or on a circuit exceeding this capacity, under expert supervision and by permission. A single-phase motor requires a one-element overload device,

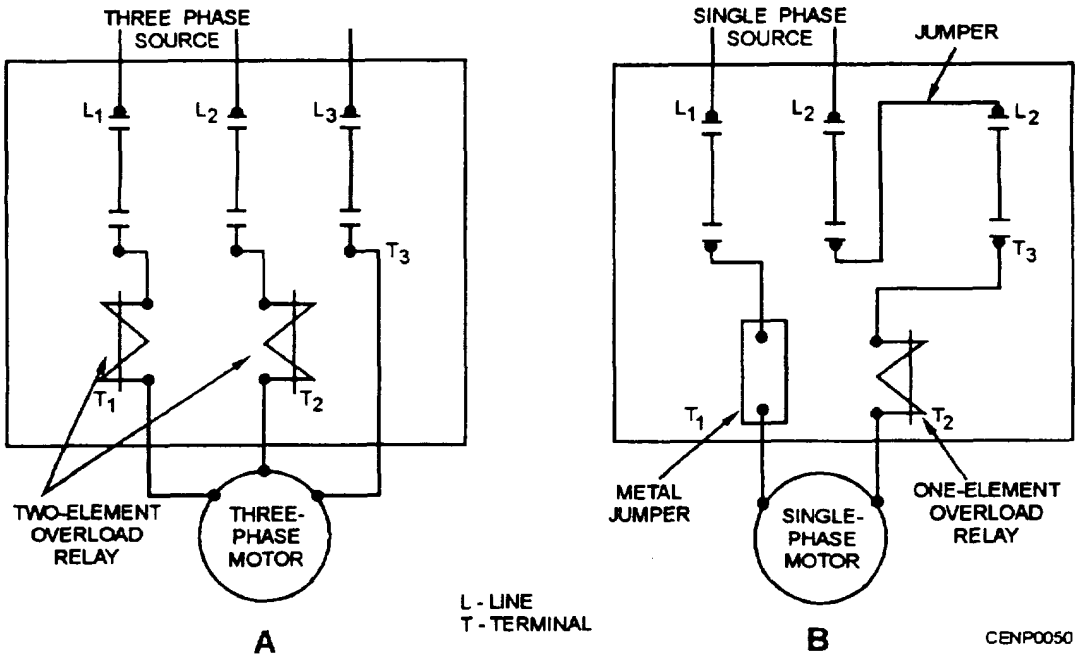


Figure 7-50.—Across-the-line manual controller.

while a polyphase motor requires a two-element overload device (fig. 7-50).

DISCONNECTS.—Disconnects may be used as controllers on motors rated up to 3 horsepower at 220 volts. They must be located within sight of the motor or be able to lock in the open position. A distance of more than 50 feet is considered "out of sight." Double-throw disconnects may be used for reversing three-phase motors if they conform to these requirements.

DRUM CONTROL.—The drum control is a lever-operated, three-position switch. The center position is usually the OFF position with the right and left positions FORWARD and REVERSE, respectively. Normally, it is used to direct the rotation of a three-phase motor. Oil-immersed drum switches are used wherever the air can become charged with corrosive gases or highly flammable dust or lint.

Magnetic Full-Voltage Starters

Magnetic starters are made to handle motors from 2 to 50 horsepower. They can be controlled by a start-stop station located locally or remotely. The starter has two different circuits: the control circuit and the load circuit.

CONTROL CIRCUIT.—The control circuit receives its power from the incoming leads to the starter. It is a series circuit (fig. 7-51) going through the start-stop station, the magnetic coil, the overload contacts, and returning to another phase. However, it may return to the ground, depending on the voltage rating of the coil.

LOAD CIRCUIT.—The current flowing through the coil activates a mechanical lever and closes the main line contacts. This closing develops the load circuit and applies power to the motor. The fourth set of contacts provides a shunt around the start button, known as the holding circuit.

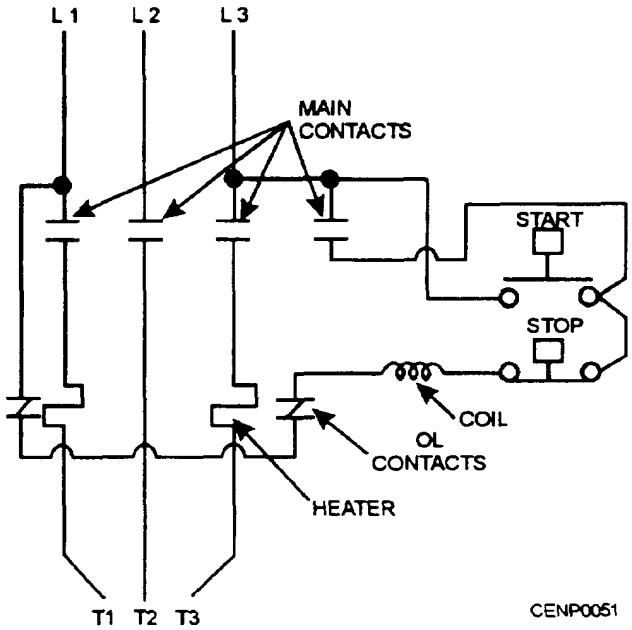


Figure 7-51.—Magnetic starter circuit.

STARTER COIL.—The coil of the starter may be de-energized in three ways. The stop button is pressed, one of the overload contacts opens, or the line voltage drops low enough to allow the coil to release. If one of these things happens, the main contacts are separated by spring pressure, removing power to the motor.

The overload contacts are opened by excess current flowing through the heater, located in the power circuit (fig. 7-51). The size of the heaters to be installed is determined by the full-load current draw to the motor. Magnetic starters are manufactured by many different companies. Information for the proper size of heater is given on the cover of the starter.

HEATERS AND HORSEPOWER.—Listed in table 7-4 is a typical horsepower and heater table for motors of different size and voltage. To determine the

Table 7-4.—Horsepower rating and heater table

Direct-Current Motors			Single-Phase AC Motors		Three-Phase AC Motors		
HP	120V	240V	115V	230V	115V	230V	460V
1/4	2.9	1.5	5.8	2.9			
1/3	3.6	1.8	7.2	3.6			
1/2	5.2	2.6	9.8	4.9	4	2	1
3/4	7.4	3.7	13.8	6.9	5.6	2.8	1.4
1	9.4	4.7	16	8	7.2	3.6	1.8
1 1/2	13.2	6.6	20	10	10.4	5.2	2.6
2	17	8.5	24	12	13.6	6.8	3.4
3	25	12.2	34	17		9.6	4.8
5	40	20	56	28		15.2	7.6
7 1/2	58	29	80	40		22	11
10	76	38	100	50		28	14

A

Heater Cat No	Trip Amps	Full Load Motor Amps Min. Max.	Max Fuse Size	Heater Cat No	Trip Amps	Full Load Motor Amps Min. Max	Max Fuse Size
42013	7.2	5.76 - 6,53	20	42022	22.4	17.9 - 19.4	80
42014	8.4	6.72 - 7.59	25	42225	25.0	20.0 - 21.8	100
42015	9.6	7.7 - 8.4	35	42226	28.0	22.4 - 24.4	100
42016	10.9	8.7 - 9.5	35	42227	32.6	26.0 - 28.3	125
42017	12.6	10.1 - 11.0	40	42228	36.3	29.0 - 31.6	125
42018	13.7	11.0 - 11.5	45	42229	42.0	33.5 - 36.5	150
42019	14.5	11.6 - 12.6	50	42230	48.0	38.4 - 41.5	150
42020	15.8	12.6 - 13.7	50	42231	52.0	41.6 - 45.2	172
42021	18.3	14.6 - 15.9	60	42232	57.0	45.5 - 49.0	200
42224	20.0	16.0 - 17.6	70	42233	60.5	49.0 - 52.5	200

B

heater number, we must know the horsepower and voltage and if the motor is single or three-phase. Once we have that information, we look at table 7-4, view A, and find the full-load motor amperage. Using the chart from table 7-4, view B, we can find the heater number for this motor. For example, we want to know the number of a heater for a 5-horsepower, 230-volt ac, single-phase motor. Checking table 7-4, view A, we find that the motor draws 28 amps. Referring to table 7-4, view B, we find heater number 42227 has an amperage range from 26.0 to 28.3. This is the heater we should use. Also in the table you will find the maximum fuse size and the amperage at which the heater will open the control circuit. Remember that each manufacturer has its own heater table to be used with its across-the-line starters.

HEATER TROUBLESHOOTING.—A heater must be manually reset at the motor starter. If the magnetic starter fails to energize, the trouble is within the control circuit. However, if the coil should energize but the motor fails to run, the trouble must be within the load circuit or motor. The load circuit can be checked at terminals TI, T2, and T3. If the proper voltage requirements is there, the trouble is most likely in the motor.

Push-Button Stations

An example of a push-button station with overload protection is shown in figure 7-52. In this case, the controller is connected to a 208-volt single-phase motor. This controller is a single-phase, double-contact device which connects or disconnects both undergrounded conductors to the motor. It has a start and stop button that mechanically opens or closes the contacts. Pressing the start button closes both contacts, and pressing the stop button opens both contacts. The control has two overload devices connected in series with the contacts. If an overload condition occurs, either overload device will open both sets of contacts. A typical application of this type control would be to control small machine tools.

Full-Voltage Reversing Starters

Reversing magnetic controllers use two magnetic across-the-line starters whose power leads are electrically interconnected to reverse two of the three phases. The two motor starters are generally contained in one box and are mechanically interlocked so that one cannot close without the other opening. They are sometimes also electrically interlocked to help prevent closing both starters at the same time.

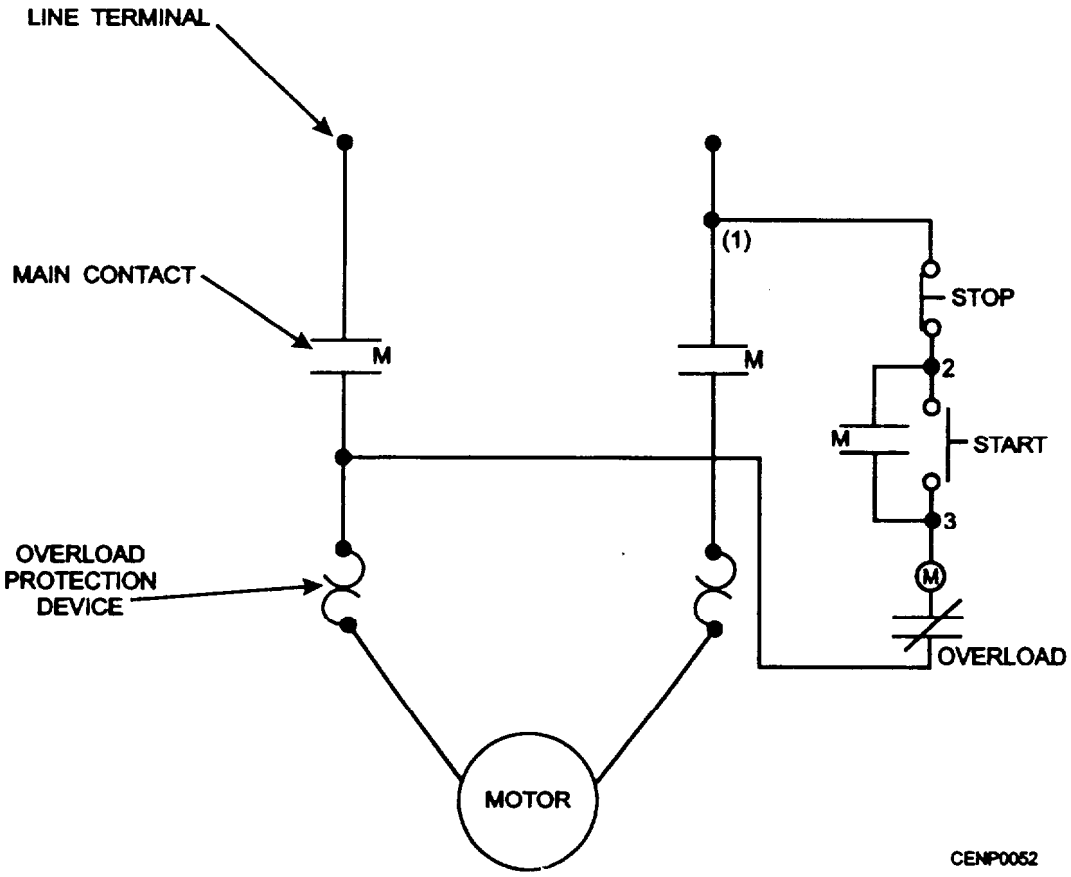


Figure 7-52.—Schematic for a single-phase manual controller with overload protection.

Reduced-Voltage Starters

Reduced-voltage starters are generally used for motors rated above 50 horsepower. Reduced-voltage starters are designed to reduce the current draw of the motor during the starting period only. They use either an autotransformer or resistor, both using the same basic principles.

Figure 7-53 is a schematic drawing of an autotransformer reduced-voltage starter. The autotransformer starter provides greater starting torque per ampere of starting current drawn from the line than any other reduced-voltage motor starter. But this type of starter is not always desirable, because, with the changing of the S and R relays, the motor is without power for a short time. Therefore, a resistance-reduced-voltage starter may be used. Resistance starters are sometimes applied where the circuit should not be opened during the transition from reduced to full voltage. They are particularly desirable when sudden mechanical shock to the driven load must be avoided.

Figure 7-54 shows a typical resistance-reduced-voltage starter. Pressing the start button energizes the S relay. The S contacts close, connecting power through the resistors to the motor. Voltage is dropped across the resistors, lowering the voltage to the motor. After a period of time, the T contact closes, energizing the R relay. The R relay contacts close, shunting around the resistors, to apply full voltage to the motor. The contact device may be a time delay relay or even a centrifugal switch, operated from the speed of the motor. Protective devices used in reduced-voltage starters are determined in the same way as we previously described.

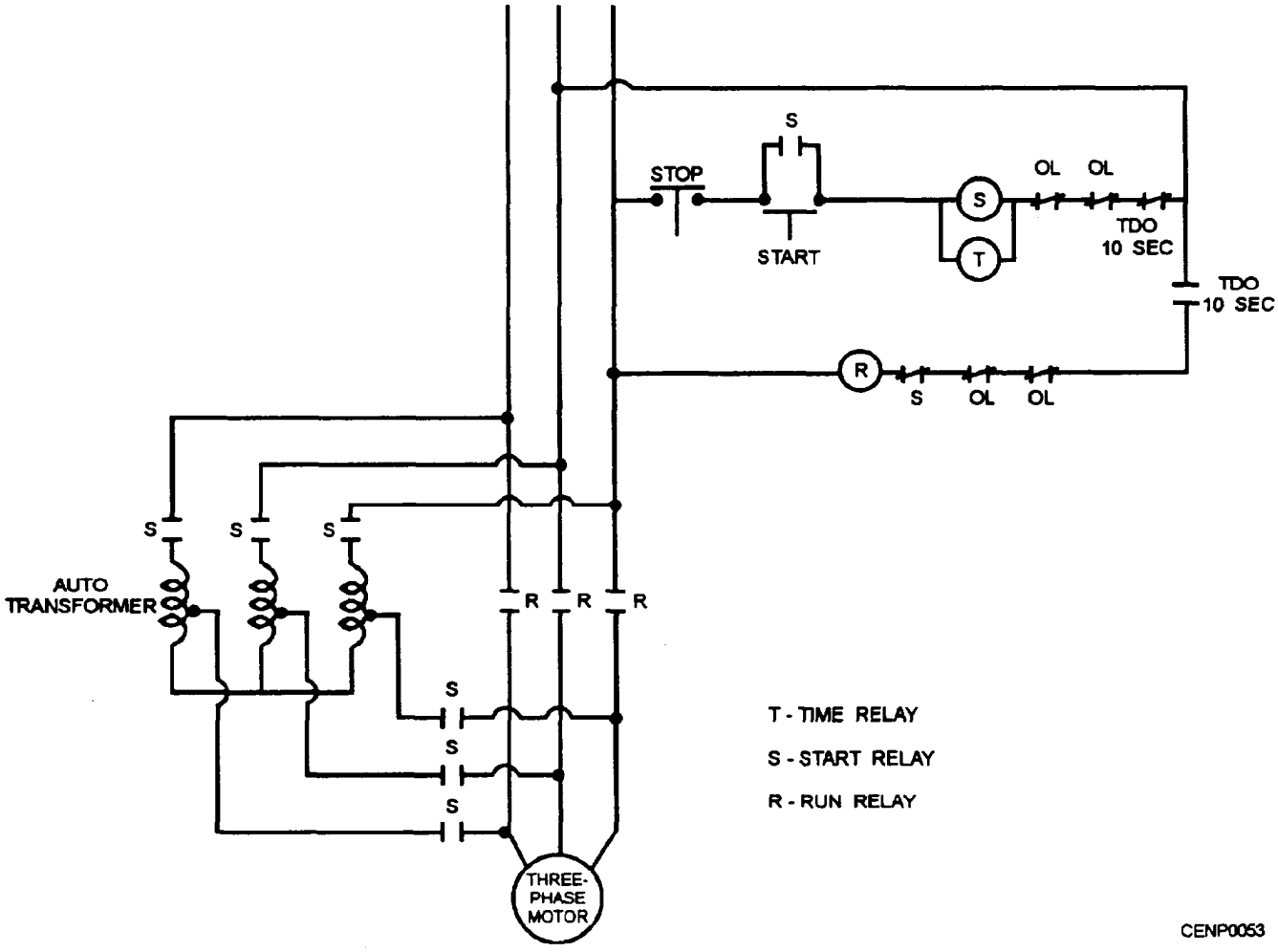


Figure 7-53.—Autotransfromer reduced-voltage starter.

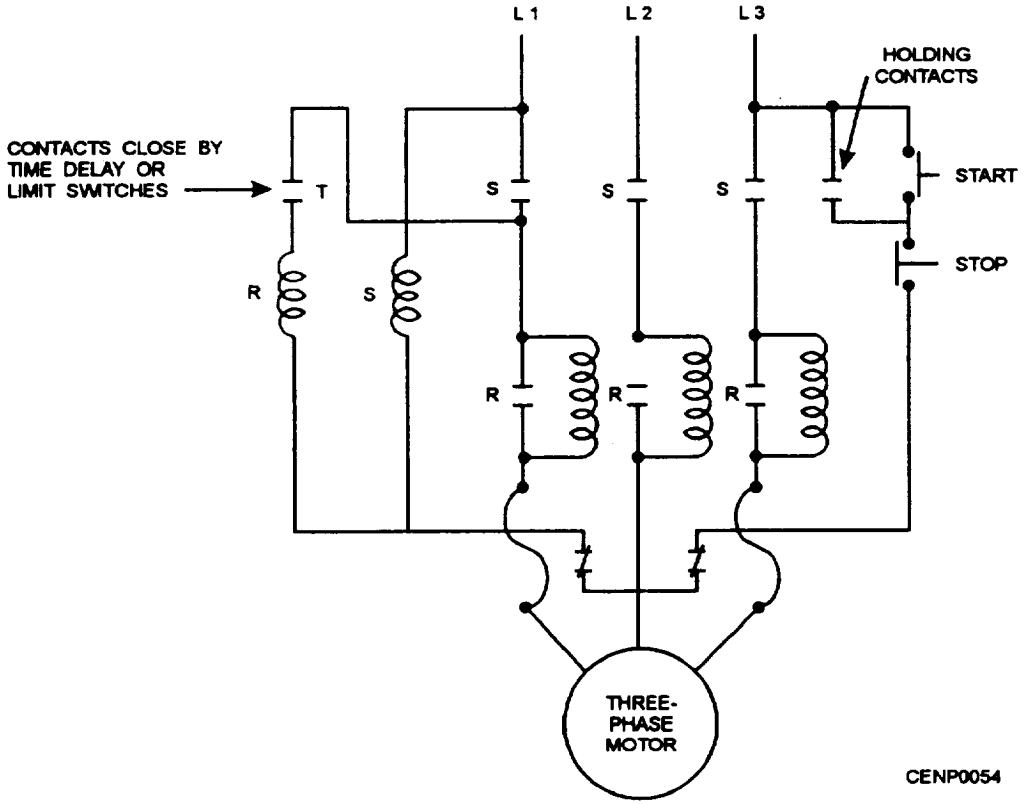


Figure 7-54.—Resistance reduced-voltage starter.

Part-Winding Starters

Part-winding starters use two magnetic starters and operate like a resistance start controller. Figure 7-55 is a schematic drawing of a wye-connected, three-phase motor. The control circuits for the S and R relays are the same as for a resistance reduced-voltage starter, and so they are not shown. The S relay is energized first, connecting voltage to only part of the winding. The motor starts to run but develops little torque. At a predetermined time, the R relay closes. This action parallels the windings in the motor, reducing their resistance and causing increased current flow and more torque.

MOTOR MAINTENANCE, TESTING, AND REPAIR

An electric motor must be checked, maintained, and repaired just like any other piece of mechanical equipment. With proper servicing, a motor will last longer and give more efficient service. Included in maintenance services are cleaning, lubrication, ventilation, and testing.

Cleaning

Inspect motors internally and externally for foreign materials, such as dust, dirt, corrosion, and paint. Open-frame motors may be blown out with compressed air. You should not apply too many coats of paint to motors. A thick coat of paint will interfere with heat dissipation.

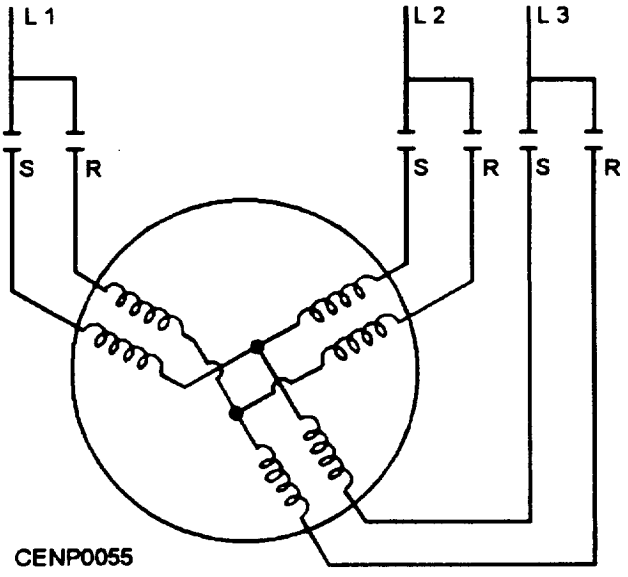


Figure 7-55.—Part-winding starter.

CAUTION

Air pressure used for cleaning should not exceed 25 psi nozzle pressure. Excessive pressure can damage the insulation on the windings.

Wipe all excess dirt, grease, and oil from the surfaces of a motor with a cloth moistened with an approved solvent.

WARNING

Do not use flammable or toxic solvents when cleaning motors. Solvents may cause injury to personnel or damage to equipment.

Lubrication

Lubrication should be done according to the manufacturer's instructions. Improper lubrication causes motor bearings to overheat and eventually causes bearing failure. Check a motor for signs of grease and oil-seal failure. If an inside seal fails, the lubricant can get into the motor windings and deteriorate the insulation. This condition also allows dust to adhere to the windings and restricts air circulation, then the motor windings heat and burn out. Inadequate lubrication causes the bearings to wear excessively and, eventually, to seize. When lubricating a motor, refer to the manufacturer's manual to determine the correct type of lubricant to use. Some motors have bearings lubricated with oil, while others require grease. Many motor bearings are lubricated and sealed at the factory and usually last the life of the bearing.

Ventilation

Check the running temperature of all motors. If the motor temperature is hotter than specified on the nameplate, you must find the problem. The normal procedure for diagnosing motor overheats is to check the motor for restricted ventilation. Inspect the area around the motor for any obstructions which could hamper free air circulation. If air circulation is not hampered in any way and the motor continues to run hot, reduce the load on the motor or use a motor with more power capability.

Testing

The proper testing of a motor should be done in a logical sequence. Proper testing can prevent unnecessary labor and parts. Testing motors is generally classed under two major methods: visual tests and operational tests.

VISUAL TESTS.—A visual test can discover a great deal about the condition of a motor and the possible causes of trouble. Read the nameplate data and be sure that the motor connections are correct for the supplied voltage.

Look at the windings to see if the insulation has overheated (or has been overheating). You can tell when the insulation is burned by the odor within the motor. If you aren't sure of the condition of the windings, test them with a megger to determine if the windings have been damaged beyond use. Connect the leads of the megger to each set of windings.

CAUTION

Disconnect the motor leads from each other to ensure reading only one winding at a time.

If the winding is good, you will get a reading of continuity. If the winding indicates a large amount of resistance, it is damaged and must be replaced.

Now connect one lead from the megger to the frame of the motor. Connect the *other* lead of the megger to each lead of the motor, one at a time. A low-resistance reading means insulation breakdown or a short to the motor frame, and replacement of the winding is necessary.

Inspect the commutator for solder thrown from the risers, and for loose, burned, high, and flat bars. Also test for high mica. Notice the surface film on both the commutators and slip rings and the general condition of the brushes. Check the air gap on large motors for any indication of bearing wear or misalignment. For large motors, take an air gap measurement at one reference point on the rotor or armature; then rotate the rotor or armature and measure four points on the stator or field frame to the same reference point. The air gap measurement should be within plus or minus 5 percent at any of these points.

Check the condition and operation of the starting rheostat in dc motors and the starting and control equipment used with ac motors. Also check the terminal connections on all of the control equipment to ensure they are correct and secure. Make sure the proper voltage is at the terminal lead of the motor.

If the visual tests have not revealed the trouble, you should perform some operational tests on the motor.

OPERATIONAL TESTS.—Perform a heat run test, observing the manufacturer's recommendations for that particular motor.

CAUTION

Do not attempt to operate a series dc motor without a load.

If the temperature of the motor in normal operation does not exceed the maximum recommended by the manufacturer, the motor is operating satisfactorily. Always refer to the manufacturer's manual for definite specifications for the motor you are inspecting.

WARNING

Be sure the master switch is in the off position before connecting or disconnecting any motor lead connections.

Because of their effect on insulating materials, high temperatures shorten the operating life of electric motors. When the windings or the bearings of a motor, not specifically designed for high temperature service, get hotter than 90 degrees centigrade, investigate the operating conditions and relieve the temperature conditions by cooling or relocating the motor. A gradually rising temperature in a motor warrants a shutdown and thorough examination of the unit. The nameplate on the motor usually specifies its normal running temperature in degrees centigrade. Check the current draw of the motor against the data on the nameplate. Excess current causes heating and, in time, will destroy the windings.

Check the motor for proper speed. A speed above or below that indicated on the nameplate signifies a malfunction in the unit. When a motor's operation is sluggish, check the line voltage to the motor. If you find the voltage low, apply the proper value and continue checking to determine if the motor is overloaded. If it is, reduce the load or replace the motor with one of a larger horsepower. There are other conditions which could make motor operation sluggish. You may find that the brushes have shifted off NEUTRAL, and you must reset them. You may also find that the armature or rotor is dragging on the stator or field poles. To correct this situation, you may need new bearings. Afield pole may be loose, causing it to drag on the armature or rotor.

Other conditions which could cause a motor to be sluggish are shorted field-winding circuits, shorted armature windings, and surface leaks across the commutator segments. After finding the fault in the motor, you may have to replace it. When you replace it, be sure to install a motor of the same size.

CAUTION

Be sure to de-energize the motor circuit before disconnecting the unit.

While the motor is running, look for any sparking at the brushes. Many faulty conditions contribute to sparking brushes at the commutator. The two major causes are a faulty armature and malfunctioning brushes. Some of the faults that could develop in an armature include the following: rough commutators, bent armature shafts, and short circuits in the armature windings. Brushes may malfunction because they are off NEUTRAL, they bind in the brush holders, they are wound beyond recommended limits, or they intermittently fail to contact the commutator because of insufficient brush spring tension. Whenever a motor is arcing at the brushes, it is advisable to disassemble it, locate the problem, and make the necessary repairs,

There are many causes of motor noise. Listen and feel for any unusual noises. You should first check the motor-mounting bolts for looseness and the alignment of the motor with the driven equipment. If the motor is secure and properly aligned, continue your inspection. Check the motor's balance. Also inspect the motor for loose rotor bars or a bent shaft. If any of these conditions exist, you will have to replace the rotor or armature. Sometimes the centrifugal switch rattles or rubs the interior of the motor housing. Align the switch and tighten the mounting bolts. If the switch has excessive wear, replace it. Check all motor accessories for looseness and tighten as needed. Check the drive pulley and the condition of the belts. Loose pulleys rattle and will damage belts. You will hear a distinct slap when the belt has been damaged.

Motor Repair

After you have performed visual and operational tests on a motor and isolated the problem, you may have to disassemble the motor to make the repairs. You should know the procedures and precautions for motor repair.

DISASSEMBLY. —The careless disassembly of a motor can cause serious damage to the delicate components within the motor. Remove and handle all parts with care and always use the proper tools. It is just as important to tag all parts, take down accurate data, and store the parts in an orderly arrangement in a safe

place. Before a motor is disassembled, consider the following:

- The area for disassembly must be clean.
- Tag all leads and the point of connection from where the leads have been removed.
- Wipe all excess dirt, grease, and oil from the exterior surface with an clean cloth moistened with an approved solvent.
- Inspect all leads for burned, cracked, or deteriorated insulation at the point of their entry into the motor.
- Turn the motor shaft by hand to determine whether the armature turns freely. If not, inspect the motor for a bent shaft, misalignment of the end bells, loose or frozen bearings, a loose pole piece, or foreign objects inside the motor.

WARNING

Use gloves or a cloth to protect your hands from the sharp edges of the keyway when turning the shaft.

End Bell Removal.—When you are removing the end bells, remember that on some motors the bearings must be removed before the end bells. To remove the end bells, use the following procedure:

1. Punch mark the frame and end bells for reassembly purposes (fig. 7-56).
2. Remove the end bell fastening screws or bolts.
3. Remove the bearing first, if necessary.
4. Part the end bells from the frame, as shown in figure 7-57.
5. Record and disconnect the leads from the internal mechanism and components.
6. Clean the end bells and frame.
7. Inspect the disassembled parts and replace as needed.

Bearing Removal.—Sometimes you can remove the bearings before removing the end bells. In other cases, the bearings slip off the shafts with the end bells. Frequently, the bearings are press fitted to the shafts and end bells, making their removal difficult. Since bearing removal varies with the different types of motors, only some of the most important procedures and precautions are listed.

- Never remove bearings in good condition from the shafts or end bells unless it is absolutely necessary.
- Remove all bearing attachment screws or bolts before attempting to remove the bearings.
- Remove ball bearings which are to be reused by arbor plates and an arbor press to prevent distortion.
- Remove ball bearings to be discarded with a hook-type puller.

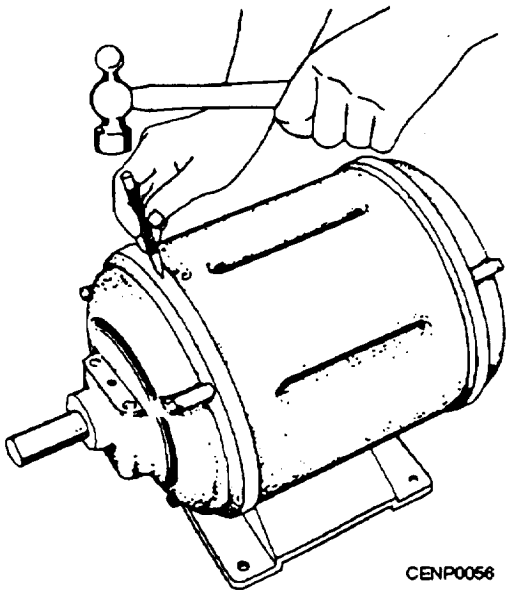


Figure 7-56.—Punch marking motor frame and end belts.

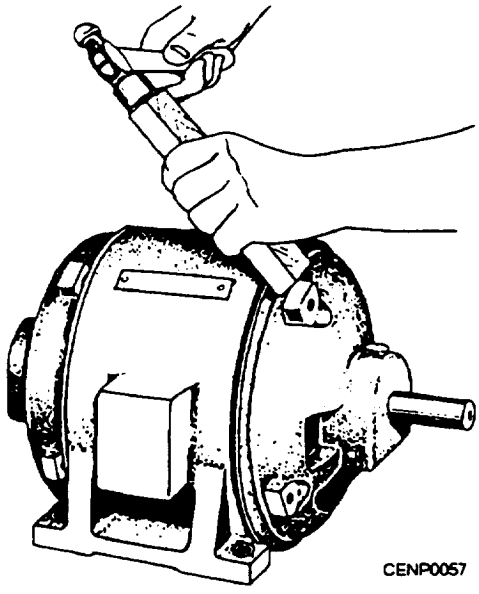


Figure 7-57.—Separating motor frame from end bells.

- Remove sleeve bearings with arbor plates and an arbor press. When an arbor press isn't available, sleeve bearings may be removed with a well-fitted arbor and hammer.
- Sometimes you may be required to remove sleeve bearings by drilling them out with a drill press.
- Handle bearings with clean, dry hands or clean canvas gloves. Handling a bearing with hands that are perspiring can cause corrosion. Fingerprint patterns are sometimes found rusted into bearing surfaces.
- Keep bearings in their packages or in oil-proof paper until they are installed

Brush Removal.—Brush removal is necessary when you are replacing brushes or you need access to parts of the unit otherwise inaccessible. If the brushes are not to be removed, place them in the raised position. Use the following procedure for removing brushes and brush rigging:

1. Record the placement and angle of brush rigging and brushes.

2. Check the brush spring pressure.

3. Remove the screws holding the brush pigtails and rigging.

4. Clean, inspect, and store the brushes and brush rigging.

Centrifugal Switch Removal.—Internal switches of the centrifugal type are usually attached to the inside of end bells. When you are removing the end bells, be careful not to break the switch springs. For removing a centrifugal switch, follow these steps:

1. Note and record the lead connections to the switch.

2. Disconnect the leads.

3. Remove the mounting screws of the stationary part of the switch which is secured to the end bell.

4. Clean and inspect the switch and replace the damaged parts.

5. Tag and store the unit.

Armature and Rotor Removal.—The removal of armatures and rotors from within the frame of the unit requires considerable care to avoid damage to the parts. For removing an armature or rotor, follow these suggestions:

1. Support the armature or rotor only by its shaft when possible.

2. Slide a thin piece of cardboard between the underside of the rotor and stator to protect the laminations and windings during rotor removal.

3. In a shop, a hoist should be used to remove the rotors of large motors.

TESTING COMPONENTS.—After a motor is disassembled, you perform certain tests to determine which components are faulty.

Field Winding.—To locate a grounded field winding, disconnect and separate the internal connections between the windings. With this done, position one lamp prod of a series test lamp to the housing. With the other test lamp prod, touch each winding lead individually. If the test lamp lights, that particular winding is grounded. Test all the windings. You may also perform this test with an ohmmeter. A reading of continuity indicates a short; no reading indicates that the field winding is not grounded.

The test for an open circuit in the field windings of a motor may also be done with a series test lamp. Touch one test lead to one coil terminal and the other lead to the opposite coil terminal. If the test lamp doesn't light, the winding is open. If it does light, an open circuit doesn't exist, and the winding is serviceable.

To test for shorts in the field winding of a motor, you can compare the relative voltage drop in each field winding section with a voltmeter. You should get the same reading for each section. A decrease in voltage drop in a section indicates a short circuit.

Armature Winding.—The first test on an armature winding should be to locate grounded circuits. This test is also performed with a series test lamp. Touch one test prod to the armature core or shaft, as shown in figure 7-58. Using the other test prod, touch each commutator segment. If the armature winding is grounded, the test lamp will light when you apply the lamp prod to the grounded armature winding or commutator segment. Replace the grounded armature when all attempts to remove the ground have failed.

When checking for a shorted armature, place the armature in an armature test set (growler). Lay the test blade lengthwise with the flat side loosely in contact with the armature core, as shown in figure 7-59. Turn the test stand to the ON position and slowly rotate the

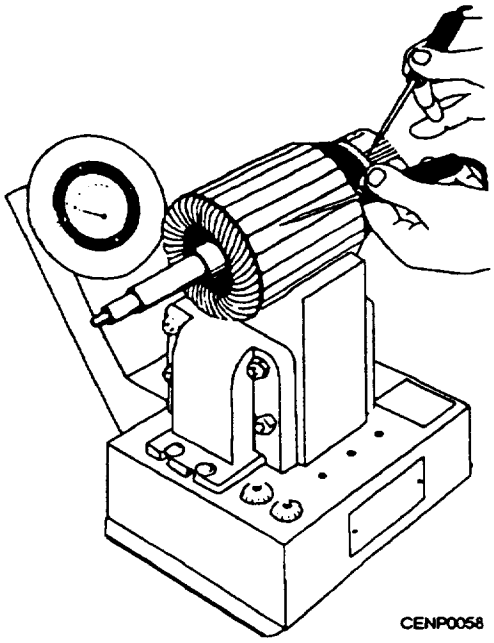


Figure 7-58.—Testing for grounds in armature windings.

armature while you hold the test blade stationary. If there is a short in the armature windings, the test blade will be attracted to the armature (magnetized) and will vibrate.

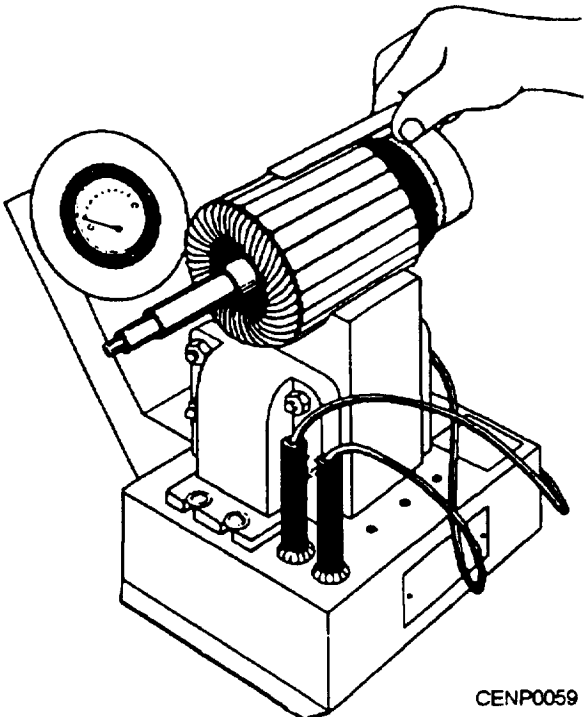


Figure 7-59.—Testing for shorts in armature windings

CAUTION

Place the test set switch in the off position before removing the armature, and never leave the test set turned on unless there is an armature placed in the core.

When you are testing an armature for an open circuit, place the armature in an armature test set and turn the test set ON. Place the armature double prods on two adjoining commutator segments and note the reading on the ammeter, as shown in figure 7-60. Rotate the armature until each pair of adjoining commutator segments have been read. All the segments should read the same. No reading indicates an open circuit, and a high reading indicates a short circuit.

CAUTION

Place the test set switch in the off position before removing the armature from the test stand.

Check the commutator for broken leads. Repair and resolder any you find. If you find an open winding, check the commutator for burned spots. They reveal the commutator segment to which the open winding is connected. Open circuits in the windings generally occur at the commutator and can be found by a visual inspection. If there is excessive sparking at the brushes with the motor reassembled, disassemble it and replace the armature.

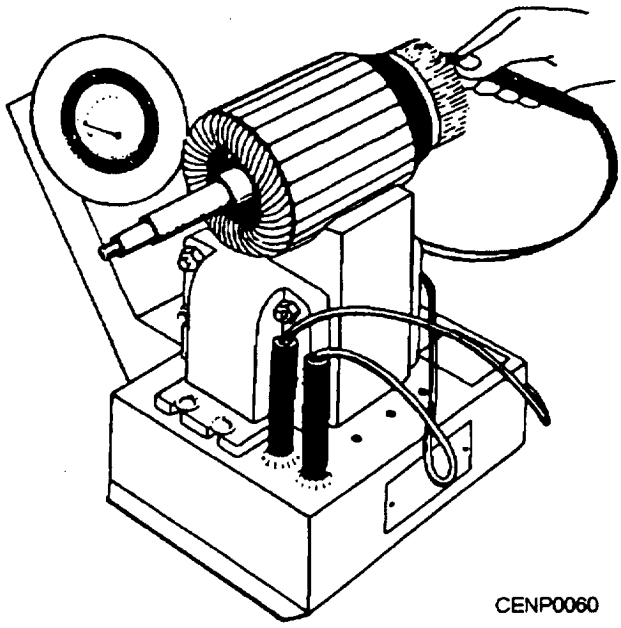


Figure 7-60.—Testing for opens in a commutator.

In testing for a grounded brush holder or rigging, touch one test lamp prod of the armature test set to the motor housing. With the other test prod, touch each brush holder individually. If the lamp lights, there is a ground in the brush holder.

CAUTION

Remove all leads to the brush holders and brushes before you attempt this test.

The color of the commutator and slip rings will indicate the type of trouble. An even chocolate-brown color indicates a normal condition and a black color indicates brush arcing. You can remove slight burns on the commutator segments by polishing the commutator as the armature rotates. Use a canvas pad, as shown in figure 7-61. To remove the deeper burns, use fine sandpaper instead of the canvas pad. When a commutator is deeply scored, it must be reconditioned in a lathe or with a special tool.

CAUTION

Never use emery cloth to polish commutators because the emery particles can lodge between the segments and cause the commutator circuits to short.

Slip rings used on rotors are usually made of bronze or other nonferrous metals. Under normal conditions, the wearing surface should be bright and smooth. When the rings are pitted, they should be polished. When excessively worn and eccentric, they should be trued with a special tool.

REASSEMBLY.—After you have inspected all parts and repaired or replaced the faulty ones, you are ready for reassembly. To assemble motors, follow in reverse order the procedures of their disassembly. Be sure to check any available literature you may find. Be sure to oil or grease the bearings as required. Remove the relief plug in the bottom of the housing while you apply grease.

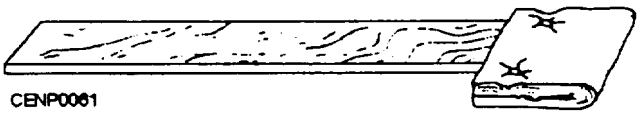


Figure 7-61.—Fabricated cleaning pad.

MOTOR CONTROLLER MAINTENANCE AND REPAIR

The most important rule to remember when you are making repairs or inspecting motor controllers is as follows:

CAUTION

Be sure the controller is disconnected from the power source before touching any of the operating parts.

Control equipment should be inspected and serviced on the same maintenance schedule as motors. Motor starters can normally be repaired on the job site at the time of inspection. After the power has been secured, the first thing you should do to keep controllers operating at maximum efficiency is to keep them free of dirt, dust, grease, and oil, both inside and out. Clean the operating mechanism and contacts with a clean, dry, tintless cloth, or vacuum cleaner. Small and delicate mechanical parts may be cleaned with a small, stiff bristle brush and a Navy-approved solvent.

Check the contacts to ensure proper electrical connections. When contacts open and close, the rolling and rubbing action keeps the contacts bright and clean. Infrequently operated contacts or contacts under heavy loads can overheat and create oxidation on the contacts.

Copper Contacts

Copper contacts are used for most heavy-duty power circuits, and, in many cases, in relay and interlock circuits. They should be inspected regularly. If projections extend beyond the contact surfaces or if the contacts are pitted or coated with copper oxide, they should be sanded down with fine sandpaper.

Welding of contacts sometimes occurs, in spite of all precautions. Low voltage is the most common cause. Welding may also result from overloads, low-contact pressure resulting from wear or weak springs, loose connections, or excessive vibrations. If welding occurs, it is an indication of trouble in the electrical system. The contacts must be replaced, but it is useless to replace them unless the cause of the welding is found and corrected.

Carbon Contacts

Carbon contacts are used when a contactor is frequently opened and closed. It is essential that the contactor be open when it is de-energized. Since carbon

contacts will not weld together when closed, they are better than metal contacts for ensuring that a de-energized contact is open. However, carbon contacts are used only when necessary. Because the current capacity of carbon per square inch of contact surface is very low, the contacts made of carbon must be relatively large.

Silver Contacts

Silver contacts are used extensively in pilot and control circuits, on relays, interlocks, master switches, and so on. They are used also on smaller controllers and on heavy-duty equipment where the contactors remain closed for long periods of time with infrequent operation. Silver contacts are used because they ensure better contact than other less expensive material.

Pure silver contacts and silver-cadmium-oxide contacts should not be replaced until they become too worn to give good service. Their appearance will indicate when they are worn to such an extent that they are no longer serviceable (fig. 7-62).

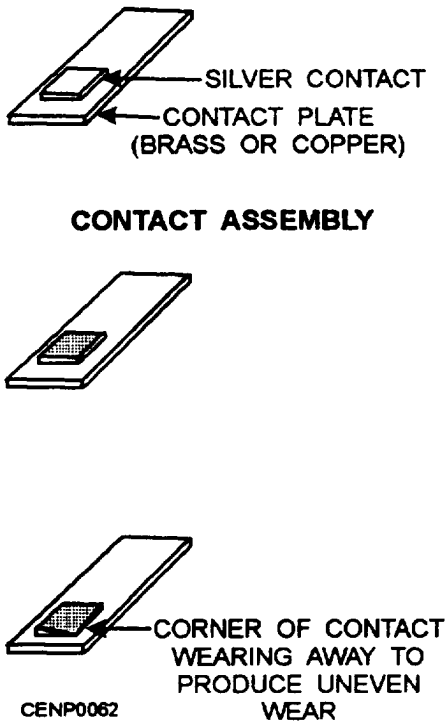


Figure 7-62.—Silver contacts.

ELECTRICAL AND MECHANICAL WEAR.—Normally, contacts are subjected to electrical and mechanical wear as they establish and interrupt electric currents. Electrical wear is usually greater than mechanical wear. If a movable contact assembly has no appreciable sliding action on its associated stationary contact assemblies, mechanical wear will be insignificant.

Electrical wear or erosion is caused by arcing when the contacts are establishing and interrupting currents. During arcing, a small part of each contact is melted, vaporized, and blown away from the contact. As a pure silver contact erodes, its arcing surface changes in color, contour, and smoothness. Figure 7-62 shows typical changes in contour and smoothness.

Normally, a new contact has a uniform silver color, a regular contour, and a smooth arcing surface. As the contact wears, discolorations usually give it a mottled appearance, showing silver, blue, brown, and black. The black color comes from the silver oxide formed during arcing. Silver oxide is beneficial to the operation of the contact.

Electrical erosion may cause uneven wear of the contacts and consequent contour irregularity. Uneven contact wear doesn't necessarily indicate that the contact should be replaced Manufacturers usually provide a total thickness of silver equal to twice the wear allowance associated with the contact to allow for uneven contact wear.

Melting and vaporization of contacts cause pitting of the arcing surface. The pitted surface has high spots which are quite small in area. Tests indicate that such a surface is better than a surface which has not been subjected to arcing because its circuit-making reliability is improved.

A silver-cadmium-oxide contact shows the same wear characteristics as a pure silver contact, except that small black granules may be evident on the arcing surface. These granules are cadmium oxide, a black material which is scattered throughout the mixture that has formed on the contacts. Silver oxide is formed during arcing, just as with a pure silver contact. The addition of cadmium oxide greatly improves contact operation because it minimizes the tendency of the contacts to weld together, retards heavy transfer of material from one contact to the other, and inhibits erosion.

WEAR ALLOWANCE.—A contact is service as long as its wear allowance, and its associated contacts, exceeds the minimum value specified by the manufacturer. (Usually the minimum value is 0.015 to 0.030 inch). The "wear allowance" of contacts is defined as the total thickness of contact material which

may be worn away before the contact of two associated surfaces becomes inadequate to carry rated current.

In an electric-motor contactor, the wear allowance of the power pole contacts is usually related to the closed position of the magnetic operator. The wear allowance of the power pole contacts of a magnetic contactor is the amount of silver that can be worn away without resulting in failure of the contacts to touch when the magnetic operator is at its closed position.

Blowout Coils

Blowout coils seldom wear out or give trouble when used within their rating. However, if they are required to carry excessive currents, the insulation becomes charred and fails, causing flashovers and failure of the device.

Arc shields are constantly subjected to the intense heat of arcing and may eventually burn away, allowing the arc to short-circuit to the metal blowout pole pieces. Therefore, arc shields should be inspected regularly and renewed before they burn through.

Arc barriers provide insulation between electrical circuits and must be replaced if broken or burned to a degree where short circuits are likely to occur.

The importance of having clean, tight electrical connections must be emphasized. Where practical, it is a good idea and common practice to solder electrical connections.

Excessive slamming on closing, particularly on ac magnetic-operated devices, will eventually damage the laminated face of the magnetic armature and may damage the shading coil.

Magnetic coils should be kept dry. Wet coils should always be dried out before using. They may be dried by baking them in a well-vented oven at not more than 194°F to prevent water from boiling in the insulation. The length of time in the oven depends on the size of the coil. If an oven isn't available, place the unit under a canvas cover roomy enough for hot air to be circulated within. Another alternative is to direct infrared lamps on the windings.

The closed pressure of contacts is an important factor in their ability to carry current. A small contact with proper contact pressure carries more current than a large one with little pressure. Contact springs must be kept in condition. Replace them when they have been damaged or have lost temper by exposure to high temperatures.

Connections should always be clean and tight. Loose connections result in overheated parts that eventually need replacing. Periodic inspections are necessary because temperature changes, vibration, and carelessness may loosen the connections.

Inspect the movable core of a controller for cleanliness. Accumulated dirt causes sluggish mechanical action which impairs the opening and closing of the contact.

Noise results if the movable and stationary pole pieces don't fit together well when the contactor is closed or when dirt or rust prevents proper closure. The most prominent noise produced in a controller comes from a broken shaded pole, which is a single turn of wire or strap, imbedded in part of the laminated magnetic structure.

Check the cabinet which houses the controller for cleanliness. Make sure the cover fits properly to keep moisture, dirt, and dust from entering. Check for corrosion of all metal parts. Table 7-5 is a guide for troubleshooting ac controllers.

Table 7-5.—Troubleshooting chart lor alternating-current controllers

Trouble	Probable cause	Remedy
Failure to close	No power.	Check power source. Replace faulty fuses.
	Low voltage.	Check power-supply voltage. Apply correct voltage. Check for low power factor.
	Inadequate lead wires.	Install lead wires of proper size.
	Loose connections.	lighten all connections.
	Open connections and broken wiring.	Locate opens and repair or replace wiring. Remove dirt from controller contacts.
	Contacts affected by long idleness or high operating temperature.	Clean and adjust.
	Contacts affected by chemical fumes or salty atmosphere.	Replace with oil-immersed contacts.
	Inadequate contact pressure.	Replace contacts and adjust spring tension.
	Open circuit breaker.	Check circuit wiring for possible fault.
	Defective coil.	Replace with new coil.
	Overload-relay contact latched open.	Operate hand- or electric-reset.
Failure to open	Interlock does not open circuit.	Check control-circuit wiring for possible fault. Test and repair.
	Holding circuit grounded.	Test and repair or replace grounded parts.
	Misalignment of parts; contacts apparently held together by residual magnetism.	Realign and test for free movement by hand. Magnetic sticking rarely occurs unless caused by excessive mechanical friction or misalignment of moving parts. Wipe off pole faces to remove accumulation of oil.
	Contacts welded together.	See CONTACTS WELDED TOGETHER section.
Sluggish Operation	Spring tension too strong.	Adjust for proper spring tension.
	Low voltage.	Check power-supply voltage. Apply correct voltage.
	Operating in wrong position.	Remount in correct operating position.
	Excessive friction.	Realign and test for free movement by hand. Clean pivots.
	Rusty parts due to long periods of idleness.	Clean or renew rusty parts.

Table 7-5.—Troubleshooting chart for alternating-current controllers—Continued

Trouble	Probable cause	Remedy
Sluggish Operation (Continued)	Sticky moving parts.	Wipe off all accumulations of oil and dirt. Bearings do not need lubrication.
	Misalignment of parts.	Check for proper alignment. Realign tc reduce friction and test for free movement by hand.
Erratic Operation (Unwanted Openings and Closures and Failure of Overload Protection)	Short circuits.	Test and repair or replace defective parts.
	Grounds.	Test and repair or replace defective parts.
	Sneak currents.	These are usually caused by intermittent grounds or short circuits in the machines or wiring circuit. Test and replace faulty parts or wiring.
	Loose connections.	Tighten all connections. Eliminate any vibrations or rapid temperature changes that may occur in close proximity to the controller.
Overheating of Coils	Shorted coil.	Replace coil.
	High ambient temperature or poor ventilation.	Relocate controller, use forced ventilation or replace with suitable type controller.
	High voltage.	Check for shorted control resistor. Check power-supply voltage. Apply correct voltage.
	High current.	Check current rating of controller. Make check for high voltage above. If necessary, replace with suitable type controller.
	Loose connections.	Tighten all connections. Check for undue vibrations in vicinity.
	Excessive collection of dirt and grime.	Clean but do not reoil parts. If covers dc not fit tightly, realign and adjust fasteners.
	High humidity, extremely dirty atmosphere, excessive condensation, and rapid temperature changes.	Use oil-immersed controller or dusttight enclosures.
	Operating on wrong frequency.	Replace with coil or proper frequency rating.

Table 7-5.—Troubleshooting chart for alternating-current controllers—Continued

Trouble	Probable cause	Remedy
Overheating of Coils Continued)	D-c instead of a-c coil.	Replace with a-c coil.
	Too frequent operation.	Adjust to apply larger control.
	Open armature gap.	Adjust spring tension. Eliminate excessive friction or remove any blocking in gap.
Contacts Welded Together	Improper application.	Check load conditions and replace with a more suitable type controller.
	Excessive temperature.	Smooth off contact surface to remove concentrated hot spots.
	Excessive binding of contact tip upon closing.	Adjust spring pressure.
	Contacts close without enough spring pressure.	Replace worn contacts. Adjust or replace weak springs. Check armature overtravel.
	Sluggish operation.	See SLUGGISH OPERATION.
	Rapid, momentary, touching of contacts without enough pressure.	Smooth contacts. Adjust weak springs. Where controller has JOG or INCH control button, operate this less rapidly.
Overheating of Contacts	Inadequate spring pressure.	Replace worn contacts. Adjust or replace weak springs.
	Contacts overloaded	Check load data with controller rating. Replace with correct size contactor.
	Dirty Contacts.	Clean and smooth contacts.
	High humidity, extremely dirty atmosphere, excessive condensation, and rapid temperature changes.	See OVERHEATING OF COILS.
	High ambient temperature or poor ventilation.	See OVERHEATING OF COILS.
	Chronic arcing.	Adjust or replace arc chutes. If arcing persists, replace with a more suitable controller.
	Rough contact surfaces.	Clean and smooth contacts. Check alignment.
	Continuous vibration when contacts are closed.	Change or improve mounting of controller.
	Oxidation of contacts.	Keep clean, reduce excessive temperature, or use oil-immersed contacts.

Table 7-5.—Troubleshooting chart for alternating-current controllers—Continued

Trouble	Probable cause	Remedy
Arcing at Contacts	Arc not confined to proper path.	Adjust or renew arc chutes. If arcing persists, replace with more suitable controller.
	Inadequate spring pressure.	Replace worn contacts. Adjust or replace weak springs.
	Slow in opening.	Remove excessive friction. Adjust spring tension. Renew weak springs. See SLUGGISH OPERATION.
	Faulty blowout coil or connection.	Check and replace coil. Tighten connection.
	Excessive inductance in load circuit.	Adjust load or replace with more suitable controller.
Pitting or Corroding of Contacts	Too little surface contact.	Clean contacts and adjust springs.
	Service too severe.	Check load conditions and replace with more suitable controller.
	Corrosive atmosphere.	Use airtight enclosure. In extreme cases, use oil-immersed contacts.
	Continuous vibration when contacts are closed.	Change or improve mounting of controller.
	Oxidation of contacts.	Keep clean, reduce excessive temperature, or use oil-immersed contacts.
Noisy Operation (Hum or Chatter)	Poor fit at pole face.	Realign and adjust pole faces.
	Broken or defective shading coil.	Replace coil.
	Loose coil.	Check coil. If correct size, shim coil until tight.
	Worn parts.	Replace with new parts.
Vibration after Repairs	Misalignment of parts.	Realign parts and test for free movement by hand.
	Loose mounting.	Tighten mounting bolts.
	Incorrect coil.	Replace with proper coil.
	Too much play in moving parts.	Shim parts for proper tightness, and clearance.

APPENDIX 1

GLOSSARY

A-E—Architect, Engineering Firm.

AMERICAN WIRE GAUGE (AWG)—The standard adopted in the United States for the measurement of wire sizes.

AMMETER—An instrument for measuring the amount of electron flow (in amperes).

AMPACITY—The current in amperes that a conductor can carry continuously under the conditions of use without exceeding its temperature rating.

AMPERE—The basic unit of electrical current

AMPLIFIER—The device that provides amplification (the increase in current, voltage, or power of a signal) without appreciably altering the original signal.

ANSI—American National Standards Institute.

BILL OF MATERIAL—Alist of standard parts or raw materials needed to fabricate an item.

BLOCK DIAGRAM—A diagram in which the major components of a piece of equipment or a system are represented by squares, rectangles, or other geometric figures, and the normal order of progression of a signal or current flow is represented by lines.

BLUEPRINTS—Copies of electrical or other types of technical drawings. Although blueprints used to be blue, modern reproduction techniques now permit printing of black on white as well as colors.

BORDER LINES—Dark lines defining the inside edge of the margin on a drawing.

BREAK LINES—Lines to reduce graphic size of an object generally to conserve paper space. Two types: long, thin, ruled lined with freehand zigzag; short, thick, wavy freehand line.

CAPACITANCE—The property of an electrical circuit that opposes changes in voltage.

CAPACITOR—An electrical device capable of storing electrical energy in an electrostatic field

CBC—Construction Battalion Center.

CESE—Civil Engineering Support Equipment.

CESO—Civil Engineering Support Office System manager responsible for maintaining NCF Table of Allowance (TOA).

COMSECONDNCB—Commander, Second Naval Construction Brigade.

COMTHIRDNCB—Commander, Third Naval Construction Brigade.

CONDUCTOR—A material that easily permits electric current to flow.

CONTINUITY—An uninterrupted, complete path for current flow.

CRIBBING—The act of placing some firm material around the below ground portion of a power pole.

CTR—Central Tool Room.

CURRENT—The passage of electrons through a conductor, measured in amperes.

DEVICE—A part of an electrical system that is intended to carry electrical energy.

DIRECT SHORT—*See* SHORT CIRCUIT.

DoD—Department of Defense.

DYNAMOMETER—An instrument that measures the strain of the pull used in pole-line construction.

ELECTROLYTE—A solution of a substance that is capable of conducting electricity.

ELECTROMECHANICAL DRAWING—A special type of drawing combining electrical symbols and mechanical drawing to show the composition of equipment that combines electrical and mechanical features.

EPA—Environmental Protection Agency.

EQUIPMENT GROUNDING—The grounding of all exposed non-current carrying metal parts of an electrical system to the earth.

FEX—Field exercise.

FLUORESCENT LAMP—A low-pressure mercury electric-discharge lamp in which a fluorescing coating on its inner surface transforms some of the ultraviolet energy generated by the discharge into light.

GROUND—A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth.

GROUNDING CONDUCTOR—Aconductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode.

GROUNDING ELECTRODE—A conductor embedded in the earth for maintaining ground potential on conductors connected to it.

HAZARDOUS LOCATION—An area where ignitable vapors or dust might cause a fire or explosion created by energy emitted from lighting or other electrical equipment.

HYDROMETER—An instrument used to measure specific gravity. In batteries, hydrometers are used to indicate the state of change by the specific gravity of the electrolyte.

INDUCTANCE—The property of a circuit that tends to oppose a change in the existing current flow.

INDUCTION—The act or process of producing voltage and current by the relative motion of a magnetic field across a conductor.

INDUCTION MOTOR—A simple, rugged, ac motor with desirable characteristics. The rotor is energized by transformer action (induction) from the stator.

INSULATION—A material used to prevent the leakage of electricity from a conductor and provide mechanical spacing or support as protection against accidental contact with the conductor.

INSULATOR—A device having high electrical resistance; used for supporting or separating conductors so as to prevent undesired flow of current from the conductors to other objects.

ISOMETRIC WIRING DIAGRAM—A diagram showing the outline of a structure and the location of equipment, such as panels, and junction boxes, and cable runs.

MAINTENANCE—Day-to-day, periodic, or scheduled work required to preserve or restore a facility or equipment so that it can be used effectively for its designed purpose. It includes work to prevent damage to or the deterioration of a facility that would otherwise be more costly to restore.

MEP—Mobile electric power.

MILITARY SPECIFICATIONS (MILSPEC)— Technical requirements and standards adopted by the Department of Defense that must be met by vendors selling materials to DoD.

MILITARY STANDARDS (MIL-STD)—Standards of performance for components or equipment that must be met to be acceptable for military systems.

MOCC—Mount-out control center.

MOTOR—A machine that converts electrical energy to mechanical energy. It is activated by ac or dc voltage, depending on the design.

MOTOR LOAD—Any device driven by a motor. Typical loads are drills, saws, water pumps, generators, and so forth. The speed and power capabilities of a motor must be matched to the speed and power capabilities of the motor load.

MOTOR STARTERS—Resistive devices placed in series with dc motor armatures to prevent the armature from drawing excessive current until armature speed develops counter emf.

MSDS—Material Safety Data Sheet. A mandatory form that should accompany any hazardous materials being issued to or used by naval personnel.

NAVFACENGCOM—Naval Facilities Engineering Command. Manages the planning, design, and construction of the U.S. naval facilities around the world.

NAVSUP—Naval Supply Command.

NCBC—Naval Construction Battalion Center.

NCF—Naval Construction Force.

NEC®—National Electrical Code®.

NFPA—National Fire Protection Agency.

OHM—The unit of electrical resistance; that value of electrical resistance through which a constant potential difference of 1 volt across the resistance will maintain a current flow of 1 ampere through the resistance.

OIC—Officer in charge.

OPEN CIRCUIT—A circuit that does not provide a complete path for the flow of current.

OPNAVINST—Instructions from the Chief of Naval Operations.

OSHA—Occupational Safety and Health Act.

P&E—Planning and estimating.

PHOTOCELL—A light-controlled variable resistor that has a light-to-dark resistance ratio of 1:1,000; used in various types of control and timing **circuits.**

PICTORIAL WIRING DIAGRAM—A diagram showing actual pictorial sketches of various parts of a piece of equipment and the electrical connections between the parts.

POLYPROPYLENE—Any various thermoplastic resins that are polymers of propylene. They are tough and hard and are used to make molded articles and fibers.

PREVENTIVE MAINTENANCE—Visual, mechanical, electrical, and electronic checks that are made to determine whether or not equipment is functioning properly.

PWC—Public Works Center.

PWD—Public Works Department.

RECEIVER—Equipment that converts electromagnetic energy into audible form.

RECTIFIER—A device that converts alternating current to direct current.

REGULATOR—The section in a basic power supply that maintains the output of the power supply at a constant level in spite of large changes in load current or input line voltage.

RELAY—An electromagnetic device with one or more sets of contacts that change position by the magnetic attraction of a coil to an armature.

RESISTANCE—The opposition of a device or material offers to the flow of current. The effect of resistance is to raise the temperature of the material or device carrying the current.

ROTOR—The revolving part of a rotating electrical machine. The rotor mat should be either the field or the armature, depending on the design of the machine.

SAFETY—Being safe from undergoing or causing injury, harm, or loss of personnel or equipment.

SCALE—The ratio between the measurement used on a drawing and the measurement of the object it represents.

SCHEMATIC DIAGRAM—A diagram using graphic symbols to show now a circuit functions electrically.

SHORT CIRCUIT—An unintentional current path between two components in a current or between component and ground; usually caused by a circuit malfunction (also known as direct short).

SINGLE-LINE DIAGRAM—A diagram using single lines and graphic symbols to simplify a complex circuit or system.

SLIP RINGS—Contacts that are mounted on the shaft of a motor or generator to which the rotor windings are connected and against which the brushes ride. Devices for making electrical connections between stationary and rotating contacts.

SOLID-STATE DEVICE—An electronic device that operates by the movement of electrons within a solid piece of semiconductor material.

SPECIFICATION—Detailed description or identification relating to quality, strength, or similar performance requirements.

STATOR—The stationary part of a rotating electrical machine. The stator may be either the field or the armature, depending on the design of the machine.

SYNTHETIC-FIBER LINE—A rope made from either nylon, polyester, polyethylene, or polypropylene.

TITLE BLOCK—A blocked area in the lower right corner of a print; provides information to identify the drawing, its subject matter, origins, scale, and other data

TOA—Table of Allowance. Personnel, equipment, and supplies needed for a particular NCF unit for that unit to function properly.

TRANSFORMER—A device composed of two or more coils, linked by magnetic lines of force; used to transfer energy from one circuit to another.

TROUBLESHOOTING—The process of locating and diagnosing faults in equipment by means of systematic checking or analysis.

UTILITY PLAN—A floor plan of a structure showing locations of heating, electrical, plumbing, and other service system components.

VOLTAGE—The term used to signify electrical pressure. Voltage is a force that causes current to flow through an electrical conductor.

WATT—The unit of electrical power that is the product of voltage and current.

WATT-HOUR—A practical unit of electrical energy equal to 1 watt of power for 1 hour.

WATT-HOUR METER—A meter used to measure electrical energy.

WATTMETER—A meter used to measure electrical power.

WHIPPING—The process of securing the ends of a fiber or wire rope to prevent the strands from unraveling.

WIRING (CONNECTION) DIAGRAM—A diagram showing the individual connections within a unit and the physical arrangement of the components.

29 CFR—Title 29 Code of Federal Regulations.

APPENDIX II

METRIC CONVERSION TABLES

Length Conversion

When You Know:	You Can Find:	If You Multiply By:
inches	millimeters	25.4
inches	centimeters	2.54
feet	centimeters	30
feet	meters	0.3
yards	centimeters	90
yards	meters	0.9
miles	kilometers	1.6
miles	meters	1 600
millimeters	inches	0.04
centimeters	inches	0.4
centimeters	feet	0.032 8
meters	feet	3.3
centimeters	yards	0.010 9
meters	yards	1.1
meters	miles	0.000 621
kilometers	miles	0.6
meters	nautical miles	0.000 54
nautical miles	meters	1852

Weight Conversion

When You Know:	You Can Find:	If You Multiply By:
ounces	grams	28.3
pounds	kilograms	0.45
short tons (2000 lbs)	megagrams (metric tons)	0.9
grams	ounces	0.035 3
kilograms	pounds	2.2
megagrams (metric tons)	short tons (2000 lbs)	1.1

Temperature Conversion

When You Know:	You Can Find:	If You Multiply By:
degrees Fahrenheit	degrees Celsius	subtract 32 then multiply by 5/9
degress Celsius	degrees Fahrenheit	multiply by 9/5 then add 32
degrees Celsius	kelvins	add 273.15°

Volume Conversion

When You Know:	You Can Find:	If You Multiply By:
teaspoons	milliters	5
tablespoons	milliters	15
fluid ounces	milliters	30
cups	liters	0.24
pints	liters	0.47
quarts	liters	0.95
gallons	liters	3.8
milliters	teaspoons	0.2
milliters	tablespoons	0.067
milliters	fluid ounces	0.034
liters	cups	4.2
liters	pints	2.1
liters	quarts	1.06
liters	gallons	0.26
cubic feet	cubic meters	0.028
cubic yards	cubic meters	0.765
cubic meters	cubic feet	35.3
cubic meters	cubic yards	1.31

Area Conversion

When You Know:	You Can Find:	If You Multiply By:
square inches	square centimeters	6.45
square inches	square meters	0.000 6
square feet	square centimeters	929
square feet	square meters	0.092 9
square yards	square centimeters	8.360
square yards	square meters	0.836
square miles	square kilometers	2.6
square centimeters	square inches	0.155
square meters	square inches	1 550
square centimeters	square feet	0.001
square meters	square feet	10.8
square centimeters	square yards	0.000 12
square meters	square yards	1.2
square kilometers	square miles	0.4

CEJA0033

APPENDIX III

FORMULAS

CONVERSION FACTORS AND CONSTANTS

$\pi = 3.14$	$2\pi = 6.28$
$\pi^2 = 9.87$	$(2\pi)^2 = 39.5$
$\varepsilon = 2.718$	$\sqrt{2} = 1.414$
$\sqrt{3} = 1.732$	LOG = 0.497

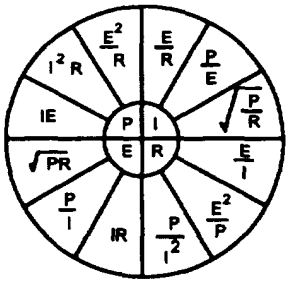
Temperature

(F to C) C = 5/9 (F – 32)
(C to F) F = 9/5 C + 32
(C to K) K = C + 73

Power

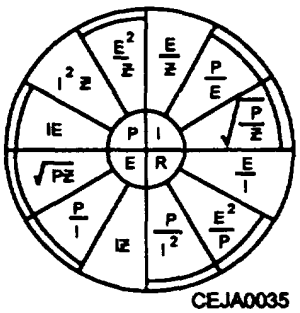
1 kilowatt = 1.341 horsepower
1 horsepower = 746 watts

OHM'S LAW – DIRECT CURRENT



CEJA0034

OHM'S LAW – ALTERNATING CURRENT



CEJA0035

SINUSOIDAL VOLTAGES AND CURRENTS

Effective Value =	0.707 x Peak Value
Average Value =	0.637 x Peak Value
Peakvalue =	1.414 x Effective Value
Effective Value =	1.11 x Average Value
Peak Value =	1.57 x Average Value
Average Value =	0.9 x Effective Value

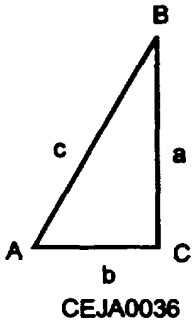
TRIGONOMETRIC FORMULAS

$$\sin A = \frac{a}{c} = \frac{\text{Opposite Side}}{\text{Hypotenuse}}$$

$$\cos A = \frac{b}{c} = \frac{\text{Adjacent Side}}{\text{Hypotenuse}}$$

$$\tan A = \frac{a}{b} = \frac{\text{Opposite Side}}{\text{Adjacent Side}}$$

$$\cot A = \frac{b}{a} = \frac{\text{Adjacent Side}}{\text{Opposite Side}}$$



CEJA0036

SPEED VS. POLES FORMULAS

$$F = \frac{NP}{120} \quad N = \frac{F\ 120}{P} \quad P = \frac{F\ 120}{N}$$

F = frequency
N = speed of rotation
p = number of poles
120 = time constant

POWER FACTOR

$$PF = \frac{\text{actual power}}{\text{apparent power}} = \frac{\text{watts}}{\text{volts x amperes}} = \frac{kW}{kVA} = \frac{R}{Z}$$

SINGLE-PHASE CIRCUITS

$$kVA = \frac{EI}{1{,}000} = \frac{kW}{PF} \qquad kW = kVA \times PF$$

$$I = \frac{P}{E \times PF} \qquad E = \frac{P}{I \times PF} \qquad PF = \frac{P}{E \times I}$$

$$P = E \times I \times PF$$

TWO-PHASE CIRCUITS

$$I = \frac{P}{2 \times E \times PF} \qquad E = \frac{P}{2 \times I \times PF} \qquad PF = \frac{P}{E \times I}$$

$$kVA = \frac{2 \times E \times I}{1{,}000} \qquad \frac{kW}{PF} \qquad kW = kVA \times PF$$

$$P = 2 \times E \times I \times PF$$

THREE-PHASE CIRCUITS, BALANCED WYE

$$\mathbf{I_{phase} = I_{line}}$$

$$\mathbf{E_L = \sqrt{3}\, E_P = 1.73\, E_P}$$

$$\mathbf{E_P = \frac{E_L}{\sqrt{3}} = 0.577\, E_L}$$

THREE-PHASE CIRCUITS, BALANCED DELTA

$$\mathbf{E_{phase} = E_{line}}$$

$$\mathbf{I_L = \sqrt{3}\, I_P = 1.73\, I_P}$$

$$\mathbf{I_P = \frac{I_L}{\sqrt{3}} = 0.577\, I_L}$$

POWER: THREE-PHASE BALANCED WYE OR DELTA CIRCUITS

$$P = 1.732 \times E \times I \times PF \qquad VA = 1.732 \times E \times I$$

$$E = \frac{P}{PF \times 1.73 \times I} = \frac{0.577 \times P}{PF \times I}$$

$$I = \frac{P}{PF \times 1.73 \times E} = \frac{0.577 \times P}{PF \times E}$$

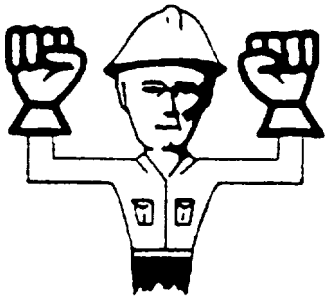
$$PF = \frac{P}{PF \times 1.73 \times E} = \frac{0.577 \times P}{I \times E}$$

VA = apparent power (voltamperes)
P = actual power (watts
E = line voltage (volts)
I = line current (amperes)

APPENDIX IV

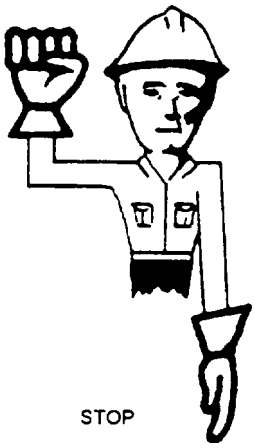
HAND SIGNALS

GENERAL



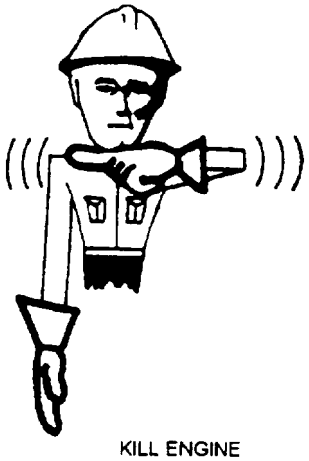
EMERGENCY STOP

1 (STOP ALL MOTION AS QUICKLY AS POSSIBLE.)



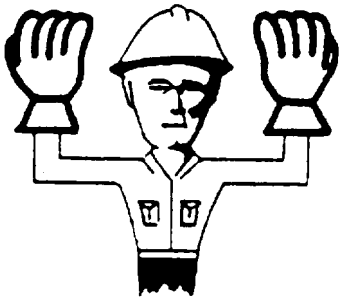
STOP

2



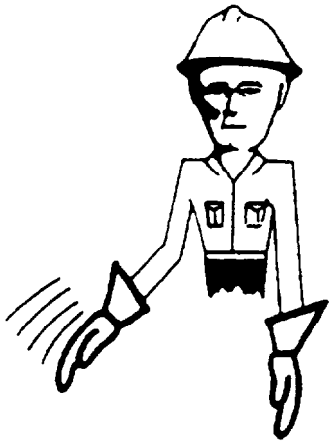
KILL ENGINE

3 (SECURE ENGINE AS PRESCRIBED.)

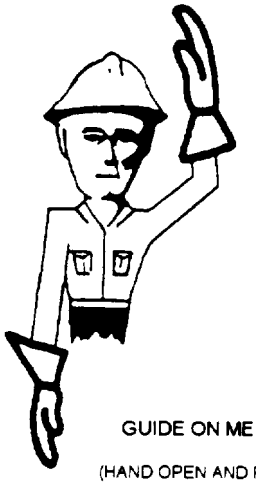


MANEUVER FOWARD SLOW AND EASY

4 (WHEN MANEUVERING IN CLOSE QUARTERS OR TO MOVE A FOOT OR TWO AT A TIME.)

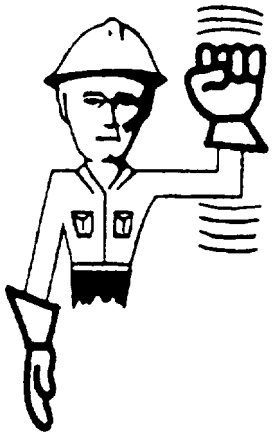


5 SLOW DOWN



GUIDE ON ME

6 (HAND OPEN AND PALM FACING INWARD.)



INCREASE SPEED

7 (HURRY UP AND MOVE OUT, DOUBLE TIME, ETC.)

HOISTING & DERRICK SIGNALS

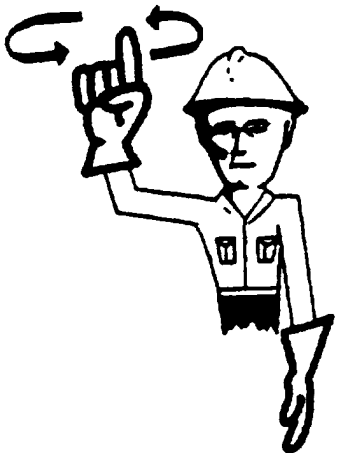


8 RAISE OR HOIST SLOWLY



9 LOWER SLOWLY

CEJA0038



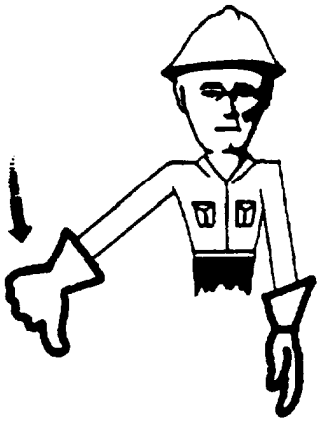
10 RAISE THE LOAD



11 LOWER THE LOAD



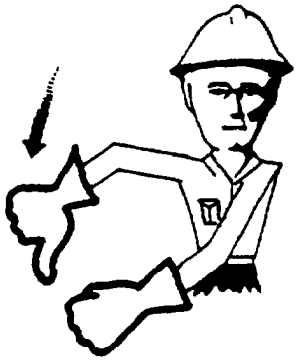
12 RAISE THE BOOM



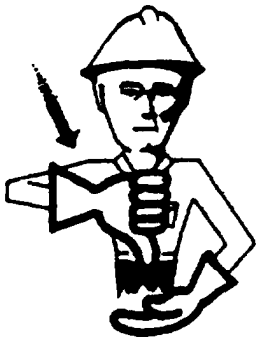
13 LOWER THE BOOM



14 RAISE THE BOOM AND HOLD THE LOAD



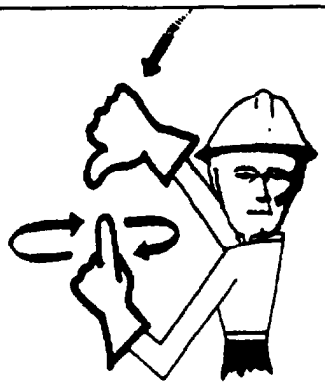
15 LOWER THE BOOM AND HOLD THE LOAD



16 LOWER THE BOOM SLOWLY



17 RAISE THE BOOM SLOWLY

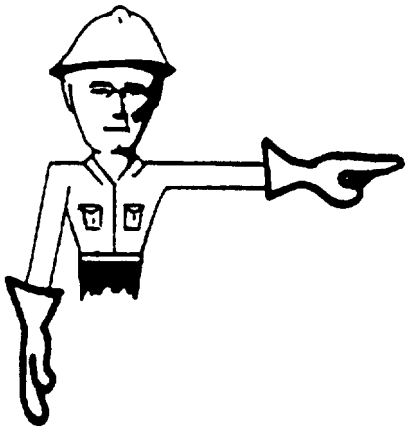


18 LOWER THE BOOM AND RAISE THE LOAD

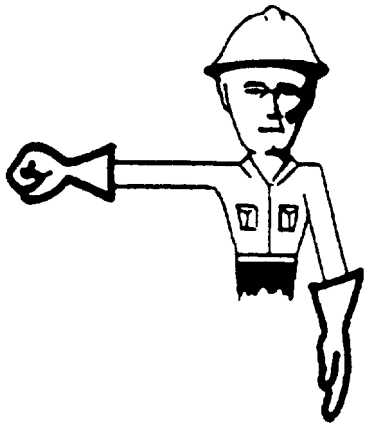
CEJA0039



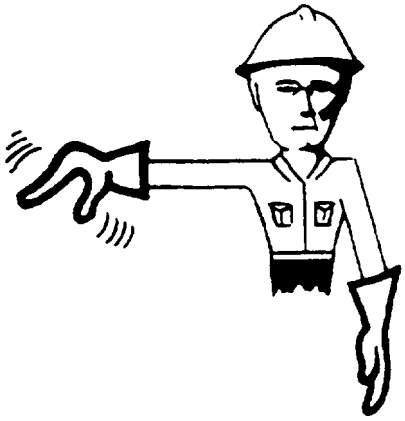
19 RAISE THE BOOM AND LOWER THE LOAD



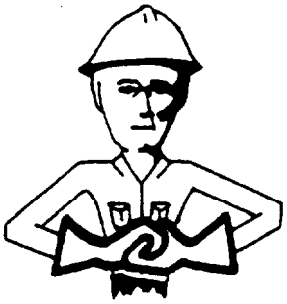
20 SWING IN DIRECTION FINGER POINTS



21 CLOSE BUCKET

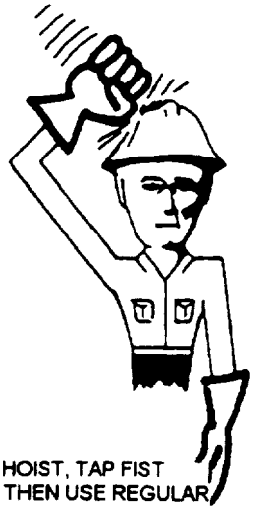


22 OPEN BUCKET



23 DOG EVERYTHING

(LOCK ALL BRAKES; DO NOT MOVE UNTIL FURTHER INSTRUCTIONS ARE GIVEN.)



24 USE MAIN HOIST, TAP FIST ON HEAD, THEN USE REGULAR SIGNALS.



25 USE WHIP LINE.

(AUXILARY HOIST) TAP ELBOW WITH ONE HAND; THEN USE REGULAR SIGNALS.

CRAWLER EQUIPT. (INCLUDES CRANES)





26 MAKE RIGHT OR LEFT TURN AS INDICATED BY CLENCHED FIST.

LEFT RIGHT

CEJA0040



27 TRAVEL BOTH TRACKS



28

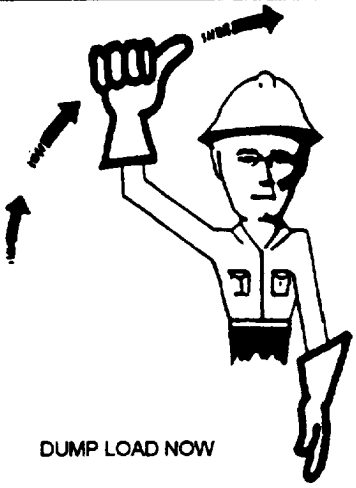
WHEN CUT, FILL OR HAUL ROAD IS TO BE DRAGGED OR BLADED, POINT TO THE AREA, THEN RUB PALMS OF HANDS TOGETHER INDICATING A SMOOTHING MOTION. APPLIES TO SCRAPERS, MOTOR GRADERS AND BULLDOZERS.



29 RAISE A LITTLE



30 LOWER A LITTLE



31 DUMP LOAD NOW

(START DUMPING AND SPREADING LOAD TO PROPER DEPTH IF GIVEN.)



32 REHAUL OR RETRACT

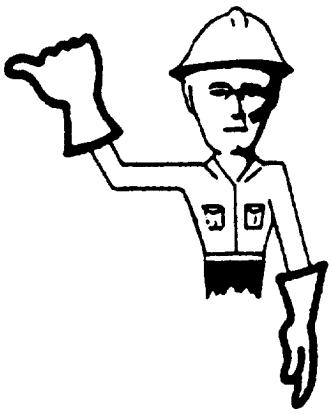


33 CROWD OR EXTEND



34

TURN RIGHT (TO THE OPERATOR'S RIGHT.)



35

TURN LEFT (TO THE OPERATOR'S LEFT.)

CEJA0041

APPENDIX V

REFERENCES USED TO DEVELOP THIS TRAMAN

Although the following references were current when this TRAMAN was published, their continued currency cannot be assured. When consulting these references, keep in mind that they may have been revised to reflect new technology or revised methods, practices, or procedures. You therefore need to ensure that you are studying the latest references.

Chapter 1

Hazard Communication, Code of Federal Regulations, 29 CFR 1910.1200, 1991.

Hazardous Material Control and Management, OPNAVINST 4110.2, Office of the Chief of Naval Operation, Washington, DC, 1989.

Seabee Supply Manual, COMCBPAUCOMCBLANTINST 4400.3A, 1987.

Chapter 2

Blueprint Reading and Sketching, NAVEDTRA 12014, Naval Education and Training Program Management Support Activity*, Pensacola, FL, 1994.

Graphic Symbols for Electrical and Electronics Diagrams, American National Standard, ANSI 2.2-1975, The Institute of Electrical and Electronics Engineers, NY, 1986.

Graphic Symbols for Electrical Wiring and Layout Diagrams, American National Standard, ANSI Y32.9-1972, The Institute of Electrical and Electronics Engineers, NY, 1972.

Chapter 3

Croft, Terrell, and Wilford I. Summers, *American Electrician's Handbook* 12th ed., McGraw-Hill, NY, 1992.

McPortland, J.F., and Brian J. McPortland, *National Electrical Code® Handbook,* 22d ed, McGraw-Hill, NY, 1996.

Navy Electricity and Electronics Training Series, Module 1, *Matter Energy, and Direct Current,* NAVEDTRA, B72-01-00-92, Naval Education and Training Program Management Support Activity*, Pensacola, FL, 1992.

Operator and Organization Maintenance Manual for a Generator Set, Diesel Engine Driven, TM5-6115-545-12, 1982.

Chapter 4

Croft, Terrell, and Wilford I. Summers, *American Electrician's Handbook,* 12th ed., McGraw-Hill, NY, 1992.

Electric Power Distribution Systems Operations, NAVFAC MO-201, Naval Facilities Engineering Command, Alexandria, VA, 1990.

Electrical Transmission and Distribution Safety Manual, NAVFAC P-1060, Naval Facilities Engineering Command, Alexandria, VA, 1990.

Kurtz, Edwin B., and Thomas M. Shoemaker, *The Lineman's and Cableman's Handbook,* 8th ed., McGraw-Hill, NY, 1996.

McPortland, J. F., and Brian J. McPortland, *National Electrical Code® Handbook,* 22d ed, McGraw-Hill, NY, 1996.

Chapter 5

Code of Federal Regulation, 29 CFR, 1991.

McPortland, J.E, and Brian J. McPortland, *National Electrical Code® Handbook,* 22d ed, McGraw-Hill, NY, 1996.

National Electrical Code®, National Fire Protection Association, Quincy, MA, 1996.

Chapter 6

Croft, Terrell, and Wilford I. Summers, *American Electician's Handbook,* 12th ed., McGraw-Hill, NY, 1992.

Kurtz, Edwin B., and Thomas M. Shoemaker, *The Lineman's and Cableman's Handbook,* 8th ed., McGraw-Hill, NY, 1996.

McPortland, J.F., and Brian J. McPortland, *National Electrical Code® Handbook,* 22d ed, McGraw-Hill, NY, 1996.

National Electrical Code®, National Fire Protection Association, Quincy, MA, 1996.

Navy Electricity and Electronics Training Series, Module 8, *Introduction to Amplifiers,* NAVEDTRA 172-08-00-82, Naval Educational Training Program Management Support Activity*, Pensacola, FL, 1982.

Navy Electricity and Electronics Training Series, Module 24, *Introduction to Fiber Optics,* NAVEDTRA B72-24-00-92, Naval Educational Training Program Management Support Activity*, Pensacola, FL, 1992.

Rosenberg, Robert, and August Hand, *Electric Motor Repair,* 3rd ed., Saunders College Publishing, Fort Worth, TX, 1987.

Wire Communications and Signal Systems, MIL-HDBK-1004/7, Department of Defense, Washington, DC, 1991.

Chapter 7

Electrician Systems Technician, AFSC 5425A and B, Department of the Air Force, Extension Course Institute, Gunter Air Force Station, Montgomery, AL, 1993.

McPortland, J.E, and Brian J. McPortland, *National Electrical Code® Handbook*, 22d ed, McGraw-Hill, NY, 1996.

National Electrical Code®, National Fire Protection Association, Quincy, MA, 1996.

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* Effective 01 October 1996, the Naval Education and Training Program Management Support Activity (NETPMSA) became the Naval Education and Training Professional Development and Technology Center (NETPDTC).

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Assignment Questions

Information: The text pages that you are to study are provided at the beginning of the assignment questions.

ASSIGNMENT 1

Textbook Assignment: "Construction Support," chapter 1, pages 1-1 through 1-25.

1-1. Safety in the conduct of rigging operations depends primarily on what factor?

1. Size of line used
2. Type of slings used
3. Paygrade of the supervisor
4. Care and common sense of personnel assigned

1-2. What is the most important operational check (inspection) made on hoisting and rigging equipment?

1. Crane operation
2. Line and rigging
3. Lifting and load
4. Load only

1-3. The strength of rigging lines depends on what factor(s)?

1. The manufacturer of the line
2. The size, fiber used, and the type of stranding
3. Tensile strength tests
4. Lay and resistance to wear

1-4. The term "whipping" refers to what factor when applied to a line?

1. It prevents twisting of the line
2. It prevents fatigue resistance of the line
3. It improves the abrasion resistance of the line
4. It prevents strands from unraveling

1-5. What precaution should you take before storing a fiber line?

1. Ensure the line is dry
2. Use forced rotation to squeeze excess water from the .line
3. Dip the line in an oil lubricant to prevent water damage
4. Check the core strength by performing a sudden strain test

1-6. Of the following areas, which one should be used for storing a line?

1. A dry, unheated building that is well ventilated
2. An air conditioned building
3. A heated and unventilated building
4. A building with many windows that allows sunlight to enter

LOAD FACTORS

A. Safe Working Load
B. Breaking Strength
C. Free Payload Strength
D. Safety Factor

Figure 1A

IN ANSWERING QUESTIONS 1-7 THROUGH 1-9, REFER TO FIGURE 1A. SELECT THE LOAD FACTOR THAT MATCHES THE SITUATION PRESENTED IN THE QUESTION.

1-7. The tension at which the line will part when a load is applied.

1. A
2. B
3. C
4. D

1-8. The load that can be applied without causing damage.

1. A
2. B
3. C
4. D

1-9. The ratio between the breaking strength and the safe working load.

1. A
2. B
3. C
4. D

1-10. What is the SWL of a new 2-inch-diameter No. 1 manila line?

1. 3,380 lb
2. 4,620 lb
3. 6,625 lb
4. 7,750 lb

1-11. Synthetic-fiber lines are used in the Navy for which of the following reasons?

1. They are easy to handle
2. They are highly resistant to mildew, rot, and fungus
3. They are light-weight and strong
4. Each of the above

1-12. Using the "rule-of-thumb" formula for computing the SWL of synthetic fiber line, determine the SWL of 1-inch-diameter nylon line.

1. 3,840 lb
2. 4,000 lb
3. 4,180 lb
4. 4,280 lb

1-13. Wire rope consists of what three parts?

1. Breech, choker hitch, and becket
2. Choker hitch, fiber line, and spreader bar
3. Wire, strands, and core
4. Strands, breech, and spreader bar

1-14. Unlaying of nonpreformed wire rope is rapid and could cause serious injury.

1. True
2. False

1-15. Wire rope with what number of (a) strands and (b) wires in each strand is the most flexible?

1. (a) 6 (b) 19
2. (a) 6 (b) 37
3. (a) 8 (b) 38
4. (a) 8 (b) 41

TENSILE STRENGTH

A. 180,000 to 200,000
B. 200,000 to 220,000
C. 220,000 to 240,000
D. 240,000 to 260,000

Figure 1B

IN ANSWERING QUESTIONS 1-16 THROUGH 1-18, MATCH THE TENSILE STRENGTH IN FIGURE 1B WITH THE TYPE OF ROPE MATERIAL USED AS THE QUESTION.

1-16. Improved-plow steel.

1. A
2. B
3. C
4. D

1-17. Mid-plow steel.

1. A
2. B
3. C
4. D

1-18. Plow-steel.

1. A
2. B
3. C
4. D

1-19. To ensure an accurate measurement of the diameter of a wire rope, you should measure the wire rope in (a) how many places on six-stranded rope and (b) how many places on eight-stranded rope?

1. (a) Two (b) three
2. (a) Three (b) three
3. (a) Three (b) four
4. (a) Two (b) four

1-20. Using the "rule-of-thumb" formula, what is the SWL of 3/4-inch-diameter wire rope?

1. 3.2 tons
2. 4.5 tons
3. 5.3 tons
4. 6.4 tons

1-21. The inspection of wire rope clips at regular intervals should also include what other task?

1. Hitting the clips with a hammer to see if the metal will flake
2. Spraying the clips with paint to show they have been inspected
3. Measuring for slippage of clips
4. Removing the clips and examining the wire rope

1-22. What is the purpose of a wire rope thimble in an eye splice?

1. It reduces abrasive wear on the wire rope
2. It increases the distance between the load and the hoist tip
3. It speeds up the work
4. It is required for hoisting cylindrical objects

1-23. Shackles should replace hooks during what lifting operation?

1. When lifting a load to an unknown radius
2. When lifting a load where personnel may be working or walking under the load
3. When the loads are too heavy for the hooks to handle
4. When lifting the load in a tight area

1-24. What should be done with a hook that has been bent by overloading?

1. Straighten it and put it back in service
2. Have the safety LCPO approve it for service
3. Weld additional steel on the sides and place it back in service
4. Cut it in half and discard it

1-25. At what time interval or under what circumstances should you inspect hooks visually?

1. Monthly
2. After 50 hr of service
3. At the beginning of each workday and before lifting a full-rated load
4. Only when the hook is used for clamshell or dragline projects

1-26. What advantage does fiber-line slings have over wire-rope or chain slings?

1. They are heavier and stronger
2. They resist damage from sharp edges
3. They are more flexible and offer protection to finished materials
4. They require less supporting equipment

1-27. An endless sling is frequently used as a choker hitch.

1. True
2. False

1-28. A single-leg sling is also known as a

1. chocker
2. strap
3. bridle
4. gripp

1-29. Two single slings can be combined to form a longer single sling.

1. True
2. False

1-30. Why is it. important to match sets of slings?

1. So they will withstand heavier loads
2. So a varied mobile lift within a small working area can be accomplished
3. So the load strain will be equal and the load will come up evenly
4. Each of the above

1-31. Which of the following components is added to heavy equipment to aid in lifting?

1. Stress bars
2. Spreader bars
3. Roll bars
4. Lifting eyes

1-32. Chafing gear is used to protect slings that are exposed to sharp edges.

1. True
2. False

1-33. Chain slings are desirable for what type of load?

1. Cold loads
2. Light loads
3. Nonsharp loads
4. Hot- and sharp-edged loads

1-34. When using chain slings, you should ensure what material is in place around the load to provide a gripping surface for the chain?

1. Fiber pads
2. A composite covering
3. Wood
4. Wire mesh

1-35. Bolts and heavy gauge wire may be used to fasten links of chain together.

1. True
2. False

1-36. Which of the following defects should you look for during a fiber-line sling inspection?

1. Deterioration caused by exposure to the weather
2. Broken fibers
3. Cut fibers
4. Each of the above

1-37. Wire-rope slings must be replaced when what percentage of wires are nicked or cut?

1. 1 percent
2. 2 percent
3. 3 percent
4. 4 percent

1-38. What type of collateral equipment is used to prevent crushing of a load?

1. Stress slings
2. Cargo pallets
3. Spreader bars
4. Rope slings

1-39. What is the advantage of using cargo pallets?

1. They make the load easier to move
2. They allow single large items to be moved more efficiently
3. Spreader bars do not need to be used
4. Single items may be moved piece by piece

1-40. Which of the following is NOT a requirement for performance as a competent signalman for a crane or hoist operation?

1. Be fully qualified with the operation
2. Ensure the suspended load never passes over anyone
3. Assist in operating the equipment, as needed
4. Wear high-visibility gloves

1-41. To ensure a load is stable and does not shift, you should rig the load so that its center of gravity is positioned in accordance with what requirement?

1. Above the hook
2. In line with the hook
3. Either 1 or 2 above
4. Below the hook

1-42. When the signalman desires to give the equipment operator instructions other than those established beforehand, the operator should perform what action first?

1. Stop all motion of the load
2. Have a runner contact the signalman
3. Blow the horn
4. Raise and lower the load about 2 feet in acknowledgement

1-43. When the distance or atmospheric conditions prevent clear visibility for signaling, what other form of communication should you use?

1. Large Q cards
2. Manual Morse
3. A flashing light
4. Two-way radio

1-44. What is the most important rigging precaution?

1. To determine the proper lifting angle
2. To determine whether hand signals being used are adequate
3. To determine the weight of all loads before attempting a lift
4. To ensure the crane can reach the material safely

1-45. Because gusty wind can affect loading and load-landing operations, you should take which of the following precautions?

1. Wrap the load with a wind-reducing material
2. Avoid handling loads that have large wind-catching surfaces
3. Add additional tie lines
4. Use additional tie-down ropes

1-46. What is the primary cause of death for riggers on the job?

1. Electrocution
2. Falling equipment
3. Cables that snap

1-47. What is the minimum safe working distance from an energized conductor of 125,000 volts?

1. 10 ft
2. 15 ft
3. 20 ft
4. 25 ft

1-48. Refer to figure 1-18 in the text. What is wrong with the lifting procedure?

1. There is only one tag line
2. The hoisting lines are plumb
3. The hoisting lines are not plumb

1-49. Under certain circumstances, it is permissible to ride on a well-rigged load.

1. True
2. False

1-50. OPNAVINST 4110.2 establishes guidance and policy for what subject?

1. Safety precautions and programs
2. Health and physical readiness programs
3. Hazardous material control and management
4. Basic skills for job orientation and OJT programs

1-51. The requirement to comply with a foreign country's HMJHW regulations (if more restrictive) is found in what document(s)?

1. Host nation Status of Forces agreement
2. United States Navy HM/HW regulations
3. United Nations HM/HW regulations
4. U.S. OSHA and EPA regulations

1-52. Of the following OPNAV instructions, which ones cover the use, storage, and disposal of HM?

1. OPNAVINST 1306.1 and 5352.1
2. OPNAVINST 4110.2 and 5100.23
3. OPNAVINST 5354.1 and 1160.4
4. OPNAVINST 5700.7 and 6110.1

1-53. The MSDS identifies the type of personnel protective clothing and equipment needed in the case of exposure.

1. True
2. False

1-54. The battalion air detachment must be capable of deploying within how many hours of notification?

1. 12
2. 24
3. 48
4. 72

1-55. A battalion air detachment should have approximately how many members?

1. 75
2. 90
3. 120
4. 160

1-56. With logistic support intact, an air detachment may operate independently of an NMCB for what total length of time?

1. 1 month
2. 6 months
3. 12 months
4. Indefinitely

1-57. What person assigns members to the air detachment in a battalion?

1. Det OIC
2. OPS officer
3. Company commander
4. Executive officer

1-58. The Table of Allowance equips the battalion for contingency conditions for a total of how many days?

1. 90
2. 120
3. 180
4. 270

1-59. What is the (a) length and (b) width of a 463L pallet cargo space, in inches?

1. (a) 104 (b) 84
2. (a) 108 (b) 84
3. (a) 104 (b) 88
4. (a) 108 (b) 88

1-60. The MOCC is under the direction of what battalion officer?

1. OPS officer
2. Air det OIC
3. Commanding officer
4. Executive officer

1-61. What is the maximum load capacity of a palletized cargo pallet?

1. 2,900 lb
2. 5,000 lb
3. 10,000 lb
4. 15,000 lb

1-62. The construction project platoon is NOT responsible for which of the following tasks?

1. Disaster recovery
2. Rapid runway repairs
3. Construction of advanced bases
4. Assigning heavy equipment for use

1-63. Tool kits should be maintained at what maximum percentage of kit assembly allowance?

1. 100 percent
2. 90 percent
3. 80 percent
4. 75 percent

1-64. On the jobsite, what person is responsible for tool stowage and security?

1. The project safety petty officer
2. The crew members
3. The crew leader
4. The company chief

ASSIGNMENT 2

Textbook Assignment: "Drawings and Specifications," chapter 2, pages 2-1 through 2-26; "Power Generation," chapter 3, pages 3-1 through 3-27.

2-1. Planning, scheduling, and manpower and material estimating are based on the information contained in which of the following sources?

1. Operating schedules
2. Operating checks
3. Maintenance records
4. Blueprints

2-2. Diagrams and schematics are maps that indicate which of the following information?

1. Configuration of circuits
2. Circuit connections
3. Components of electrical equipment
4. Each of the above

2-3. Diagrams and schematics are an invaluable aid when used properly for which of the following purposes?

1. Project installation
2. Electrical troubleshooting
3. Repair of electrical components
4. Each of the above

2-4. American National Standard Institute (ANSI) is the mandatory publication used by the Navy for graphic and wiring symbols.

1. True
2. False

2-5. What letters designate the title block for electrical and mechanical drawings?

1. P and W
2. E and M
3. A and C
4. E and S

2-6. Blueprints are identified in the title block by which of the following methods?

1. By a designation letter in the lower right-hand comer
2. By a drawing number in the lower left-hand comer
3. Both 1 and 2 above
4. By a drawing number in the lower right-hand comer

2-7. The blueprint revision block is usually noted in what location?

1. Upper right-hand comer
2. Lower right-hand comer
3. Upper left-hand comer
4. Lower left-hand comer

2-8. Original drawings are scaled accurately, but your drawing may be reduced slightly.

1. True
2. False

2-9. The term “blueprint reading” means interpreting the ideas expressed by others.

1. True
2. False

2-10. The legend block on a blueprint defines what information?

1. Construction materials
2. Symbols and special marks
3. Equipment parts
4. The work schedules

2-11. Which of the following graphic symbols represents a duplex receptacle outlet, split-wired?

1. 
2. 

3. 
4. 

CEJA0029

2-12. The “bill of materials” block on a blueprint identifies parts and materials by stock number or other appropriate number and also lists the quantity used or required.

1. True
2. False

2-13. The standard procedure for supplementing construction drawings with written descriptions is known by what name?

1. NCF construction manual procedures
2. Project workmanship procedures
3. Fabrication specifications
4. Specifications

2-14. The specification standards for NCF construction projects are prepared by what authority?

1. CINCLANTFLT
2. NAVFACENGCOM
3. COMCBLANT
4. CINCPACFLT

2-15. The Naval Facilities Engineering Command prepares what type of specifications?

1. Federal
2. Military
3. NAVFAC
4. Project

2-16. Why are specifications important to a construction project?

1. They define instructions from the engineer
2. They eliminate possible misinterpretation and ensure positive control of the project
3. They show the time limits for each step of the project
4. They list the tools needed for the project

2-17. Federal specifications dictate what level of requirement?

1. Minimum
2. Satisfactory
3. Fully acceptable
4. Maximum

2-18. What type of specification designates technical requirements and tests for materials, products, and services used on a construction project?

1. Federal
2. Military
3. NAVFAC
4. Project

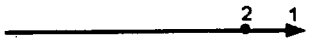
2-19. When there is conflicting information between the project drawings and project specifications, what decision should you make?

1. Ask the resident officer in charge of construction (ROICC) to clarify the information
2. Follow the project specifications
3. Follow the project drawings
4. Ask the operations department to clarify the information

2-20. A directional symbol on a project blueprint is usually identified in what way?

1. By a circle labeled "S"
2. By a circle labeled "P"
3. By an arrow labeled "S"
4. By an arrow labeled "N"

2-21. Which of the following architectural symbols depicts wiring concealed in a floor?

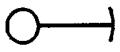
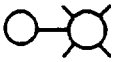
1.
2. 

3.
4.

CEJA0030

2-22. Which of the following graphic symbols represents a power pole with a streetlight?

1. 
2. 

3. 
4. 

CEJA0031

2-23. Nonstandard symbol(s) is/are located under what drawing heading?

1. Title block
2. Legend
3. Notes
4. Bill of materials

2-24. What type of drawing is informal in character?

1. Customer drawing
2. Engineering drawing
3. Freehand sketches
4. Architectural drawings

2-25. What construction drawings are sometimes used interchangeably?

1. Preliminary and secondary
2. Customer and designer
3. Working and construction
4. Architectural and engineering

2-26. Generally, working drawings are divided into a total of how many categories?

1. One
2. Two
3. Three
4. Four

2-27. What is another name for a plot plan?

1. Floor plan
2. Detail plan
3. Sectional plan
4. Site plan

2-28. What type of plan shows the changes in the surrounding area where buried cable or conduit will be located?

1. Floor plan
2. Detail plan
3. Sectional plan
4. Site plan

2-29. What type of drawing represents a view of a finished structure?

1. Floor
2. Elevation
3. Selection
4. Detail

2-30. Mechanical drawings include which of the following drawing systems?

1. Refrigeration and air conditioning
2. Heating and ventilating
3. Water supply, sewage, and drainage
4. Each of the above

2-31. What type of electrical diagram shows the relationship of major parts of a wiring circuit?

1. Isometric
2. Block
3. Wiring
4. Connection

2-32. What type of electrical diagram shows the wiring between components and the relative position of the components?

1. Block
2. Electrical
3. Wiring
4. Isometric

2-33. What type of electrical diagram is a valuable troubleshooting tool?

1. Connection
2. Wiring
3. Electrical
4. Schematic

2-34. What type of electrical diagram uses symbols instead of pictures to show electrical connections?

1. Wiring
2. Schematic
3. Block
4. Isometric

2-35. What noise level hazard is associated with the operation of a 60-kilowatt generator?

1. 50 dBa to 75 dBa, with no protection required
2. 84 dBa to 91 dBa, needs single- or double-hearing protection
3. 65 dBa to 83 dBa, with no protection required
4. 84 dBa to 91 dBa, with no protection required

2-36. A generator supplying power for an advanced base should be in what location?

1. At the barracks site
2. At the edge of the base
3. At the point of smallest demand
4. At the point of largest demand

2-37. Because of noise levels, fire hazards, and air circulation, Navy regulations require that you separate a generator from the load by at least how many feet?

1. 25
2. 20
3. 15
4. 10

2-38. A generator should not be operated while inclined more than how many degrees from level?

1. 5°
2. 10°
3. 15°
4. 25°

2-39. Paralleling generator sets must be within how many feet of each other?

1. 15
2. 25
3. 50
4. 75

2-40. An auxiliary fuel supply must be located within how many feet of a generator?

1. 15
2. 25
3. 50
4. 75

2-41. Which of the following pieces of information is NOT required by builders to construct a generator shelter?

1. Arrangement of the exhaust system
2. Number of generators to be sheltered
3. Size of the generators
4. Electrical power load

2-42. What device(s), connected in parallel, permit(s) easy connection to batteries to supply power?

1. Battery release component
2. Battery quick-release pin
3. Power receptacle
4. Two-slave receptacles

2-43. You are preparing your own electrolyte for a battery needed to start an advanced-base electric power generator. You are using an acid of 1.835 specific gravity and desire a specific gravity of 1.290. What proportion of (a) water to (b) acid should you use to achieve the desired specific gravity?

1. (a) 8 (b) 3
2. (a) 11 (b) 3
3. (a) 8 (b) 4
4. (a) 11 (b) 4

2-44. The temperature of electrolyte placed in a battery should be within what temperature range?

1. 50°F to 90°F
2. 60°F to 90°F
3. 50°F to 100°F
4. 60°F to 100°F

2-45. Before putting a battery freshly filled with electrolyte into service, you should let it stand for at least how long?

1. 5 min
2. 20 min
3. 1 hr
4. 24 hr

2-46. When making battery connections on a generator set, you should always connect the negative battery terminals last.

1. True
2. False

2-47. What type of charge is given to generator batteries as part of the normal maintenance routine?

1. Fast charge
2. Equalizing
3. Normal

2-48. When a battery is being charged, what substance is being released at (a) the positive plates and (b) the negative plates?

1. (a) Oxygen (b) hydrogen
2. (a) Electrolyte (b) water
3. (a) Hydrogen (b) oxygen
4. (a) Water (b) electrolyte

2-49. When charging a battery, you should never allow the temperature of the electrolyte to exceed what maximum temperature?

1. 110°F
2. 115°F
3. 120°F
4. 125°F

2-50. After using a hydrometer, you should flush it out with fresh water.

1. True
2. False

2-51. The water coolant level of a generator radiator should be within how many inches of the top?

1. 1
2. 2
3. 3
4. 4

2-52. After filling the radiator of a generator with a coolant, you should take which, if any, of the following actions?

1. Let the coolant sit in the radiator for a minimum of 1 hr before you start the generator set
2. Fasten a tag near the radiator cap indicating the type and degree of protection the coolant provides
3. Use an antifreeze solution tester to ensure the antifreeze content is sufficient for the existing temperature
4. None of the above

2-53. The day tank on a generator serves which of the following functions?

1. It permits engine operation for at least an additional 12 min
2. It provides a settling point for contaminants
3. It provides an area for draining the fuel tank
4. It permits engine operation for a minimum of 5 min

2-54. On a generator engine exhaust, what is the purpose of the hinged cap?

1. It provides information on how the engine is running
2. It prevents birds from constructing nests in the exhaust system
3. It prevents water from entering the exhaust system
4. It enables the engine to be choked in an emergency

2-55. When grounding a generator with a driven metal rod (solid), you must ensure that the ground rod meets or exceeds which of the following standards?

1. It is embedded below the permanent moisture level
2. It has a minimum diameter of 5/8 in.
3. It is driven to a minimum depth of 8 ft
4. Both 2 and 3 above

2-56. When connecting the ground rod to the generator set, you should use a ground lead of at least what minimum size?

1. 6 AWG
2. 8 AWG
3. 10 AWG
4. 12 AWG

2-57. The NEC states that if you are using a single ground rod to ground a generator set, it must have what maximum resistance to ground?

1. 25 ohms
2. 30 ohms
3. 35 ohms
4. 40 ohms

2-58. In cold weather locations where multiple ground rods are needed to bring the resistance down to the correct ohm reading, the rods should be separated by what minimum distance?

1. 8 ft
2. 2 ft
3. 6 ft
4. 4 ft

2-59. How should you convert generator voltage output from 120/208 volts to 240/416 volts?

1. By transposing any two wires on the load terminal block
2. By positioning the voltage change board to the voltage desired
3. By flipping one of the change boards over and installing it for the voltage desired
4. By installing a transformer for the desired voltage

2-60. You are instructed to check the phase sequence of an incoming alternator and make the hookup. After you connect phase sequence meter lead A to X_1, B to Y_1, and C to Z_1, the meter rotates counterclockwise. When you connect meter lead A to X, B to Y, and C to Z, the meter rotates clockwise. What are the correct hookup connections?

1. X to X_1, Y to Y_1, and Z to Z_1
2. Z to X_1, Y to Z_1, and X to Y_1
3. X to Y_1, Y to X_1, and Z to Z_1
4. X to Z_1, Y to X_1, and Z to Y_1

2-61. When inspecting a generator, you should check which of the following fluid levels?

1. Fuel
2. Radiator coolant
3. Crankcase lubricant
4. Each of the above

2-62. Which of the following devices can be used to ring out unmarked conductors in a conduit?

1. Ohmmeter
2. Bell and battery
3. Buzzer and battery
4. Each of the above

2-63. One purpose for keeping a generator station log is to help determine when a particular piece of equipment needs preventive maintenance.

1. True
2. False

2-64. A generator station log must contain descriptions of not only the hourly performance of the generator but also the performance of all controlling and indicating devices of the equipment.

1. True
2. False

IN ANSWERING QUESTION 2-65, REFER TO FIGURE 3-19 IN THE TEXT.

2-65. The generator control cubicle is divided into an engine section and what other section?

1. Indicator
2. Generator
3. Production
4. Paralleling

2-66. When starting a generator set, you note that the air cleaner condition indicator lamp is ht. What does this indicate?

1. The generator has not yet cranked
2. The louvers are not open
3. The air cleaner is functioning properly
4. The air cleaner requires servicing

2-67. Normally, a generator should be allowed to warm up what minimum length of time before a load is applied?

1. 1-2 min
2. 3-4 min
3. 5 min
4. 10 min

2-68. When the generator kilowatt meter indicates that more than the rated kilowatts are being consumed, what action, if any, should you take?

1. Open the circuit breaker
2. Rotate the voltage adjustment control
3. Reduce the load
4. None

2-69. When you notice a significant change in the coolant temperature of a generator that is in operation, what action should you take?

1. Reduce the load
2. Notify maintenance personnel
3. Remove the generator from the line
4. Check the operator's log to see if this is a recurring event

2-70. Before one or more ac generators may be operated in parallel to feed a single bus, the output must be carefully matched in all of the following characteristics except which one?

1. Current
2. Frequency
3. Phase relationship
4. Voltage

2-71. When you attempt to parallel two generators and the main circuit breaker opens on either generator, what is the most probable cause?

1. The phase sequence or voltage levels are incorrect
2. The output is slightly out of phase
3. The incoming generator is defective
4. The incoming generator is losing speed

2-72. During paralleling operations, the synchronizing lights do not blink on and off in unison. What is the most probable cause?

1. Voltage levels to the two generators are not the same
2. The phase sequence is not correct
3. The incoming generator is defective

2-73. An outgoing generator should run with no load for about what length of time before you shut it off?

1. 1-2 min
2. 3-4 min
3. 5 min
4. 10 min

2-74. Testing and replacement of faulty generator components are included in what category of maintenance?

1. Depot
2. Intermediate
3. Routine
4. Organizational

2-75. What is the purpose of generator preventive maintenance?

1. To provide accurate records on each individual generator
2. To eliminate problems for the generator operator
3. To provide jobs for maintenance personnel
4. To keep the generator running trouble-free

ASSIGNMENT 3

Textbook Assignment: "Power Distribution," chapter 4, pages 4-1 through 4-45.

3-1. A power distribution system includes all the parts of an electrical system between the power source and the customer's service entrance.

1. True
2. False

3-2. What is the primary purpose of a line crew?

1. To meet the project completion date
2. To ensure on-the-job safety
3. To control cost overruns

3-3. A hard hat for a line crew member must be rated to withstand what maximum voltage?

1. 5,000
2. 10,000
3. 20,000
4. 30,000

3-4. When should you install grounding sets on a jobsite?

1. When working on new construction
2. When the disconnecting means is not in sight
3. When the line crew is spread out over a long span of pole-line construction

3-5. What is the minimum required clearance, in feet, between crew personnel and a 20,000-volt circuit?

1. 6
2. 2
3. 3
4. 8

3-6. What is the most popular type of anchor?

1. Plate
2. Never-creep
3. Deadman
4. Expanding

3-7. A "down guy" used at the end of a pole line to counterbalance the pull of the line conductors is what type of guy?

1. Balancing
2. Counterbalance
3. Counteracting
4. Terminal

3-8. Guys installed to protect the facilities and limit the damage if a conductor breaks are known by what term?

1. Storm guys
2. Line guys
3. Both 1 and 2 above
4. Span guys

3-9. An anchor guy with a horizontal strut at a height above the sidewalk to clear the pedestrians is referred to as a head guy.

1. True
2. False

3-10. What type of guy is used to transfer the strain on a pole to another structure?

1. Arm
2. Head
3. Span
4. Stub

3-11. What type of guy is used on steep hills to counteract the downhill strain of the line?

1. Arm
2. Head
3. Span
4. Stub

3-12. What type of guy is used to counteract the force caused by an uneven number of dead-end conductors on one side of a crossarm than on the other?

1. Arm
2. Head
3. Span
4. Stub

3-13. What type of guy is installed between a line pole and a pole on which there is no energized equipment?

1. Arm
2. Head
3. Span
4. Stub

3-14. What type of guy is often installed to obtain adequate clearance for guy wires extending across a street or highway?

1. Arm
2. Head
3. Span
4. Stub

3-15. When there is no excessive strain, single crossarms should be installed in a straight line in what manner?

1. Every other crossarm should face the same direction
2. All crossarms should face north if the distribution system is running north and south
3. All crossarms should face east if the distribution system is running east and west
4. All crossarms should face the same direction

3-16. Double crossarms are used for which of the following purposes?

1. To eliminate excessive strain
2. To provide additional safety whenever the line terminates
3. To provide support at comers and angles
4. Each of the above

3-17. When a branch circuit takes off at a right angle to the main line, what type of crossarm is required?

1. Double
2. Buck
3. Side
4. Single

3-18. What factor determines the spacing of insulator pins?

1. The length of the crossarm
2. The size of insulator pins
3. The line voltage
4. The quantity of insulator pins

3-19. What is the purpose of guying a pole?

1. To maintain proper leveling of crossarms
2. To keep a pole-mounted transformer from pulling a pole out of alignment
3. To offset the strain applied on the pole from a load pulling in the opposite direction
4. To aid in the proper sag of individual wire spans

3-20. What type of insulator should be used when the right-of-way is narrow?

1. Post
2. Pin
3. Suspension
4. Strain

3-21. What, in anything, can be done to suspension insulators that permits the same-size insulator to be used for varying high voltage?

1. Redip the insulators in epoxy
2. Link the insulators together
3. Insert fiber glass sheets between the insulators
4. Nothing

3-22. What type of conductor wire is commonly used for line conductors?

1. Hard-drawn copper
2. Annealed copper
3. Medium-hard-drawn copper
4. Aluminum and aluminum/steel

3-23. Aluminum wire when compared to copper wire has what percentage of conductivity?

1. 80%
2. 66%
3. 60%
4. 45%

3-24. Conductors are classified as solid or stranded.

1. True
2. False

3-25. What is the largest and smallest size of conductors used in distribution systems?

1. 5/0 and 0
2. 2/0 and 0000
3. 3/0 and 20
4. 4/0 and 30

3-26. What is the purpose of the distribution substation system?

1. It changes distribution circuit voltage to transmission voltage
2. It changes transmission voltage to distribution circuit voltage
3. It changes distribution circuit voltage to usable 120/240 volts
4. It changes three-phase voltage to single-phase voltage

3-27. A distribution transformer reduces the voltage of the distribution circuit to a usable voltage, usually 120/240 volts.

1. True
2. False

3-28. Which of the following cutouts, when blown, causes the resultant arc to attack the walls of the fiber tube?

1. Open link
2. Enclosed fuse
3. Open fuse

3-29. What type of primary circuit is used when lighting makes up the substantial portion of the load?

1. Wye-delta
2. Delta-wye
3. Delta
4. Wye

3-30. A secondary circuit carries 600 Vac or less.

1. True
2. False

3-31. When installing a service drop over a driveway, you must maintain a minimum aboveground clearance of how many feet?

1. 18
2. 16
3. 14
4. 12

3-32. What is the purpose of the distribution lightning arresters?

1. They protect the insulators
2. They protect the distribution transformers
3. They protect the fuse cutouts
4. Each of the above

3-33. High-voltage switches are divided into what general classes?

1. Air
2. Oil
3. Vacuum
4. Each of the above

3-34. Of the following types of switches, which one produces an arc when a current-carrying circuit is opened?

1. Air
2. Oil
3. Vacuum
4. Manual

3-35. A three-phase, air-break switch is opened in what manner?

1. Manually, one phase opens at a time only
2. Automatically, one phase opens at a time only
3. Manually or automatically, all phases open at the same time
4. Manually or automatically, one phase opens at a time

3-36. What type of high-voltage switch should NOT be opened under load?

1. Oil
2. Air
3. Vacuum

3-37. The purpose of a disconnect switch is to isolate a line so it is dead electrically.

1. True
2. False

3-38. High-voltage oil switches are immersed in oil for what primary reason?

1. To keep the switch from corroding
2. To keep the switching mechanism lubricated
3. To break the circuit when the switch is opened
4. To keep the switching mechanism cool

3-39. An oil recloser can perform which, if any, of the following actions?

1. It automatically recloses the open circuit after detecting an overload fault in the system
2. It carries excessive current for a period of 5 minutes
3. It opens a circuit once an overload fault has cleared
4. None of the above

3-40. When may you find all three phases of an oil switch in one container?

1. When the container is large enough to accommodate all three phases
2. When it is important to open all extremely high-voltage switches together
3. When they are pad-mounted only
4. When the voltage is not extremely high

3-41. When linemen place a recloser in the "single-shot" mode, it is for what reason?

1. So it resets automatically
2. So it cannot reset automatically
3. So it resets only one time
4. So it resets only three times

3-42. Aerial bucket trucks are essential when working on what type of poles?

1. Wooden poles
2. Concrete poles
3. Steel poles
4. Both 2 and 3 above

3-43. An earth auger is designed to dig holes up to how many feet deep?

1. 5
2. 6
3. 7
4. 8

3-44. What type of power distribution equipment is most commonly used to set poles?

1. Utility truck
2. Aerial bucket truck
3. Earth auger
4. Each of the above

3-45. What is the purpose of a pole gin?

1. It keeps the pole straight
2. It lifts the pole in place
3. It provides a secure point for attaching other lifting equipment
4. It keeps the pole from falling during manual pike lifting

3-46. Which of the following advantages is/are apparent when you use a block and tackle?

1. The user can pull downward while lifting the load
2. The manual force being applied need only be a fraction of the weight of the load being lifted
3. Both 1 and 2 above
4. Support equipment is not required

3-47. Snatch blocks ordinarily are used when it is necessary to change the direction of the pull on a line.

1. True
2. False

3-48. When you are operating a bucket truck, what should be your prime concern?

1. Smooth operation
2. Job completion time
3. Safety of operation
4. Insulation from high-power lines

3-49. The handline is considered a piece of personal equipment.

1. True
2. False

3-50. The bulldog grip is used for which of the following tasks?

1. To straighten conductors
2. To pull ground rods
3. To apply strain on guy wires

3-51. What is the purpose of putting the face of a pole on the inside curve?

1. To make all the poles uniform
2. To allow the strain on the crossarms to be against the curve of the pole
3. To eliminate the use of guy wires
4. To conform to a common practice used by all linemen

3-52. A gain should be installed how many inches from the top of a utility pole?

1. 12
2. 18
3. 24
4. 30

3-53. At what depth should you set a 60-foot pole, in soil?

1. 5 ft
2. 7 ft
3. 8 ft
4. 11 ft

3-54. At what sloping angle, if any, should the roof or the top of a new pressure-treated pole be cut?

1. 10^{o}
2. 15°
3. 20°
4. None

3-55. What tools should you use to remove dirt from a hole 4 feet deep that has been dug manually?

1. Pick and shovel
2. Pick and spoon shovel
3. Shovel and digging bar
4. Digging bar and spoon shovel

3-56. To allow for tamping backfill, you should ensure the hole is approximately how many inches larger than the base of the pole?

1. 10
2. 8
3. 6
4. 4

3-57. When you are raising a pole, what device serves as a support at each new position to temporarily support the weight of the pole?

1. A butt board
2. A jenny
3. A cant hook
4. A crossarm

3-58. When erecting a power-line pole, a piker should brace the pike pole on his stomach.

1. True
2. False

3-59. Assume you are mounting a crossarm on a pole. After you have set the pole, what steps are necessary to complete the crossarm installation?

1. Leveling the crossarm and fastening the crossarm braces to the pole only
2. Leveling the crossarm and tightening the through bolt only
3. Tightening the through bolt and fastening the crossarm braces to the pole only
4. Leveling the crossarm, fastening the crossarm braces to the pole, and tightening the through bolt

3-60. Normally, when conductors are being strung, they are taken from a reel that is

1. rolled over the ground
2. held solidly in place
3. mounted on an axle that revolves freely
4. placed on its side and left free to turn

3-61. For what purpose is the neutral conductor placed on a center crossarm pin?

1. To provide a clear space for the lineman to climb through
2. To serve as a way of identifying hot conductors
3. To conform to traditional Navy practices

3-62. When wires have been pulled to approximately the desired position, a lineman should measure the sag at what location(s)?

1. On the end nearest the cable reel
2. At the center of the span
3. In a span on either end of the group of spans
4. On the end farthest from the cable reel

3-63. To ensure that lines are installed correctly, you should use what method(s) to measure line sag?

1. Traction dynamometer
2. Target sighting
3. Timing vibration
4. Each of the above

3-64. Refer to table 4-2 in the text. What is the desired sag for a 175-foot span of AWG No. 2 wire at 60°F?

1. 13.0 in.
2. 16.5 in.
3. 22.0 in.
4. 28.0 in.

3-65. After stringing and sagging the conductors properly, when should you tie the conductors to the insulators?

1. After 1/2 hours, but before 4 hours, depending upon the length of the run
2. After 24 hours, regardless of the size of the wire or the length of the run
3. As soon a possible
4. After exactly 2 hours

3-66. Concerning the use of tie wire in tying-in conductors, which of the following statements is correct?

1. You should not wrap the tie wire too tightly
2. You should always use annealed tie wire
3. You may reuse tie wires that are long enough
4. You should always use No. 2 tie wire

3-67. On power distribution lines, pole ground connections are required at which of the following intervals?

1. Every mile only
2. Every pole
3. Every pole with equipment
4. Every other pole

3-68. On existing distribution lines, the pole ground rods should be (a) how many inches in diameter and (b) how many feet long?

1. (a) 5/8 (b) 8
2. (a) 5/8 (b) 10
3. (a) 3/4 (b) 8
4. (a) 3/4 (b) 10

3-69. Upon discovering enlarged tongue holes on your body belt, you should replace the body belt.

1. True
2. False

3-70. The minimum satisfactory length of pole gaffs on the inner surface of lineman's climbers is at least

1. 5 1/2 in.
2. 3 1/2 in.
3. 1 1/4 in.
4. 1 in.

3-71. Gaffs should be sharpened in what manner?

1. With an emery wheel, but not to a needlepoint
2. With an emery wheel, to a needlepoint
3. With a file, but not to a needlepoint
4. With a file, to a needlepoint

3-72. While climbing a pole with the aid of climbers, you must grasp each side of the pole with your hands for what primary reason?

1. To support a part of your weight
2. To provide proper balance
3. To aid in sinking the gaffs into the pole
4. To maintain a stiff-legged, position

3-73. You have climbed a pole to the desired height and have positioned your feet so the left foot is slightly higher than the right with the knees slightly bent. You are now ready to secure the pole strap. What should be your next action?

1. Unsnap one end of the pole strap
2. Wrap your right arm around the pole
3. Crook your left arm around the pole
4. Grasp one end of the pole strap with your left hand

3-74. When performing pole-top rescue on an electric shock victim, you should perform what step first?

1. Clear the victim from any live conductors
2. Contact someone who can assist you
3. Provide for your own safety
4. Evaluate the situation

3-75. When performing pole-top rescue, you should use what type of knot in the line to lower a victim?

1. Blackwall hitch
2. Square
3. Clove hitch
4. Three half-hitches

ASSIGNMENT 4

Textbook Assignment: "Interior Wiring," chapter 5, pages 5-1 through 5-45.

4-1. What is the purpose of the National Electrical Code (NEC®)?

1. To safeguard the contents of buildings only
2. To safeguard personnel and buildings only
3. To safeguard personnel, buildings, and contents of buildings
4. To establish maximum electrical standards

4-2. A conductor used in connecting equipment in the circuit of a wiring system to a grounding electrode or electrodes is described by what term?

1. Grounded
2. Grounded conductor
3. Grounding conductor

4-3. A circuit conductor that is grounded intentionally is described by what term?

1. Grounded
2. Grounded conductor
3. Grounding conductor

4-4. What term means connected to the earth or to some other conducting body that serves in place of the earth?

1. Grounded
2. Grounded conductor
3. Grounding conductor

4-5. What common wiring system is used in housing to provide 110/220-volt services?

1. Two-wire, single-phase system
2. Three-wire, single-phase system
3. Three-wire, three-phase system
4. Four-wire, three-phase system

4-6. A four-wire electrical system typically has how many (a) hot wires and (b) neutral wires?

1. (a) Three (b) two
2. (a) Four (b) one
3. (a) Three (b) one
4. (a) Four (b) two

4-7. What device is installed as part of the service entrance to record power consumption?

1. Current transformer
2. Watt-hour meter socket
3. Wattmeter
4. Voltage recorder meter

4-8. The service entrance must provide a means for disconnecting the service entrance conductors from the interior building circuits.

1. True
2. False

4-9. Overcurrent protective devices are required for many types of electrical circuits; however, they are not required for service conductors in conjunction with the service disconnects.

1. True
2. False

4-10. Which of the following overcurrent protection devices are permitted with service entrances?

1. Fuse blocks
2. Circuit breakers
3. Knife-blade switches
4. Each of the above

4-11. A metal underground water pipe may be used as the primary grounding electrode when it is in direct contact with the earth for a minimum of how many feet?

1. 10
2. 15
3. 20
4. 25

4-12. What type of wiring is used most frequently for interior wiring jobs?

1. Solid No. 14 AWG
2. Solid No. 12 AWG
3. Stranded No. 14 AWG
4. Stranded No. 10 AWG

4-13. What is the current-carrying capacity of each conductor when you have ten No. 12 AWG conductors in the same conduit?

1. 12 A
2. 14 A
3. 17.5 A
4. 20 A

4-14. What information is shown on the outer jacket of nonmetallic cable?

1. Manufacturer's name or trademark
2. Maximum working voltage
3. Wire size and cable type
4. Each of the above

4-15. When a length of 7/8-inch-diameter Romex cable is run in a Quonset hut, it is necessary to make some 90-degree bends. What is the minimum radius of a bend, in inches, for this cable?

1. 1.3
2. 4.4
3. 6.0
4. 7.5

4-16. A conductor must be provided free air space in a box for what primary reason?

1. So it has enough space for splicing
2. So it has enough space for a device
3. So heat does not build up
4. So the cover fits securely in place

4-17. Conductors that run through or terminate in an outlet box are counted in what manner?

1. Each conductor, be it fixture wire or grounding wire, is counted as one wire each
2. Fixture wire and grounding wires are counted together as one
3. Each conductor that enters the box counts as two wires
4. Each conductor that terminates is counted as one; internal grounding wire and fixture wires are not counted

4-18. What causes an "A" bracket to make an extremely strong mounting?

1. It is made to be welded
2. It is boxed-in on all sides
3. It is nailed from both front and side
4. It is made so the wall material holds it in place

4-19. In houses, what is the most popular installation height for receptacle outlet boxes?

1. One foot from the floor line
2. Hammer length height
3. Any convenient height
4. Just above the finishing material

4-20. What is the normal mounting height, in inches, for switch boxes and outlet boxes in a laundry room?

1. 44
2. 46
3. 48
4. 50

4-21. What are the stages for installing nonmetallic cable?

1. Roughing in and roughing out
2. Roughing in and finish work
3. Finishing up and finish work
4. Routing and finish product

4-22. The electrical print requires that you run a concealed cable perpendicular in a floor joist above a basement floor. How should the cable be run?

1. Through bored holes in the floor joist or in notches cut into the floor joist
2. Across the edges of the joist and secured with straps
3. Through rigid steel conduit strapped to the joist
4. Through Type I plastic conduit strapped to the hoist

4-23. When roughing in, what amount of cable, in inches, should you leave in the box to attach devices?

1. 10
2. 8
3. 6
4. 4

4-24. What type of electrical grounding consists of connecting all exposed noncurrent-carrying metal parts to earth?

1. Equipment
2. Lighting
3. System
4. Ground rod

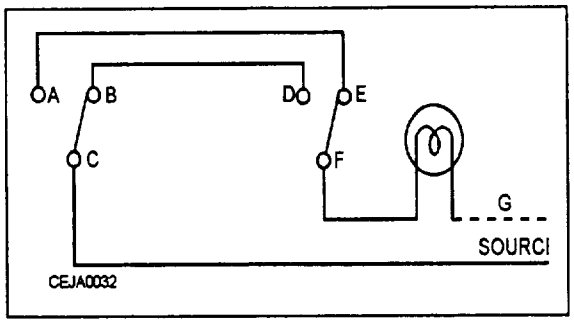


Figure 4A

IN ANSWERING QUESTIONS 4-25 AND 4-26, REFER TO FIGURE 4A.

4-25. What does the broken line "G" represent?

1. The hot wire
2. The neutral
3. The traveler
4. The toggle

4-26. Which of the following switch blade letter combinations will cause the lamp in the circuit NOT to light?

1. AC and EF
2. BC and DF
3. BC and EF

4-27. In remote-control wiring systems, low-voltage transformers reduce 120 volts to what usable voltage?

1. 12 V
2. 24 V
3. 45 V
4. 75 V

4-28. A conduit threading die is used for which of the following reasons?

1. To thread conduit over 1 -inch diameter only
2. To make a tapered thread on conduit
3. To thread and cut conduit in one operation

4-29. The solvent-welding technique for joining PVC conduit is superior because the finished joints are

1. waterproof and vaporproof
2. explosionproof
3. corrosion resistant

4-30. What number of 90-degree bends are permitted in a run of conduit?

1. One
2. Two
3. Five
4. Four

4-31. What type of bender makes a full 90-degree bend in conduit with a single motion?

1. Sweep
2. Hickey
3. Field
4. One-shot

4-32. The distance from the back of a 90-degree bend to the end of the conduit is referred to by what term?

1. Stub-up
2. Radius
3. Take-up
4. Offset measurement

4-33. Two adjacent 90-degree bends in the same conduit make up what type of bend?

1. Box-offset
2. Double-right-angle
3. Double-offset
4. Back-to-back

4-34. Offset bends are used to avoid contacting a part of the structure or to bring the conduit out from the structure to match a knockout in a box or panel.

1. True
2. False

4-35. The practice of taking small bites to reduce kinking or crimping should be used when you are bending with what type of bender?

1. One-shot
2. EMT
3. Hickey
4. Hydraulic

4-36. Generally, what is the smallest size raceway that can be installed?

1. 1/4 in.
2. 3/8 in.
3. 1/2 in.
4. 3/4 in.

4-37. EMT and IMC conduit must be supported (a) within how many feet of each box and (b) at intervals of how many feet thereafter?

1. (a) 1.5 (b) 10
2. (a) 1.5 (b) 6
3. (a) 3 (b) 10
4. (a) 3 (b) 6

4-38. Flexible metal conduit must be supported within how many inches of each box or fitting?

1. 12
2. 18
3. 24
4. 36

4-39. A CE finds that a run of conduit between boxes will have five 90-degree bends. What, if anything, should the CE do to complete the conduit run?

1. Use a concealed Condulet
2. Increase the radius of each bend
3. Use a Condulet instead of one of the bends
4. Nothing

4-40. According to the NEC®, the bends in one conduit run cannot exceed how many degrees?

1. 120°
2. 240°
3. 300°
4. 360°

4-41. Which of the following tools is/are required to restore a hook on the end of a fish tape?

1. A set of vise grips
2. A vise and pair of pliers
3. A pair of longnose pliers and a pair of side-cutting pliers
4. A pair of pliers and a torch

4-42. What advantage is there when you pull conductors from the second floor of a structure to the first floor?

1. A fish tape is not required
2. The weight of the wires helps in the pull
3. The task only requires one person

4-43. Which of the following tools makes a good handle for pulling a fish tape?

1. Hammer
2. Side-cutting pliers
3. Adjustable wrench
4. Open-end wrench

4-44. What condition occurs when too many conductors have been installed in the conduit?

1. The power factor improves
2. The smaller conductors ampacity improves
3. Overheating occurs and the conductor ampacity decreases
4. Overheating occurs and the conductor ampacity increases

4-45. What explosion hazard classification identifies the most hazardous condition?

1. Class 1, division 1
2. Class 2, division 1
3. Class 1, division 2
4. Class 2, division 2

4-46. Where is the most hazardous space inside a gasoline station?

1. Within 18 inches of the floor
2. Within 18 inches of the ceiling
3. Between the spaces described in 1 and 2 above

4-47. Not counting the main, what maximum number of overcurrent devices are authorized for lighting and appliance panelboards?

1. 24
2. 30
3. 36
4. 42

4-48. A single overcurrent device in a panelboard must not exceed what percentage of its capacity?

1. 125%
2. 100%
3. 80%
4. 75%

4-49. In a three-phase panelboard, what phase, if any, should be clearly marked?

1. A
2. B
3. C
4. None

4-50. What is the maximum voltage, if any, of a knife-blade fuse?

1. 6,000 volts
2. 600 volts
3. 60 volts
4. None

4-51. What are the three classes of circuit breakers?

1. Instantaneous, time-delay, and intermediate
2. Thermal, magnetic, and combination thermal-magnetic
3. Thermal, magnetic, and time-delay
4. Instantaneous, combination, and intermediate

4-52. Which of the following circuits in a home requires the use of a GFCI type of circuit breaker?

1. 120-V/20-A receptacles in bathrooms
2. 120-V/20-A receptacles in bedrooms
3. 240-V/30-A dryer circuit
4. 240-V/30-A range circuit

4-53. What is the purpose of balancing the load on a panelboard?

1. To increase voltage drop
2. To reduce total current flow
3. To increase neutral current flow
4. To reduce voltage drop

4-54. What are the three types of shorts or grounds?

1. Full, solid, and recurring
2. Solid, floating, and recurring
3. Full, partial, and floating
4. Solid, partial, and floating

4-55. Which of the following meters can NOT be used on an energized circuit?

1. Voltmeter
2. Ohmmeter
3. Ammeter
4. Phase rotation meter

4-56. When choosing continuity testing equipment, it is of primary importance that you select

1. low-resistance instruments to prevent arcing
2. high-current instruments for accuracy
3. low-power-draw instruments to save energy
4. low-voltage instruments to reduce sparking

4-57. When you take a voltage reading on the neutral side of an inoperative lamp to ground and you read applied voltage, what condition is indicated?

1. An open in the ungrounded conductor
2. An open in the grounded conductor
3. A short in the lamp
4. A ground in the circuit

4-58. What happens to a circuit when a resistor is put in series with the circuit?

1. The current increases, causing the lamps to be brighter
2. The current remains constant, but the lamps become dimmer
3. The current decreases, causing the lamps to be brighter
4. The current decreases, causing the lamps to be dimmer

4-59. When you are operating a lamp below the rated voltage, lamp life is decreased with a sacrifice in light output.

1. True
2. False

TYPES OF LAMPS

A. Clear
B. Quartz-Iodine
C. Hard Glass
D. Long Life

Figure 4B

I-N ANSWERING QUESTIONS 4-60 THROUGH 4-62, SELECT FROM FIGURE 4B THE TYPE OF LAMP THAT MATCHES THE CHARACTERISTICS GIVEN AS THE QUESTION.

4-60. Made of special glass with high resistance to thermal shock.

1. A
2. B
3. C
4. D

4-61. Installed where lamp replacement costs are high.

1. A
2. B
3. C
4. D

4-62. Lasts twice as long as regular general-service incandescent lamps.

1. A
2. B
3. C
4. D

4-63. A ballast is required in a fluorescent lamp for what reason?

1. To limit current and supply proper voltage
2. To limit voltage and supply proper current
3. To act as a capacitor and improve the power factor
4. To act as a reactor and improve the power factor

IN ANSWERING QUESTIONS 4-64 THROUGH 4-66, REFER TO TABLE 5-6 IN THE TEXT.

4-64. Which of the following conditions can cause incandescent lamps in a lighting circuit to burn out frequently?

1. High voltage
2 Excessive vibration
3. Wrong rating for conditions
4. Each of the above

4-65. A fluorescent lamp is slow to light after the switch is turned on. If the line voltage is proper, what action should you take to correct the condition?

1. Turn the luminaire ON and OFF several times
2. Replace the starter
3. Remove the lamp and scrape the ends
4. Seat the lamps firmly

4-66. What is the best indication that a fluorescent lamp is nearing the end of its useful life and will soon burn out?

1. It is slow starting
2. It has increased noise from the ballast
3. It is flickering
4. It is flashing ON and OFF

ASSIGNMENT 5

Textbook Assignment: "Communications and Lighting," chapter 6, pages 6-1 through 6-22.

5-1. Before installing a public address system, you should refer to which of the following publications and/or guidance?

1. National Electric Code®
2. Manufacturers' recommendations
3. Both 1 and 2 above

5-2. What voltage source is required for a solid-state amplifier?

1. 24 V
2. 48 V
3. 120 V
4. 220 V

5-3. From the following factors, which one(s) is/are important when matching speakers and amplifiers?

1. Both should fit in the console
2. Voltage input must be the same
3. Speaker impedance and amplifier output impedance should match
4. Both require low frequency

5-4. Circuit protection for an amplifier is accomplished by internally wiring a circuit breaker to the amplifier.

1. True
2. False

5-5. What condition exists when you mismatch speakers and amplifiers?

1. It overloads the amplifier and may damage the speakers
2. It overloads the speakers and may damage the amplifier
3. It increases the power delivered to the speakers
4. It decreases the power delivered to the speakers

5-6. What condition exists when installed speakers are out of phase?

1. One speaker increases in volume and both speakers tone quality improves
2. Both speakers increase in volume and the tone quality improves
3. Both speakers lose volume and the tone quality is degraded
4. One speaker loses volume and the tone quality is degraded; the other speaker improves in tone quality

5-7. When speakers are facing in the same direction, what method of connection results in the speakers being in phase?

1. - to + and + to -
2. + to + and - to -
3. + to - and - to +
4. + to - and + to -

5-8. What causes a hum or makes the amplifier oscillate in a complex public address system?

1. Stray current is fed back to the amplifier
2. Inconsistent voltage supply
3. Inadequate voltage supply
4. Excessive voltage supply

5-9. Which of the following problems often causes a public address system to operate poorly?

1. A loose connection
2. A broken wire
3. A faulty soldering joint
4. Each of the above

5-10. A basic intercom system consists of which of the following configurations?

1. Signaling-master
2. All-master
3. Single-master multiple remote
4. Both 2 and 3 above

5-11. A master station and remote station may be combined as long as the capacity of which of the following stations is not exceeded?

1. Master
2. Remote
3. Either 1 or 2 above

5-12. In installing an intercom system, you should be most concerned with which of the following wire installation requirements?

1. Using only solder connections
2. Length of wiring cable
3. Cable not exceeding permissible resistance
4. Individually color coding each wire

5-13. What optical waveguide medium is preferred for fiber-optic research?

1. Glass fibers
2. Gas-filled pipes
3. Laser beams
4. Tubes with focusing lenses

5-14. What is the purpose of a light-emitting diode?

1. It bends the light source
2. It launches light into the fiber
3. It measures the light rays
4. It changes the light color

5-15. Which of the following factors is/are NOT an advantage of fiber-optic cable?

1. It is smaller and weighs less than electrical conductors
2. It is less expensive than other cable
3. It has increased bandwidth and capacity
4. It is free of short circuits and sparks

5-16. In an optical fiber, the cylindrical dielectric rod is immediately surrounded by which of the following optical fiber parts?

1. Buffer
2. Cladding
3. Coating
4. Core

5-17. Which of the following materials is NOT an outstanding conductor of electricity?

1. Copper
2. Dielectric
3. Steel
4. Water

5-18. Which of the following types of optical fiber parts reduces loss of light from the core of optical fibers?

1. Buffer
2. Coating
3. Cladding
4. Both 2 and 3 above

5-19. Which of the following types of optical fiber parts protects the optical fibers from physical damage?

1. Buffer
2. Coating
3. Both 1 and 2 above
4. Cladding

5-20. Fiber-optic cables are not affected by static fatigue.

1. True
2. False

5-21. A fiber-optic data link performs which of the following functions?

1. It converts an electrical input signal to an optical signal
2. It sends an optical signal over an optical fiber
3. It converts an optical signal back to an electrical signal
4. Each of the above

5-22. Which of the following components perform(s) the basic function of the fiber-optic data link?

1. Transmitter
2. Optical fiber
3. Receiver
4. Each of the above

5-23. Which of the following splicing methods is/are used for fiber-optic cable?

1. Cadweld
2. Mechanical
3. Fusion
4. Both 2 and 3 above

5-24. Fiber-optic connections are sensitive to which of the following factors?

1. Temperature
2. Moisture
3. Dust
4. None of the above

5-25. Which of the following types of fiber-optic connectors is/are used to connect fiber-optic cable?

1. Butt-jointed
2. Expanded-beam
3. Both 1 and 2 above
4. Solderless crimp

5-26. What fiber-optic component allows the redistribution of optical signals?

1. Coupler
2. Ring
3. Collector
4. Distributor

5-27. What type of device redistributes an optical signal without optical-to-electrical conversion?

1. Passive coupler
2. Active coupler
3. Fiber-optic collector
4. Fiber-optic distributor

5-28. What type of device splits or combines a signal electrically and uses fiber-optic detectors and sources for input and output?

1. Passive coupler
2. Active coupler
3. Fiber-optic collector
4. Fiber-optic distributor

5-29. What FAS standard abbreviation designates candlepower luminous intensity?

1. ed
2. dc
3. cp
4. pc

5-30. A lumen unit is equal to what amount of power, in watts?

1. .00015
2. .0015
3. .015
4. .15

5-31. Whenever HID lamp resistance decreases, lamp heat increases.

1. True
2. False

5-32. Which of the following lamps is/are an HID light source?

1. Mercury
2. Metal-halide
3. High-pressure sodium
4. Each of the above

5-33. What device prevents HID lamp current from increasing indefinitely?

1. A film-disk cutout
2. An accelerator limiter
3. A ballast
4. A ground

5-34. In the construction of an HID lamp, which of the following materials may be added to the arc tube?

1. Sodium
2. Mercury
3. Metal halide
4. Each of the above

5-35. A high-pressure mercury lamp inner-arc tube is made of what material?

1. Copper
2. Lead
3. Mercury
4. Quartz

5-36. Mercury lamps used for lighting fall into what wattage range?

1. 15 to 175
2. 35 to 400
3. 40 to 1,000
4. 175 to 1,500

5-37. Which of the following lamps has the highest light-producing efficiency?

1. Mercury vapor
2. Sodium
3. Fluorescent
4. Incandescent

5-38. To aid in starting, the arc tubes of high-pressure sodium lamps are filled with what gas or vapor?

1. Argon
2. Sodium
3. Mercury
4. Xenon

5-39. A metal-halide lamp is more efficient than a mercury lamp by what percentage?

1. 10%
2. 20%
3. 30%
4. 50%

5-40. Which of the following HID lamps has the best lumen-maintenance characteristic?

1. Mercury
2. Metal-halide
3. High-pressure sodium

5-41. What is the rated life expectancy of a 3 5 -watt high-pressure sodium lamp?

1. 1,000 hours
2. 10,000 hours
3. 16,000 hours
4. 24,000 hours

5-42. What material coats the inside of a fluorescent tube and gives off light when bombarded by electrons?

1. Mercury
2. Phosphor
3. Sodium
4. Silver

5-43. An HID lamp ballast is used for which of the following purposes?

1. To control lamp current
2. To provide sufficient voltage
3. To match lamp voltage to line voltage
4. Each of the above

5-44. What type of lamp has an end-of-life characteristic that matches this statement? “End-of-life results from a change in the electrical characteristic when the ballast can no longer sustain the lamp.”

1. Fluorescent
2. Mercury
3. Metal halide
4. High-pressure sodium

5-45. What type of lamp has an end-of-life characteristic that matches this statement? “End-of-life results from blackening of the arc tube that is caused by electrode deterioration.”

1. Fluorescent
2. Mercury
3. Metal halide
4. High-pressure sodium

5-46. What type of lamp has an end-of-life characteristic that matches this statement? “End-of-life results when an aging lamp requires more voltage to stabilize and operate than the ballast is able to provide.”

1. Fluorescent
2. Mercury
3. Metal halide
4. High-pressure sodium

5-47. A light fixture serves which of the following purposes?

1. It holds the lamp
2. It prevents damage to the lamp
3. It directs the light beam
4. Each of the above

5-48. A series lighting circuit with an autotransformer for stepping up the current to 15 or 20 amperes provides which of the following additional advantages?

1. It permits the use of rugged lamp filaments
2. It gives longer life to the lamps
3. It provides higher lamp efficiency
4. Each of the above

5-49. A series streetlight system is powered by a constant-current regulator that usually supplies what amount of amperes?

1. 5.6
2. 6.6
3. 15.0
4. 20.0

5-50. What device is used in a series lighting circuit to prevent circuit failure from a burned out filament?

1. Film-disk cutout
2. Cycle starter
3. Restrike starter
4. Ballast

5-51. When a filament of a lamp burns out, the entire circuit voltage appears across the film-disk, thereby puncturing the disk and causing the circuit to continue bypassing the burned-out filament.

1. True
2. False

5-52. Which of the following methods of installation of series lighting circuits is used on a one-wire circuit?

1. All the lamps are connected on the outgoing wire
2. All the lamps are connected on the return wire
3. All the lamps are connected in a closed-loop circuit
4. All the lamps are connected in an open-loop circuit

5-53. What advantage is gained when you combine an open-loop and a closed-loop circuit?

1. They are less expensive to construct
2. They are less expensive to maintain
3. They are easier to troubleshoot
4. They are more economical to operate

5-54. You can identify a series streetlight circuit quickly by which of the following features?

1. Wiring is a different color than that of the primary distribution system
2. White insulators are used to identify wiring
3. Wiring is always the lowest base wire on the utility pole

5-55. Constant-current regulators should be protected by lighting arresters on what side(s) of overhead circuits?

1. Primary
2. Secondary
3. Both 1 and 2 above

5-56. The primary and secondary windings of a constant-current transformer are stationary.

1. True
2. False

5-57. Which of the following sizes of regulators is mounted on a platform?

1. 0.5 to 5 kilovoltamperes
2. 6.0 to 10 kilovoltamperes
3. 11.0 to 19 kilovoltamperes
4. 20.0 kilovoltamperes and larger

ASSIGNMENT 6

Textbook Assignment: "Electrical Appliances, Equipment, Motors, and Generators," chapter 7, pages 7-1 through 7-56.

6-1. Electrical appliances are categorized into how many different types?

1. One
2. Two
3. Three
4. Four

6-2. A hot water heater is what type of appliance?

1. Fixed
2. Portable
3. Stationary

6-3. A window air conditioner is what type of appliance?

1. Fixed
2. Portable
3. Stationary

6-4. A toaster is what type of appliance?

1. Fixed
2. Portable
3. Stationary

6-5. When you have a major appliance with a broken part, it is permissible to replace the part with another brand name appliance part.

1. True
2. False

6-6. What is the connected receptacle requirement for portable appliances?

1. A single-pole, 20-A, 110-V disconnect
2. A double-pole, 15-A, 110-V disconnect
3. A 15-A, 110-V duplex outlet
4. A 30-A, 110-V duplex outlet

6-7. What type of disconnecting means is permissible for portable appliances?

1. A single-pole, 20-A, 110-V disconnect
2. A receptacle and attachment plug
3. A breaker within the power panel
4. A unit switch that is not part of the appliance

6-8. What publication should you consult before installing a ground in an appliance circuit?

1. Project specifications
2. NAVFAC guide specifications
3. *National Electrical Code*®
4. *Lineman's Handbook*®

6-9. What term identities a branch circuit that supplies electrical energy to one or more outlets to which appliances are connected?

1. Receptacle
2. Lighting
3. Equipment
4. Appliance

6-10. Permanently connected lighting fixtures may be connected to an appliance branch circuit only if the lights are in the same room.

1. True
2. False

6-11. Which of the following areas/rooms is NOT a branch circuit location?

1. Dining area
2. Kitchen area
3. Breakfast room
4. Small bedroom or computer room

6-12. What number of branch circuits are required to be installed in a laundry room?

1. One
2. Two
3. Three
4. Four

6-13. What minimum number of appliance branch circuits are required in a kitchen?

1. One
2. Two
3. Three
4. Four

6-14. Which, if any, of the following circumstances allows the ground prong from a three-prong power cord to be removed?

1. If the duplex outlet grounding convenience is not available
2. If the circuit does not exceed 20 amperes
3. When the equipment in use is double-insulated
4. None of the above

6-15. In a washing machine, what component is the heart of the electrical system?

1. Motor
2. Timer
3. Pump
4. Transmission

6-16. Which of the following statements describes a washing machine timer function/operation?

1. It is a synchronous-type motor
2. It has a ratchet mechanism that permits it to advance manually
3. It controls the operation of the washer
4. Each of the above

6-17. In a washing machine, what component engages the friction wheel of the motor to extract water from the tub?

1. Transmission
2. Electrical solenoid
3. Thermal overload
4. Pulley belts

6-18. What is the major cause of washing machine pump failure?

1. Clogged hoses leading to and from the pump
2. Belt slippage between the friction wheel of the pump and the motor
3. Foreign objects lodged in the pump
4. Failure of the solenoid

6-19. In a washing machine, what minimum water pressure is needed to overcome the mixing valve plunger spring pressure for water to fill?

1. 10 lb
2. 15 lb
3. 20 lb
4. 25 lb

6-20. In a washing machine, what is the end result, if any, of loosening the water-level switch screw?

1. It allows the water level to rise
2. It allows the water level to fall
3. It sets the water level to normal
4. None

6-21. Most washing machines have what minimum number of safety switches?

1. One
2. Two
3. Five
4. Four

6-22. What device de-energizes the washing machine timer motor during the filling cycle?

1. The water level switch contacts
2. The inlet valve contacts
3. The water pump

6-23. What is a good starting point in troubleshooting a washing machine?

1. Check the timer
2. Try starting the machine
3. Check the water supply
4. Check the safety switches

6-24. An electrical clothes dryer is not as complicated as a washing machine.

1. True
2. False

6-25. In an electric dryer, what component controls the temperature of the air that passes through the clothes?

1. The high- and low-limit thermostats
2. The timer
3. The safety thermostats
4. The electric heater

6-26. Where are the thermostats located on an electric dryer?

1. On the back wall of the drum
2. On the side wall of the drum
3. In the door panel
4. In the exhaust housing

6-27. A surface burner may be set to what number of positions on a modem electric range?

1. 5
2. 10
3. 15
4. 20

6-28. What type of meter should be used to check for an open in a heating element of an electric range?

1. Ammeter
2. Wiggins
3. Voltmeter
4. Ohmmeter

6-29. The most reliable method of testing switches in an electric range is to measure their

1. resistance
2. voltage
3. current
4. temperature

6-30. A heating element is faulty when a voltage reading is present across the terminals of a closed switch.

1. True
2. False

6-31. A hot water heater thermostat responds to changing water temperature at what location within the tank?

1. Top of the tank
2. Middle of the tank
3. Bottom of the tank

6-32. When the top part of a hot water tank has reached its preset temperature, what is the position of the (a) top contact and (b) bottom contact of the double-throw thermostat?

1. (a) Open (b) open
2. (a) Closed (b) open
3. (a) Open (b) closed
4. (a) Closed (b) closed

6-33. A double-throw thermostat on a hot water heater controls which of the following heating elements?

1. Lower
2. Upper
3. Both lower and upper

6-34. Manual and automatic are the two general classes of appliance control.

1. True
2. False

6-35. What type of switch is used to reduce arcing and pitting of its contacts when its position is changed?

1. Toggle
2. Hydraulic control
3. Rotary
4. Bimetallic blade

6-36. A helix control uses what principle of operation?

1. A thermostatic metal that coils and uncoils when heat is applied
2. A make-and-break action that interrupts current flow
3. A fluid-filled capillary tube that is heated by the appliance and maintains a constant temperature
4. A three-position switch that changes the heat level

6-37. Which of the following actions should you take to adjust the temperature control of a hydraulic control switch?

1. Increase or decrease the amount of fluid in the capillary tube
2. Shorten or lengthen the capillary tube
3. Replace the control
4. Loosen the two slotted screws and move the slotted adjusting plate left or right

6-38. What should be your first step before troubleshooting a circuit?

1. Make a visual inspection
2. Secure the power
3. Study the schematic
4. Check for loose connections

6-39. What item should you check first before attempting to locate an electrical fault in an appliance?

1. The outlet for power
2. The power cord
3. Both 1 and 2 above
4. The multimeter

6-40. Which of the following steps should you take before working on an electrical appliance?

1. Open the switch to the appliance
2. Lock and tag all switches in the open position
3. Remove the protective devices
4. Each of the above

6-41. When a switch of an appliance is tested with an ohmmeter, what does a reading of 0 ohms indicate if the switch is on?

1. A bad switch
2. An open switch
3. A direct short in the switch
4. A good switch

6-42. For an ammeter to measure current in a circuit, it must be connected in what manner?

1. Across the line
2. In parallel with the circuit source and load
3. In series with the circuit source and load
4. In series-parallel with the load and line

6-43. When measuring current of unknown amperage with an ammeter that is capable of measuring several ranges, you should make the first measurement with the meter set at what range?

1. A range slightly higher than the estimated current
2. The highest range
3. The range of the estimated current
4. The lowest range

6-44. The presence of three internal resistors in a voltmeter schematic indicates that what voltmeter characteristic?

1. The meter is more rugged than one with only one resistor
2. More protection is provided to this meter than to one with only one resistor
3. The meter has three voltage ranges and scales
4. The meter may be used for three times its rated voltage

6-45. Which of the following conditions indicate(s) you are measuring ac voltage with a line voltage indicator?

1. The neon lamp indicator glows
2. You hear an audible hum
3. You feel a vibration when the testing indicator is hand-held
4. Each of the above

6-46. When you are measuring dc voltage with a line voltage indicator, both the positive and negative electrodes glow.

1. True
2. False

6-47. What action should you take after completing a test with an ohmmeter?

1. Turn the meter to the dc supply positive
2. Turn the meter to the dc supply negative
3. Turn the meter off
4. Set the selector switch to R_1

6-48. You are preparing to take a voltage reading with a multimeter. After you have determined the approximate voltage on the circuit you are about to test, what should be your next step?

1. Turn off the power to the circuit
2. Plug the test leads into the appropriate jacks
3. Connect the test leads to the conductors
4. Set the function switch

6-49. What is the difference between a megger and a typical ohmmeter?

1. A megger uses ac voltage; an ohmmeter uses dc voltage
2. A megger can apply a much higher dc voltage to a circuit than an ohmmeter
3. A megger, unlike an ohmmeter, has an indicator within the instrument enclosure

6-50. When you are conducting an insulation resistance test using a megger, which of the following conditions can cause the needle to deflect to zero?

1. There is no resistance between the test leads
2. The test leads are touching each other
3. The insulation is broken near the test points
4. Each of the above

6-51. What is the purpose, if any, of keeping records of insulation tests?

1. Technical publications recommend it
2. The scheduling of future tests
3. Trends may indicate future problems
4. None

6-52. Of the following conditions, which one(s) would cause a motor to have a low insulation resistance when tested?

1. Moisture
2. Dirt
3. Dust
4. Each of the above

6-53. When taking an insulation resistance test on a cable that is a performance natural, you get a reading of 6.0 megohms at a temperature of 104°F. What is the correct value of resistance?

1. 19.56 megohms
2. 23.10 megohms
3. 24.90 megohms
4. 30.48 megohms

6-54. When taking an insulation resistance test on an oil-filled transformer, you get a reading of 2.0 megohms at a temperature of 131°F. What is the correct value of resistance?

1. 10.0 megohms
2. 22.4 megohms
3. 31.0 megohms
4. 31.7 megohms

6-55. When taking an insulation resistance test around a piece of high-voltage equipment, you should take which of the following actions?

1. Ground the megger
2. Disconnect the apparatus
3. Work under direct supervision
4. Each of the above

6-56. When taking an insulation resistance test, when, if ever, should you discharge a cable of its capacitance?

1. Before making the test only
2. After making the test only
3. Before and after making the test
4. Never

6-57. What are the four main parts of a split-phase electric motor?

1. Stator, rotor, end plates, and centrifugal switch
2. Poles, armature, core, and shaft
3. Starting windings, running windings, frame, and rotating core
4. Coils, end bells, bearings, and commutator

6-58. The centrifugal switch disconnects a motor's starting windings at what percentage of the motor's full speed?

1. 50%
2. 75%
3. 80%
4. 100%

6-59. To reverse the direction of rotation of a split-phase motor, you should interchange the connection of what leads of the motor?

1. Power
2. Running winding
3. Starting winding
4. Centrifugal switch

6-60. You are using an electric motor and the rotor suddenly locks. What is the possible cause of this malfunction?

1. The input voltage is high
2. The motor bearings are worn out
3. The centrifugal switch did not open at the desired speed
4. The motor current is too high

6-61. Before you take an electric motor completely apart, which of the following actions should you take?

1. Take out the pulley connected to the motor shaft
2. Mark the position of the shaft
3. Put a center punch mark at the stator ends and their matching end plates
4. Identify and mark the starting and running winding leads

6-62. The starting winding of an electric motor is always placed what number of degrees out-of-phase with the running winding?

1. 30
2. 45
3. 90
4. 120

6-63. Capacitor motors have what advantage over split-phase motors?

1. Capacitor motors are less expensive
2. Capacitor motors weigh less
3. Capacitor motors have higher starting currents
4. Capacitor motors have higher starting torque

6-64. What type of electric motor can be operated with either ac or dc power?

1. Split phase
2. Salient pole
3. Capacitor start
4. Capacitor run

6-65. The stator and rotor windings in a salient-pole universal motor are connected in what manner?

1. In series with the power source
2. In series with the centrifugal switch
3. In series with the capacitor
4. In parallel with the power source

6-66. The rotation of a three-phase electric motor can be reversed by interchanging what leads?

1. All three of the motor's leads
2. Any two of the motor's leads
3. The starting winding leads
4. All three leads of the power source

6-67. What are the horsepower and voltage limitations of manual motor controllers?

1. 7.5 hp at 600 volts, three-phase and 3.0 hp at 220 volts single-phase
2. 2.0 hp at 600 volts, three-phase and 1.0 hp at 220 volts single-phase
3. 20.0 hp to 50.0 hp at 220 volts, three-phase or single phase
4. 2.0 hp or less at 300 volts or less, single-phase only

6-68. Which of the following types of motors, if any, is allowed to be controlled by a toggle switch?

1. All single-phase motors
2. 2.0 to 5.0 hp motors only
3. Motors of 2.0 hp or less
4. None

6-69. On a shaded pole motor, the starting windings are (a) constructed and (b) located in what manner?

1. (a) Of small gauge magnet wire (b) wound on top of the running windings
2. (a) Of large gauge magnet wire (b) wound on top of each stator pole
3. (a) Of copper bands (b) wrapped around one tip of each stator pole

6-70. Shaded-pole motors have which of the following characteristics?

1. High torque
2. Large horsepower
3. Low torque
4. High voltage

6-71. On a three-speed, split-phase fan motor, the windings are connected in what manner for low speed operation?

1. The running winding is connected across the line and the starting winding is connected in series with the auxiliary winding
2. The running winding is in series with half the auxiliary winding
3. The starting winding is in series with half the auxiliary winding
4. The running and auxiliary windings are in series across the line and the starting winding is connected across the line

6-72. For a wye-connected three-phase electric motor, what number of leads are brought out to the terminal box?

1. 12
2. 9
3. 6
4. 4

6-73. Air pressure used for cleaning open-frame electric motors should not exceed what psi?

1. 10
2. 15
3. 25
4. 30

6-74. Motor contactors that remain closed for long periods of time with infrequent operation use what material for contacts?

1. Aluminum
2. Carbon
3. Copper
4. Silver

6-75. In troubleshooting an alternating-current controller, you notice the coils are overheating. Which of the following is a probable cause for this condition?

1. Loose connections
2. Inadequate spring pressure
3. Misalignment of parts
4. Open armature gap